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NPTEL ONLINE COURSE

Ecology and Environment

Risk Assessment and LCA: Lecture 2

Transfer of Pollutants in the Environment

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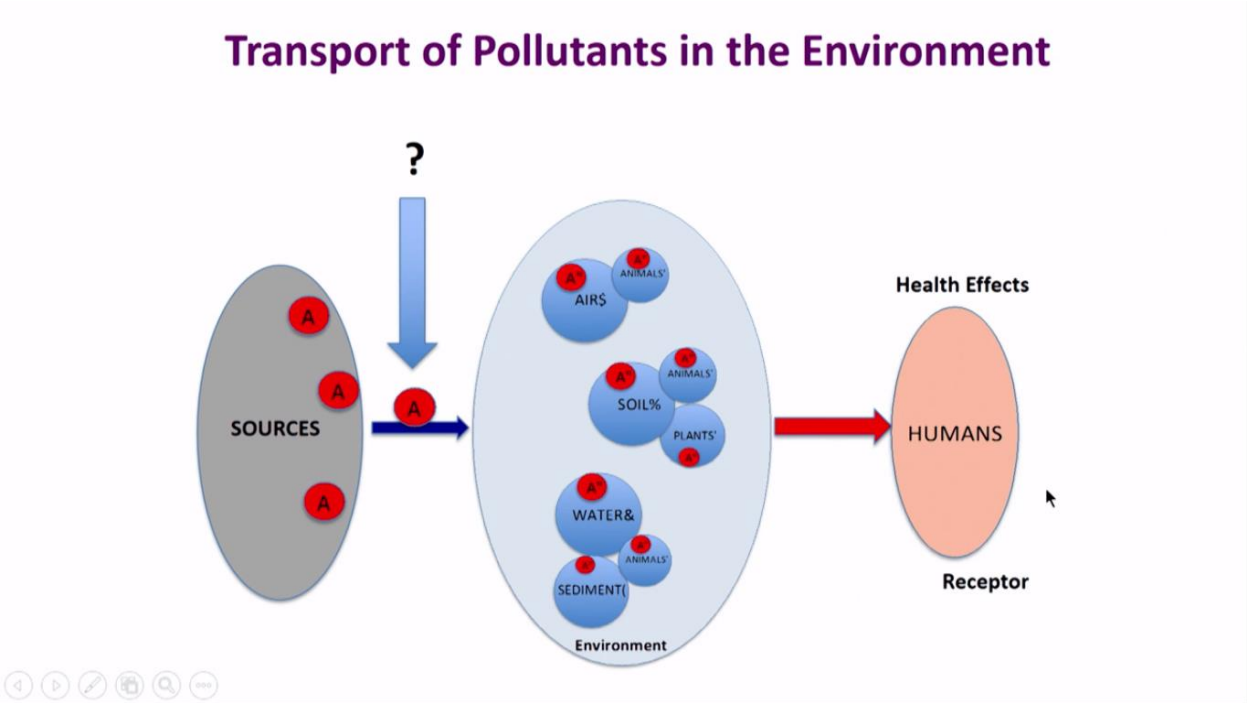
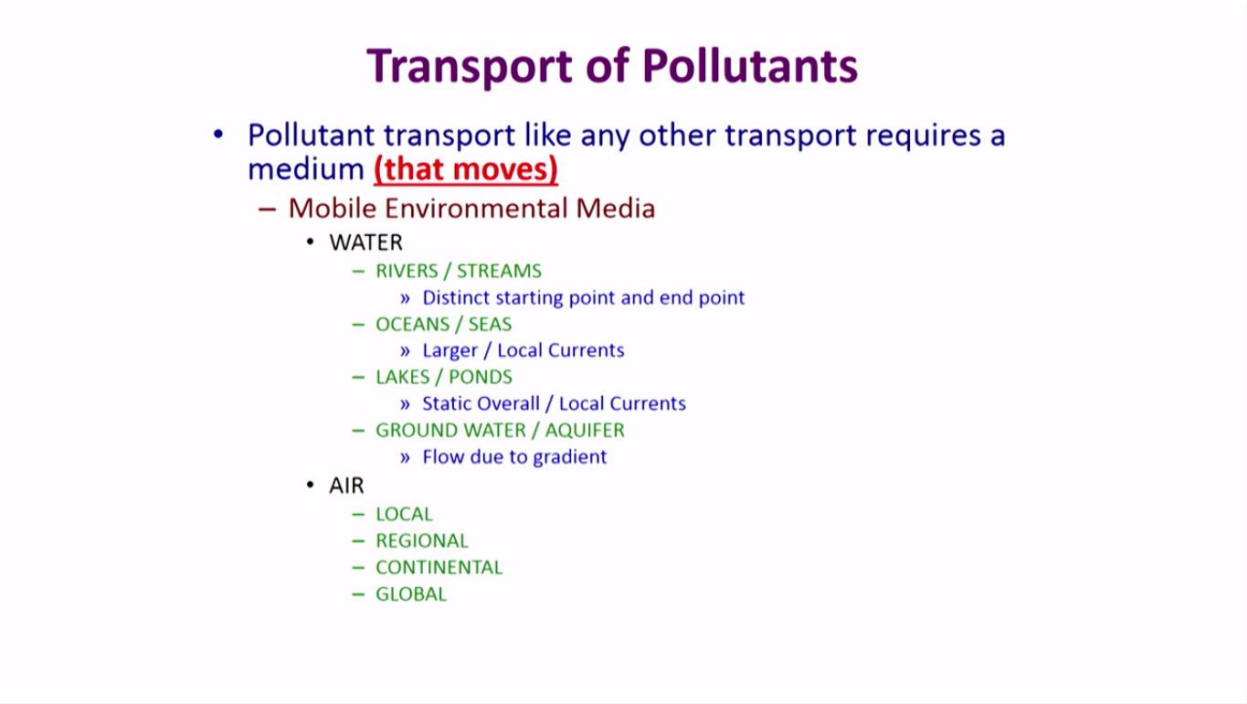
Welcome to the second lecture of the module discussing risk assessment and lifecycle analysis in the ecology and environment course. In the previous lecture, we talked a little bit about health risk assessment and the definition of health risk, and we came up to a point where we discussed the entry of a pollutant from a particular source into the environment. So, in this lecture, we will discuss a little more about the transport of pollutants in the environment. So, we see that the sources, there are various sources, different processes, product manufacturing, and different things, the source could be anything. It could be natural or anthropogenic, but we are talking mainly about anthropogenic sources which are mainly things that we do, and these sources release chemicals into the environment here, and from there it gets to the human being.



So, the question is what is this transport? How do they get transported from the place where they are released into the environment and then to the humans?



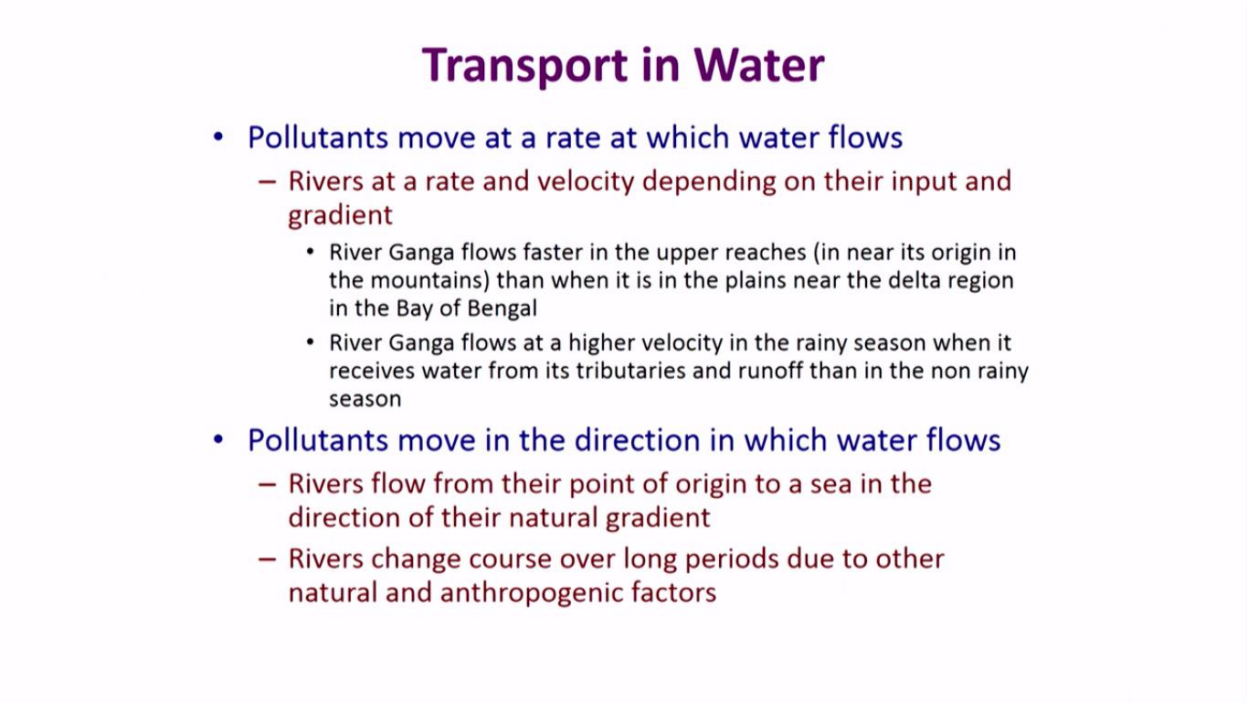
So, transport of pollutants, transport of any chemical or any pollutant like any other transport requires a medium that moves. So, in the environment, this means that there is a medium that moves. There are only two mediums that move in the environment. One is water, and one is the air. So, we take a brief look at these two environmental

media; water and air. And see how at what extent they move and then how can they influence the transport of pollutants in the environment. So, water can be divided – the way water is present in the environment is in different forms as surface water which is essentially rivers, oceans, lakes and then as groundwater. So, rivers and streams have a very distinct starting point and an end point, and they flow. That is one of the major things. They have a velocity, and they flow from point A to point B, and we know that many of the rivers start sometimes in the mountains and end up in the sea, is not necessarily true, but this is one example of a river system. Streams are generally classified as a small thing, a small canal that is connecting to rivers or connecting a lake to a river and such and such. So, we have canals for irrigation and for stormwater drainage in major cities. We have oceans and seas. This is a very large body of water connecting sometimes different continents, and seas are generally names given to smaller sections of this oceanic body. They do not have a very specific starting and end point, and they also do not have a specific start and end point and also do not have a very well-defined flow, but they have flow in them inherently and this you see that in the form of waves that is always moving and there is a current. There are a large number of currents which are small and large in size that move, water moves as rivers within the seas and oceans and this can carry pollutants. And this is also a function of season. Different seasons these currents move in different directions, and therefore pollutants can move in the different direction as well.

Then we have lakes and ponds these are very small. These are smaller in comparison to the oceans or sometimes the rivers, but there are very large lake systems in the world. There is one such as the Great Lakes systems in between the United States of America and Canada, the border there are five Great Lakes, and there are other big lakes in Europe and Africa. And these are – overall, they are static, but depending on their size they also can have local currents that move which both laterally as well as vertically. There is a vertical movement that can be generated within the lakes as a result of convection, thermal convection and density difference and this is more predominant in colder regions where there is very significant temperature differences between different layers of water and therefore that this induces some kind of vertical mixing.

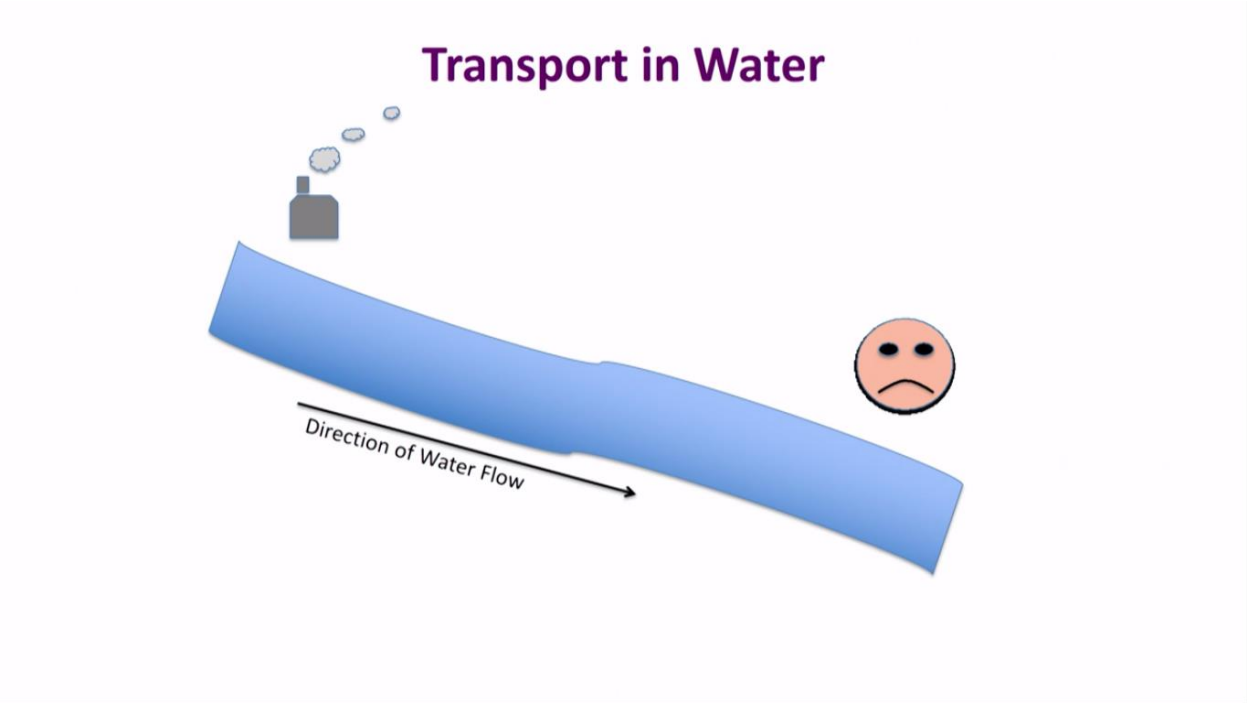
If you look at groundwater, groundwater or the other terms for groundwater is an aquifer. Groundwater aquifer also flows, and there is a gradient because groundwater is sitting on top of bedrock. It is just soil which is filled with water, and it moves in the direction of this gradient, this slope that exists between a particular point and another point neighboring to that and the flow is very slow. So, there is a difference in the way in which the flow occurs in each of these systems, and that is understanding of this system is very important to understanding how a pollutant moves.

We come to air, we have different scales of air, what we consider as air. It is a very local air, for example, the air above Chennai behaves in a certain way. There are land breeze, sea breeze and there are certain patterns that depend on the topography and geography of this region and the air mass movement above a place like Chennai is very different from the air mass movement in a place like Bombay or Delhi or any other city location in India or worldwide. There are also regional air masses. This is also dependent on the weather patterns in that system and this we have continental air mass on a global scale. So, we see that there are – there is a lot of debate and discussion with relates to global warming where we look at carbon dioxide concentrations across the world. An average concentration across the globe is a result of air mass that is carbon dioxide released from one place it moves to other places, and there is a mixture, mixing of this on a global scale, and therefore one has to worry about what others are doing in this context. So, we will discuss that in a different module and a little bit of that later in this module as well.



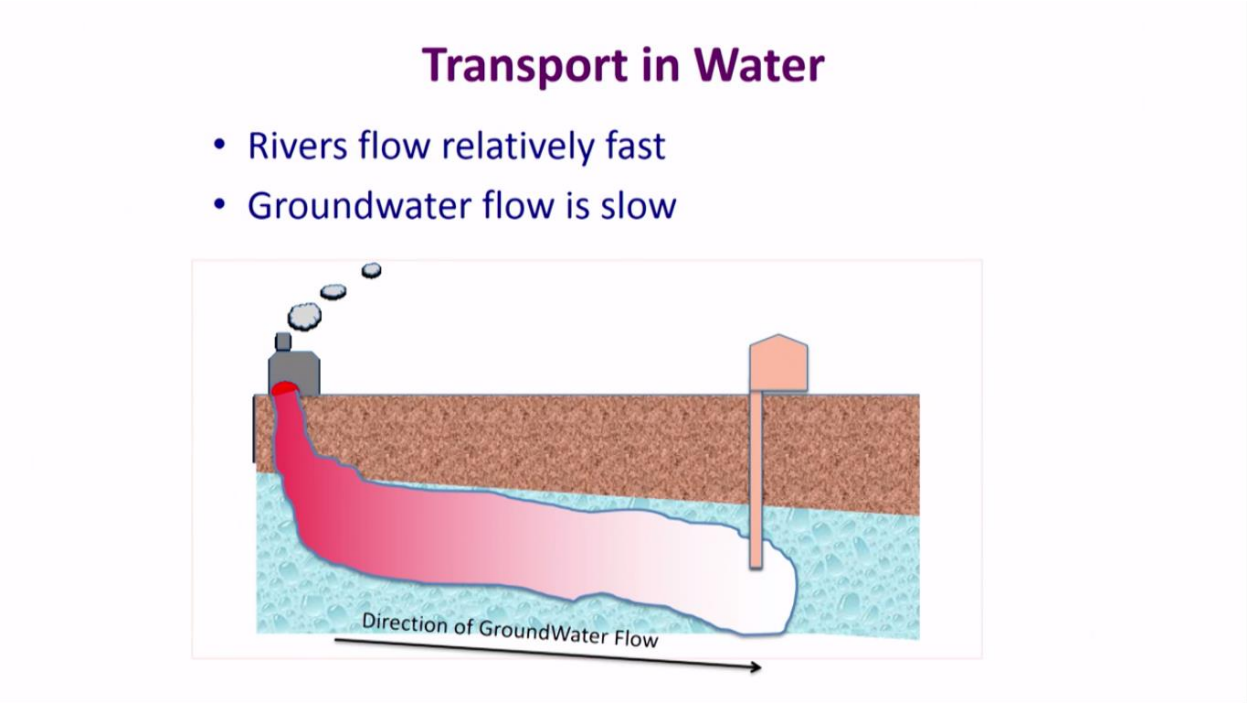
So, transport in water, we look at transport in water. Pollutants move at a rate at which the water moves, by and large. So, there are – when water does not move there are pollutant also moves but we will not discuss that here at this point. It is not relevant to this particular discussion, and there is something a little more details to that, that is not required at this point.

Pollutants do move at a rate at which water flows. If water flows they move along with it and rivers in general move at a rate and a velocity and it depends on the amount of water, they receive and also on the slope of the river. For example, the river Ganga flows very fast in its upper reaches when it is in the hills than when it reaches the plains near the delta region near the Bay of Bengal. And river Ganga also flows at a higher velocity during the monsoon period when it receives a lot of water inflow from its tributaries and runoff than during the non-rainy season when it is fairly dry, and the size of the river also changes as a result of it. And definitely the pollutant moves in the direction in which the water moves. So, rivers do have a definite flow path in general. They do have; the rivers have known to change directions as a result of geographical changes that occurs over a very long period due to natural and anthropogenic factors.



So, to give you an idea just to illustrate this transport of water. So, there is a river that is flowing in a certain direction, as indicated by this blue stream, and there is a location, there is a particular facility let us call it a unit, an industrial unit or anything, any source of pollution; is indicated by this symbol which has a hazardous material. And if this hazardous material is released into water, it flows towards a receptor. It is indicated by this happy human face and while it is flowing continuously, and we assume that there is always some material being deposited and if this person if this receptor uses water from this location, it is very likely that it can cause a health effect in this particular human being.

So, there is, in the sense that if you are downstream to a polluting source and you are likely to see the effect of, you are likely to be exposed to this particular contaminant. This happens in rivers.



In groundwater, the flow in comparison to rivers is very significantly slow, because groundwater, if you look at this cross-section here, this is soil, what we generally call as an unsaturated medium which is soil, which may have moisture but not enough to be called as groundwater. Groundwater is when the sand, the soil is completely saturated with water. All the pore spaces are filled with water, and we have a source here. We also have a receptor. The groundwater is accessed by means of a well, and we see that the well water is rising in this well and this is supplying this particular receptor with groundwater. And if it happens that there is a release of a pollutant that is sitting in here into the soil, over a period of time this will move, and it moves slowly because this is not like a river. This flow in a porous media is much slower because there is a lot of resistance to flow and it goes, it keeps going, and the water that is seen here is still not hazardous because it has not seen the effect of this. It is been some time since the flow, the release has happened, but the well does not still see the pollution, and once the well sees the pollution, you see that the water then becomes contaminated and then as a result of which the receptor also becomes -- can become unhealthy, and this is the effect of groundwater.

Transport in Water

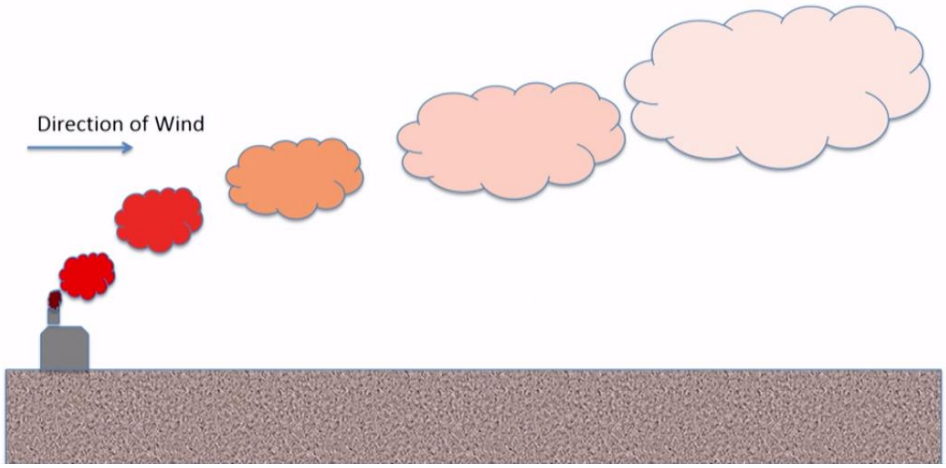
- Coastal Regions
  - Due to Currents
  - Wave Action
  - Pollutant release at one point on a coast can appear at a different location

The transport of pollutants requires a very good understanding of the nature of water in natural systems and how it behaves as a result of human intervention

In coastal regions there is also pollutant release from at one point can move to another location due to currents and wave action and – so the summary of this is transport of pollutants requires a good understanding of the nature of water. How it moves in natural systems and whether it has diurnal variations or seasonal variations and all that is important to assess if a particular pollutant that is released from one place thus will have any effect on the population living in a different location.

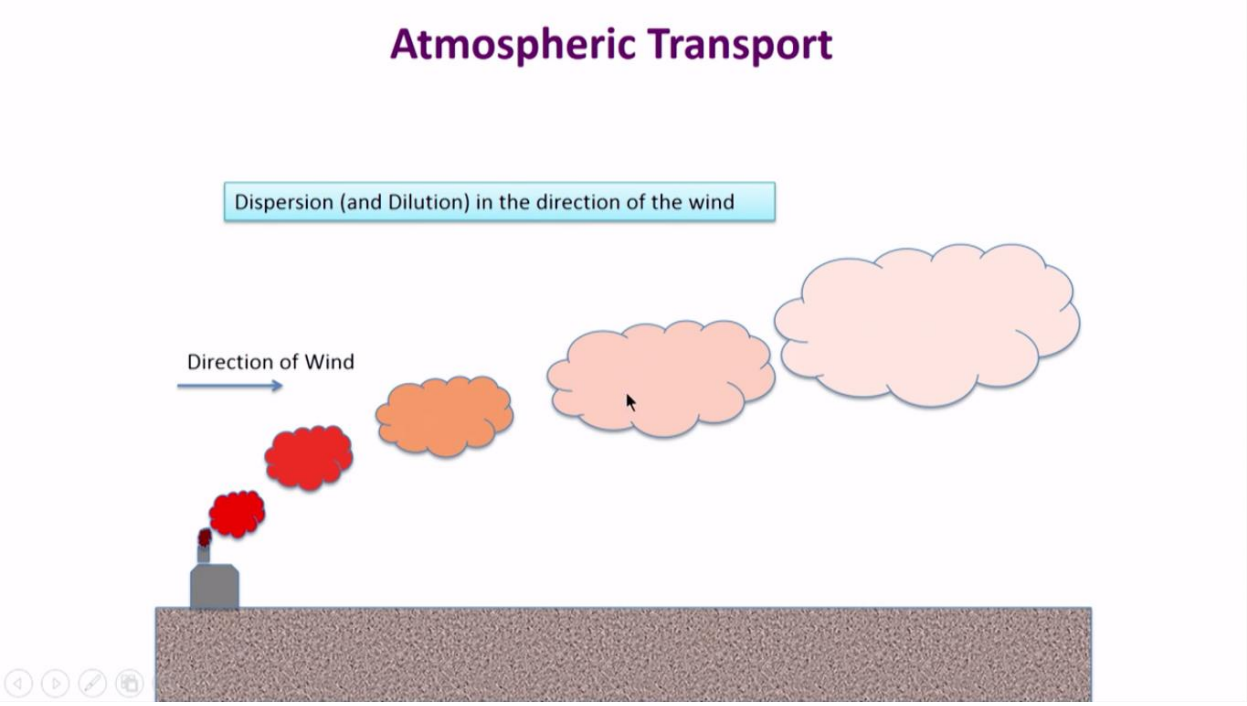
Atmospheric Transport

Dispersion (and Dilution) in the direction of the wind

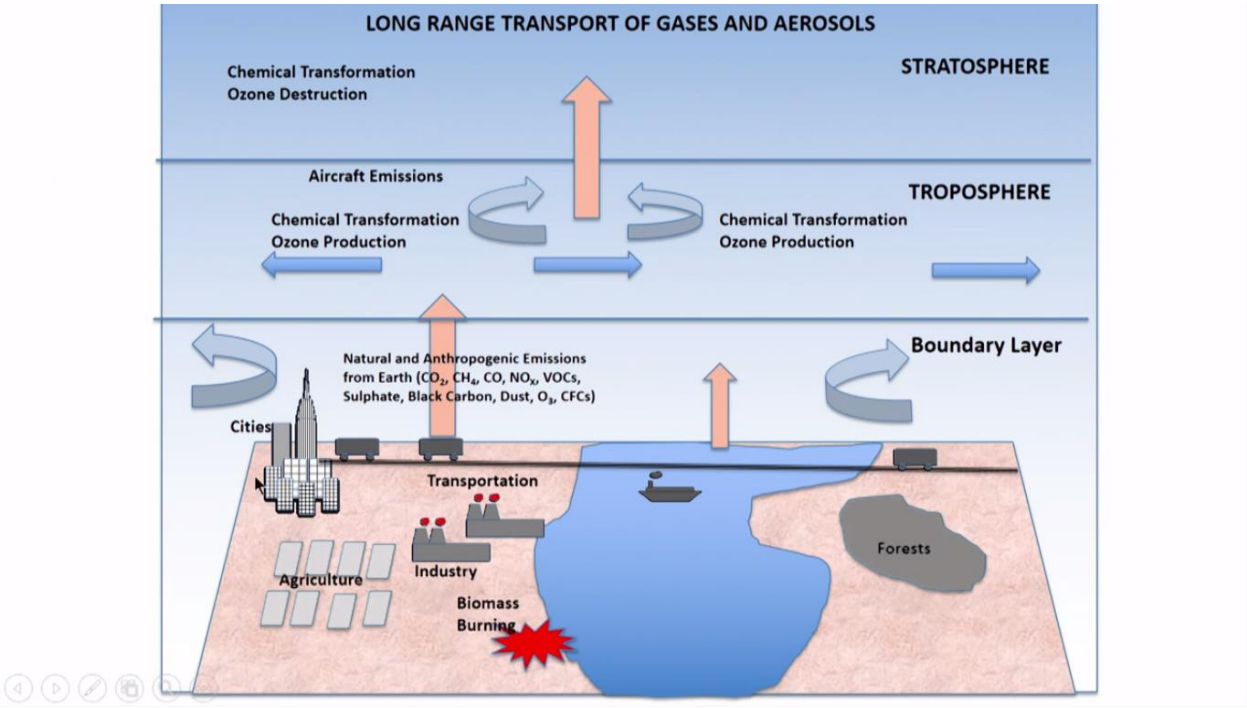


If you come to atmospheric transport, this is a schematic that generally explains, a release, a source that is releasing and atmospheric transport is released in the in the gas phase and therefore there is you see in the form of a puff. Sometimes you can visualize it. You can see exhaust coming from factories which take the shape of a cloud, and they have a certain shape, and that shape indicates how they are moving in the atmosphere. And you can see it very clearly, and this is also a function of the local meteorology as well as at that particular time what kind of weather system exists in that location.

So, the direction of wind plays a very important role in where the pollutant is going. Once it is released, it is going in the direction of the wind, and we can see that in this particular schematic.



And it is usually diluted. As it goes further away from the source, it is diluted. You can see from the from the way in which the pollutant moves, we can see that the pollutant is diluted in this particular region here. The concentration as indicated by the color it becomes smaller and smaller because the pollutant disperses, it spreads, and the spreading is also a function of the meteorology and the temperature that exists at that point. So, the puff the pollutant air mass can also behave in different ways depending on the system that exists here, and for example, it can behave like this where it can reach the ground very quickly. It can also behave like this where it does not reach the ground at all. It just keeps going up, and somebody on the ground is not exposed to this particular air mass that is going here. So, this is all important in air pollution management where we depending on the local meteorology and the local this thing we can try to design exhaust methods where which have the least impact on human beings, on a receptor.

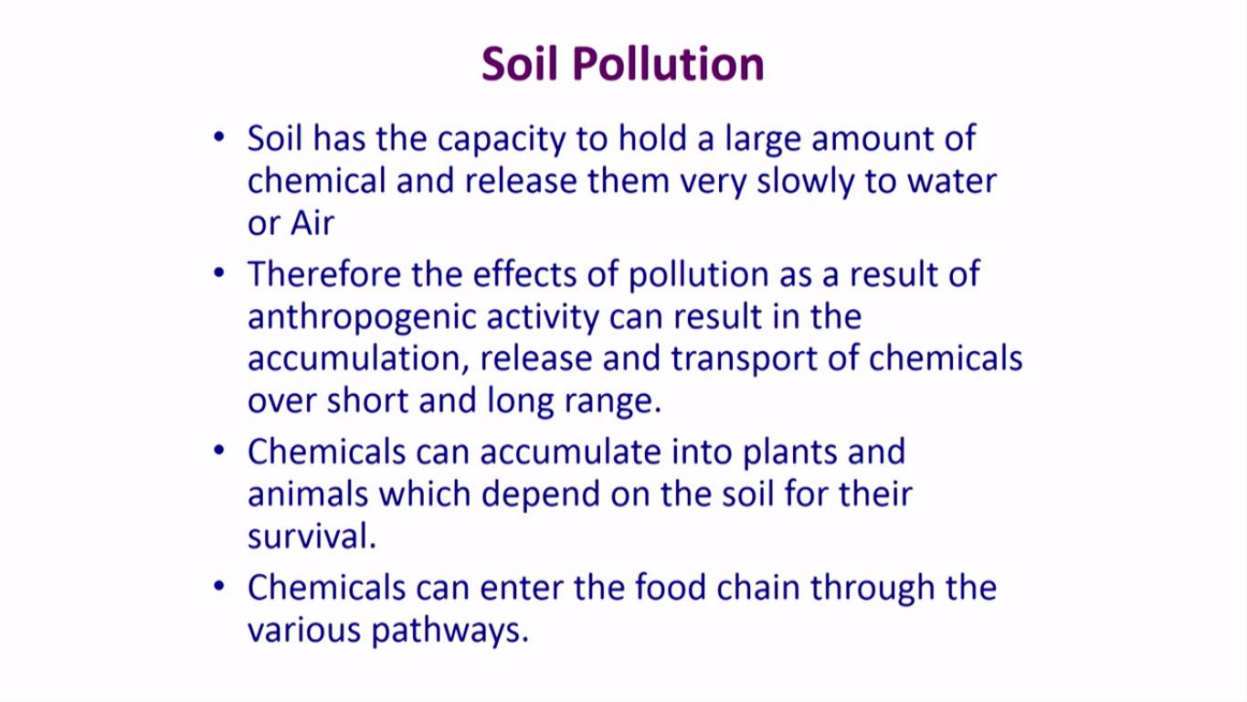


This slide here shows a general overview of the long-range transport of gases and aerosols. So, this is a general schematic representation of what you would find in our current society. We have cities and small towns. This essentially represents the residential and the business centers in various cities. We also have agriculture, large agricultural sectors. We have an industrial sector. We have a transportation sector which is in both on the land and as well as in the sea and in water bodies, and we have forests which are natural systems which can also release a significant amount of things.

So, there is as we see here we have a large amount of natural and anthropogenic emissions that are released into the environment and this contain gases such as carbon dioxide, methane and hazardous chemicals which is volatile organic carbon compounds and so on and a large amount of combustion sources release nitrogen oxides, sulfur oxides, and particulate matter. So, when we are talking about the impact of this, we are talking about transport. So, obviously there is local transport as we saw in the previous slide. Very close to the surface there is material is moving laterally in the direction of the wind, but the wind structure is not as simple as what we see outside, and there is a vertical gradient, and there is also the vertical mixing of the wind. And it is fairly complicated and as the wind gets more and more turbulent there is this structure becomes very complicated and difficult to even characterize. But by and large we see that there is a mixing of pollutant in this region and then there is also exchange between what is the called as the lower region is called as the boundary layer where most of the changes of the velocity of air is happening and then to the upper layer of the troposphere which is the one that is closest to the Earth's surface, here the chemical has an opportunity to transform. Chemical reactions can occur in the presence of other entities and from here there is exchange into the stratosphere. We also have sources now in the troposphere such as aircraft emissions. With the high volume of aircraft that are flying across the Earth if you just open any of the Google map and then we over overlay with the number of aircraft running around it sometimes covered with aircraft throughout the day and the night in different parts of the world. So, the very significant amount of aircraft emissions that occur in the upper troposphere about 30,000 feet and in that kind of range. Then they also exchange into the stratosphere. Some of it exchange into the stratosphere where one of the big examples of chemical transformation in the stratosphere is that of ozone destruction, ozone depletion or the ozone hole that we that is observed on top of Antarctica and this gives a very good indication as to the long-range transport of aerosols and gases.

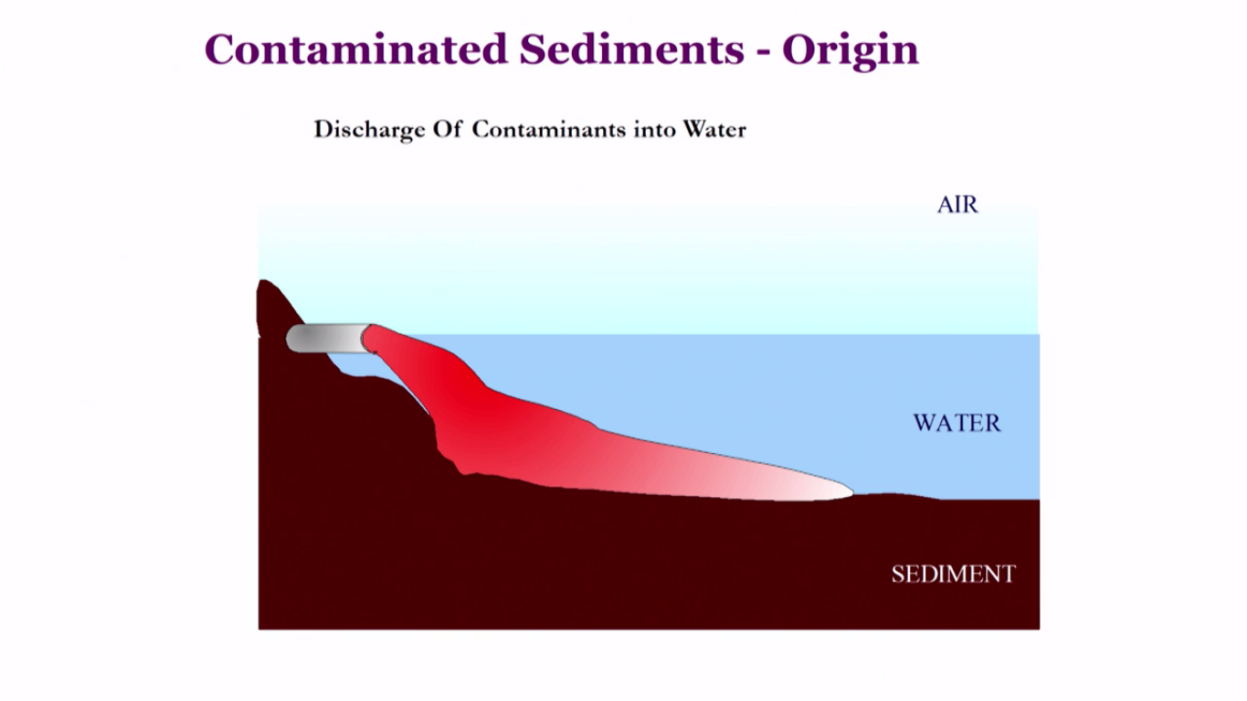
The other example of long-range transport of aerosols is the presence, is the measurement in the presence of anthropogenic chemicals or chemicals that relate to specific industrial human activity that is present in locations

where there is no human activity. For example, in the polar region where there is not much of Industry very low-low intensity of industry, we find chemicals in the ice that do not belong there, and it has come from somewhere else. So, it has traveled a long distance and deposited there. And it may have an impact on the local ecology and the animals and plants that represent in that system. And of course, there is this large section of what these emissions do to things like global warming. So, global warming is a different problem altogether. It is, in the context of human intervention. In general, when we talk about health risk, carbon dioxide and the greenhouse gases do not enter this discussion. That is a different topic altogether which will be dealt with in a different module.



We look at soil pollution. The soil has a very different kind of structure than water or air. So, soil is non-mobile, but the issue with soil is soil has capacity to hold a large amount of chemical, both organic and inorganic, more of the organic chemicals. A very large fraction of the chemicals that are manufactured and potentially released into the environment belong to the class of organic chemicals for various applications in industry. And there is, it is possible that a large fraction of these enter the soil for various reasons, and the soil can hold them for a long time and the only way they release it, is, they release it slowly to the atmosphere and they release it slowly to the water-down below, by whenever there is rain it can get slowly, dissolve slowly or get it get pushed into the, towards the water table or can release above into the atmosphere.

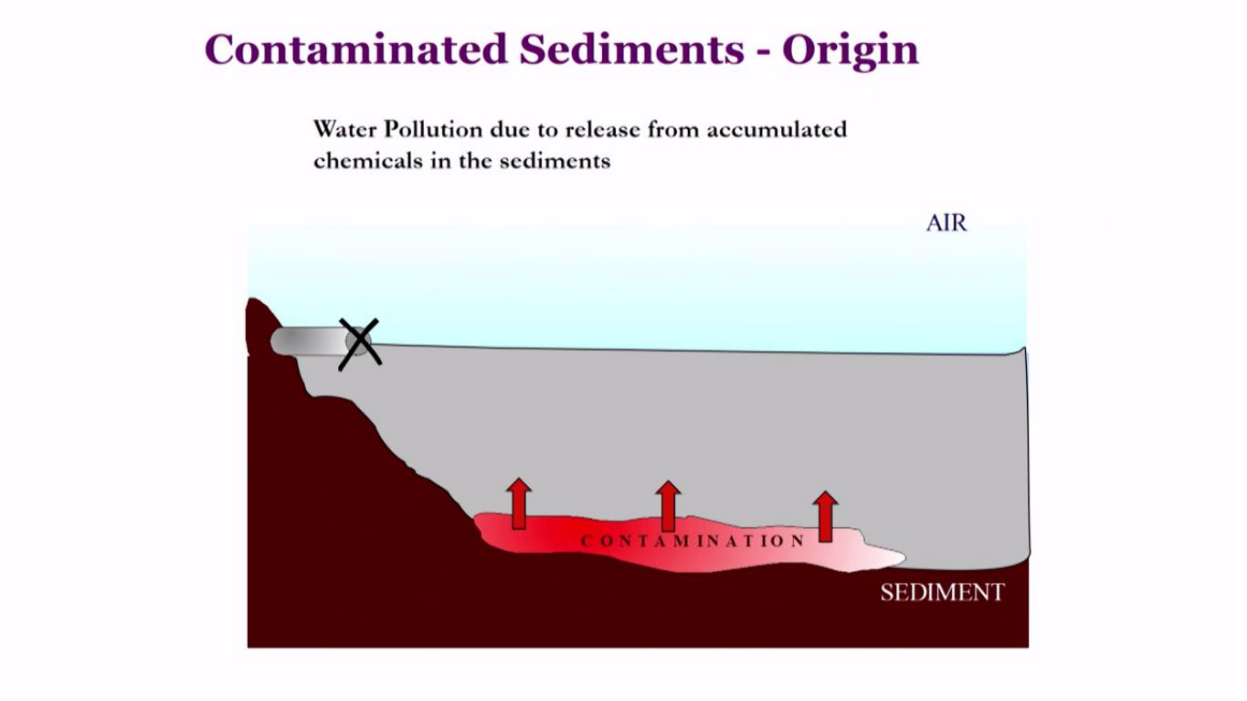
So, the last few slides have shown that the pollution can result in an anthropogenic act as a result of the human activity can result in long range and short-range transport of chemicals, and they can also accumulate into in the soil. When they are in the soil, soils are in contact with plants and they can accumulate into plants and then and the animals that survive on this plants or on the soil can also come in contact with into our food chain and therefore we can be exposed to it even if it is in the soil. So, even though there is no mobile part, there is always movement for example chemicals move in plants. There is experimental evidence show that it moves. So, water moves through plants. We water the roots, it travels through the plant so because water is moving through some mechanism it is not necessarily the same as what you see in a river or in an ocean, but it is a different mechanism of movement. We have not discussed it here, but it happens in the biological systems, and this can take the chemical into the fruit or the flower or any part of the plant, and there is a risk of the chemical getting into the food chain.



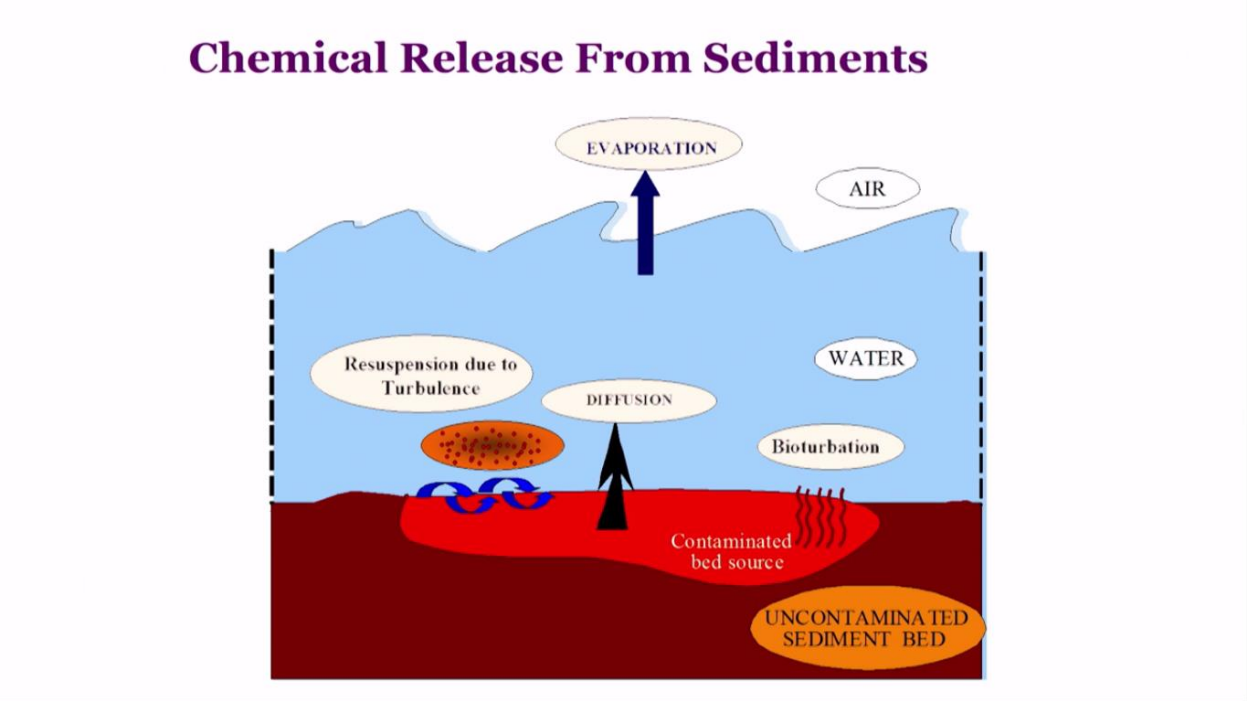
The other compartment of the environment is sediments, and this is not seen usually because it is hidden from view for most part. This is the mud that is present under a water body. As you can see in this schematic there is air, there is water, and below the water there is sediment. So, you have lake sediments, you have river sediments, we have ocean floor which are all important. It is a big very large compartment, and you can see it when there is no water or if you go under the water if you take a probe and go under the water. So, very often we do not see but in India, we have a large number of rivers that do not run, have water perennially and therefore we you get an opportunity to see the bed of the river and therefore you can find out if there is anything there.

In large, different parts of the world where there is perennial water supply and rivers serve a very important commercial transport purpose such as the large rivers in Europe and in the United States and also the Great Lake regions where we have a significant amount of commercial activity and all along coastal regions. In India we have a large amount of commercial activity along the coasts where there are, you see the concentration of chemical plants or any such activities happening along the course. So, there is a high probability of contamination if incorrect methods of disposal or due to accidents or any such events chemicals can get into the water and they can go into the sediment and sit there.

So, this schematic shows that when this happens when chemically is being released so, this is not an indicator that somebody is actually putting a pipeline and dumping chemicals into the water. It is just – it represents a source. There is a source, and whatever that source might be it might be continuous or just discrete, and the water gets polluted, and we realize that water is polluted. We find out what the source is, and we stop it.

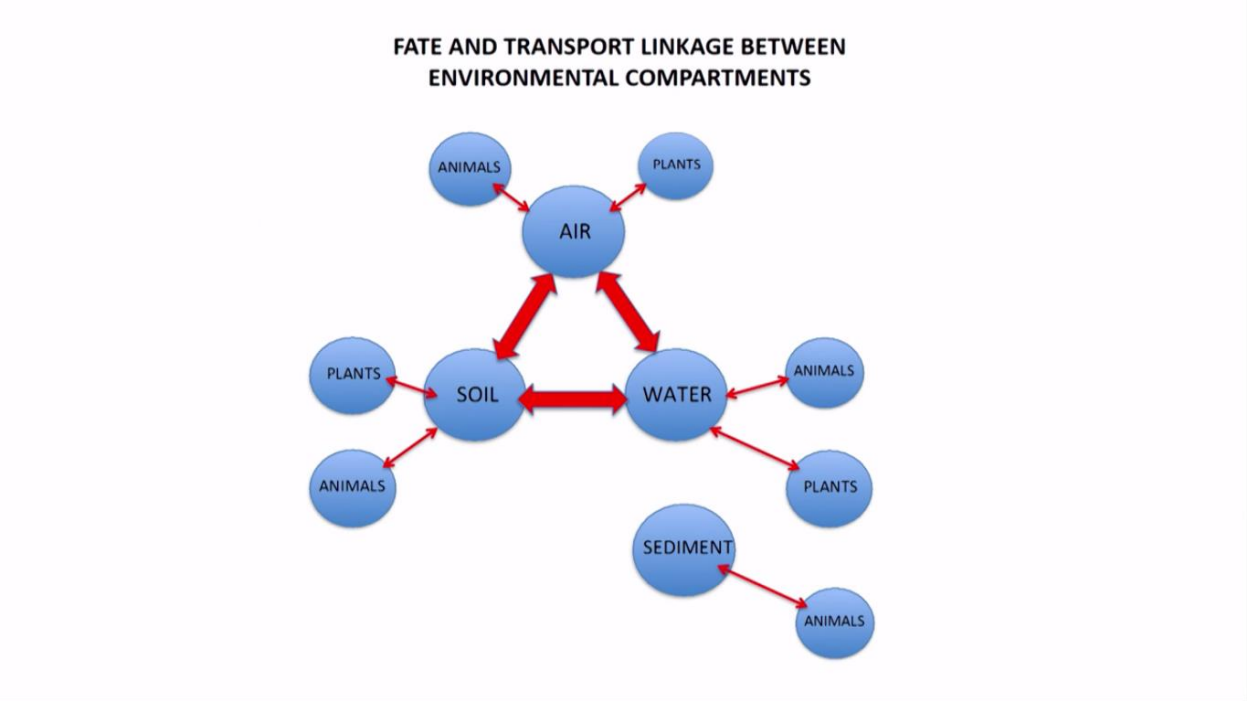


We also find that the water continues to be polluted because it is not coming from here and it is coming from here, from the contaminated source and like soil the contaminated sediments can hold a large amount of contaminant of chemicals, and if it gets there, it will stay there for a long time and release very slowly.



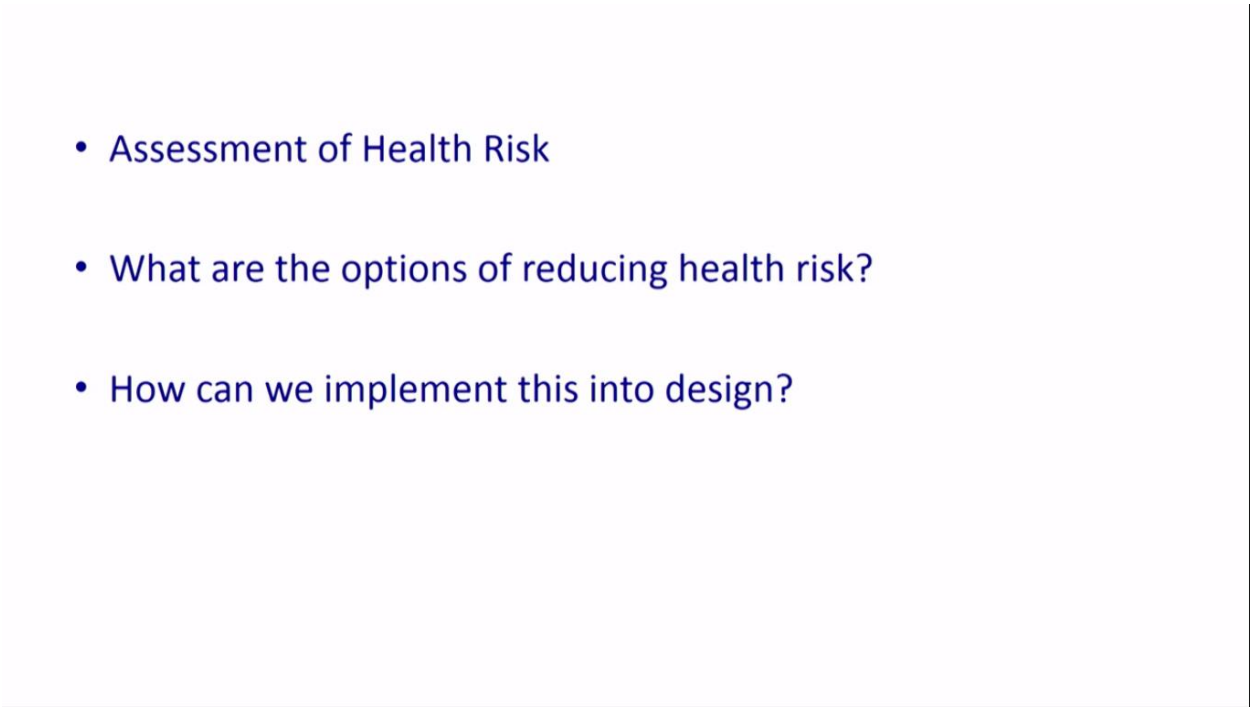
So, it can result in one of those chronic health effects over a period of time. It does not go to a concentration where you can see it immediately, and it also accumulates in fish and other plant living there. And this just continues in the

chain of chemical movement through the environment, and so these are some of the processes by which once it is in the sediment it can move into the water and can also move into the air.



So, this slide gives a comprehensive view of the linkages between different compartments in the environment for chemicals and exchange. So, the chemical exchange can happen between air and soil. If there is a chemical in the air, it can get into the soil by the exchange. It can be there in the soil it can evaporate it can cause an air pollution problem. If it is in the soil, it can go to water and cause a groundwater pollution problem. If it is there in the water, it can go to air and air pollution problem and so on. If it is there in any of these three major phases, it can also go into the other compartments that are associated with it such as animals and plants and also sediment. Sediments exchange with water, and there are animals and plants that are associated with the sediment as well.

So, this is a very complicated linkage of fate and transport of chemical in our environment, and you can add anything else that you would like into this chart, anything any other structure, any other man-made, human-made structure that might intervene and the effects can be studied.



So, the assessment of health risk, the transport of chemicals is a very important step. And we know that once we know a particular source, and you know that it can get into the environment, and it can get into a particular receptor. And there are- one can now then look at what are the possible methods in which we can try to mitigate or address this health risk, and how to reduce it, and how to implement this into the design. So, we will look at some of these aspects in the next lecture when we talk more about this.

Thank you.