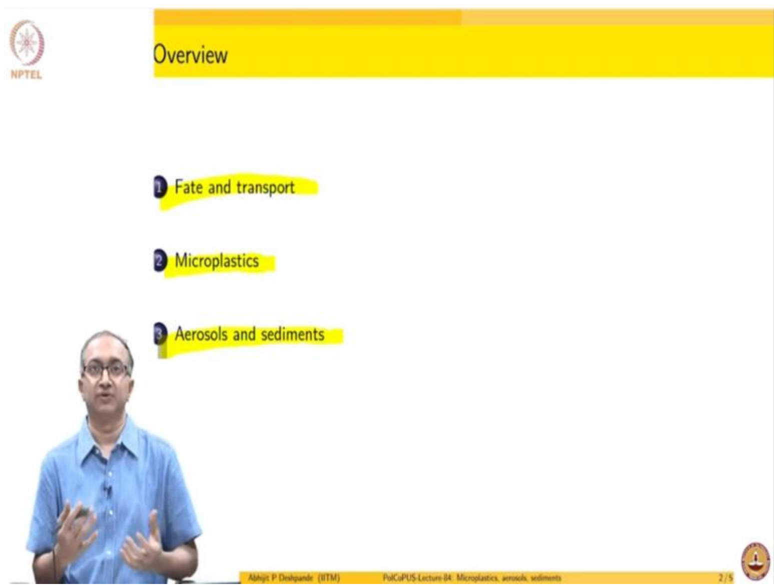
PolCoPUS
Prof. Abhijit P Deshpande
Department of Chemical Engineering
Indian Institute of Technology, Madras

Lecture No -84
Microplastics Aerosols, Sediments

Hello, welcome to the week 12 of this course on polymers, in this week we will focus on polymers and environment. We will look at in this lecture, the impact of polymers not just in the form of the way we dispose it off but the size reduction of the polymers in the environment and therefore how does it get permeated throughout various locations in soil or in air or in sediments or in the water bodies.

And the week we will also review the important field of biodegradable polymers and what is the current status in terms of some of the most common biodegradable polymers that are out there.

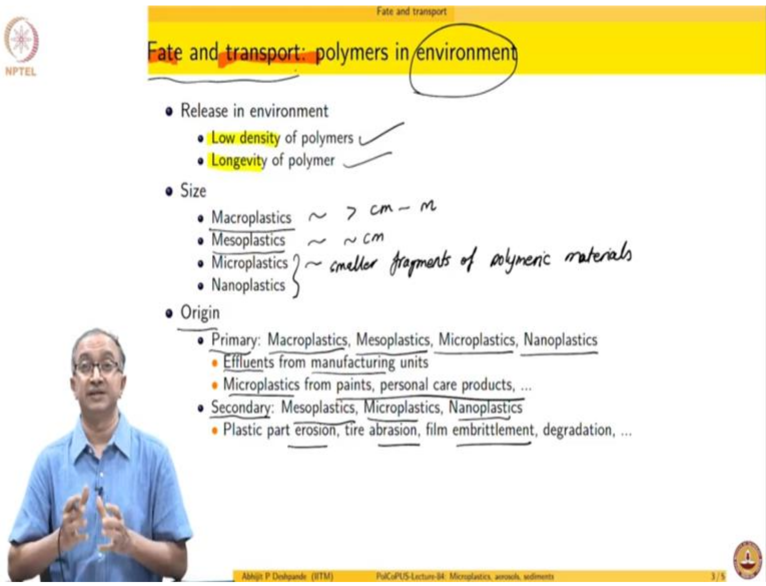
(Refer Slide Time: 00:58)



So let us begin, what we will do is look at the fate and transport which we have already summarized before and see how and why polymers migrate to different parts of the environment and then specifically we will look at smaller fragments of polymers and over the last decade or so there is an increasing realization that a plastic bottle, when disposed impacts the environment in multiple ways in addition to the bottle itself being there.

There are in fact other processes which happen which lead to formation of microplastics and subsequent impacts, so we will review that and also then look at the presence of these microplastics in air or in sediments in soils.

(Refer Slide Time: 01:46)



So let us again review quickly as to what is the overall fate and transport as to how do polymers end up in environment and we have highlighted this before given the density of polymers is low and this is low in comparison to, let us say silt or soil like materials or minerals in organic compounds which have densities which are higher than 2, 2.5 or and much higher while polymers more most often will have density slightly less than 1.

For example, for LDPE or crystalline semi crystalline polymers may be 1.3 thereabouts. So you can see that the density is close to water and so therefore the tendency of plastic objects to get carried over long distances by floating or going along with the water is very high and of course we know that given the covalently bonded macromolecules, the chance for attack in terms of oxidation or any other degradative mechanism is not as high.

And therefore, these macromolecules tend to be extremely long surviving in the environment. So given these two factors put together they get transported over long distances and they stay in the environment over long times and so when we think of the polymeric materials which are out there in the environment, what we should also think of is what is the sizes in which they are there and generally we classify them as macro plastics and this is basically the objects made of plastics themselves.

Which we throw it could be a thin plastic bag it could be a PET bottle it could be a broken chair or any other let say automotive part or any other toy objects which are basically macro plastics. So this is the either the final service part itself or some fragment of it and the dimensions here of course are centimeters and beyond. And then, what happens is, sometimes due to the interaction with environment.

Sometimes due to the process of waste handling many of them get broken down to about centimeter size pieces and so generally, we can think of these as greater than centimeters and they can go as high as meters while mesoplastics are around a centimeter and they are about. So these are small fragments of different plastic objects that are in the environment and because of erosion breakage mechanical loads embrittlement, aging of polymers.

So several processes that we have discussed during the course that can lead to breakage of these polymers and therefore centimeter, few centimeters couple of centimeters fragments are, what are mesoplastics and then microplastic and nanoplastics are much smaller fragments of polymeric materials. And you might think in terms of you know where do they come from? So these micro and nanoplastics come from actually the macro and mesoplastics.

So generally we can think for each of these macro plastic to nanoplastic what is the origin and so when we say primary it is basically what we are disposing and so we of course dispose macro plastics itself or even if we are because of our improper waste management practices we have macro plastics come into the environment. Sometimes, because of the processing at an industrial scale sometimes because of the breakage that happens during the service life what gets again into the environment is mesoplastic which are fragments of the original part.

In fact, microplastics and nano plastics also come in as primary sources because for example in paint we have a microscopic polymeric particles as an ingredient. You will be surprised to know many of our cosmetic products or personal care products also contain some amount of polymeric particles; inks for example. So some various such products are there latex materials which are there which are the lattices of rubber like polymeric particles in a solvent, so all of these contain polymeric particles which are of microscopic size.

So they when get discharged into the environment again they come and get mixed with either water, soil or air depending on what the conditions are and similarly nanoplastics also and in fact in the last 10, 15 years given our interest in manipulating materials at the nanometer scale there has been a lot of interest generated in terms of getting particles of nanometer size and using them in several materials and including polymeric materials for properties enhancement.

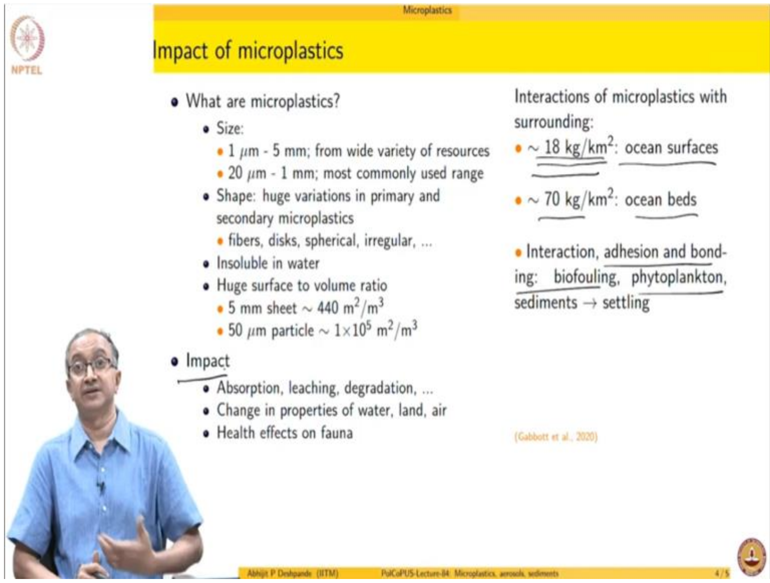
So by design we generate a set of particles which are nanometer size and include them in our polymeric material of interest and so naturally when this gets into the waste stream again these nanometer size particles are directly again getting into the atmosphere. So each of these are primary sources so they could be effluents from manufacturing units, they could be basically by design put into the products and so these are the primary sources.

Now the macro plastics that we put in the environment given that they are low density and getting carried over long distances and over long times what happens is due to processes of environmental degradation which can cause erosion breakage and embrittlement and all these processes basically we lead to formation of smaller and smaller particles. So a bottle, it will initially break down to maybe a few centimeter fragments.

And then from the surface of these fragments or from its corners and things like that we will have processes of microplastics and nanoplastics generated. So therefore there is a complex origin and that is why we have to really look at fate and transport, how is a polymeric material there in the environment. In which form is it there whether nanoplastic or macroplastic and what is its fate and how is it getting transported.

So this is a very important area in terms of looking at polymers in the environment and long term sustainability of these materials.

(Refer Slide Time: 09:11)



So let us look at microplastics in more detail as this is something which has become of great concern over recently and microplastics are basically polymeric particles which are smaller in dimensions and generally the definition is still being worked out and large number of resources tend to refer to basically a micron to few millimeters, couple of millimeters to 5 millimeters as the size which is definition for the microplastics.

However most commonly used definition is submillimeter particles, so particles which are less than one millimeter but they are higher than 20 microns and one of the things about these particles is that there is huge variation in shape because many of these arise due to interaction between the environment and the macro and mesoplastic which are there in the environment. The fragmentation processes are random in nature they depend on what kind of conditions the polymeric material is getting exposed to.

And therefore you can have fibers, disks, spherical particles, irregular shape all of these are possible, of course if it is a primary source then sometimes. For example, we may be using fibers and so since primary source itself is fibers, what gets into the environment is also fibers. So the different shapes that are out there of these microplastics depend on both, what is the primary source and how the shapes that were put into these materials for applications.

And also depends on the environmental degradation processes which lead to very complicated shapes and of course these are insoluble in water, just the way many of these polymeric materials are and the key thing about these particles is the fact, that if one bottle of PET gets broken down into these. Let us say 20 micron size particles, the huge surface area that polymer, polymeric material is now interacting with the surrounding is a great point for us to think about.

So just to give you some numbers a 5 millimeter sheet, basically this is a kind of sheet which is usually there for many of the plastic parts around us. We are looking at around 440 meter square per meter cube kind of area for this we can think in terms of maybe a 10 centimeter by 10 centimeter kind of a sheet. So this is the kind of surface area per unit volume. But just look at what happens if the same polymer is now as a 50 micron particle.

We are looking at orders of magnitude higher surface area per unit volume and it is the surface area through which the interaction with the surrounding happens, whether it is surrounding water, surrounding air, surrounding soil particles, so whatever may be the surrounding the interaction happens through these interfaces of polymer with the surrounding. So we have an extremely large area of interactions between the microplastics and the surrounding.

So this is something for us to therefore think about that their impact can be much larger than what we think when we say that how does a polymer object, let say a plastic bottle interact with surrounding water or air. The same amount of polymer dispersed as very fine microplastics will have lot more interactions because of extremely large surface area. And of course why would these impact be, because the phenomena of absorption, leaching, degradation all of the features that we have already discussed.

If let us say this polymer can absorb some organic substances from the surrounding, it can also leach some of the additives which are there in the polymer and as we have discussed that it can absorb in one location it can leach in another location. So all this becomes very effective because of the huge amount of surface area and because of this the other impact that it can cause is change in the surrounding medium.

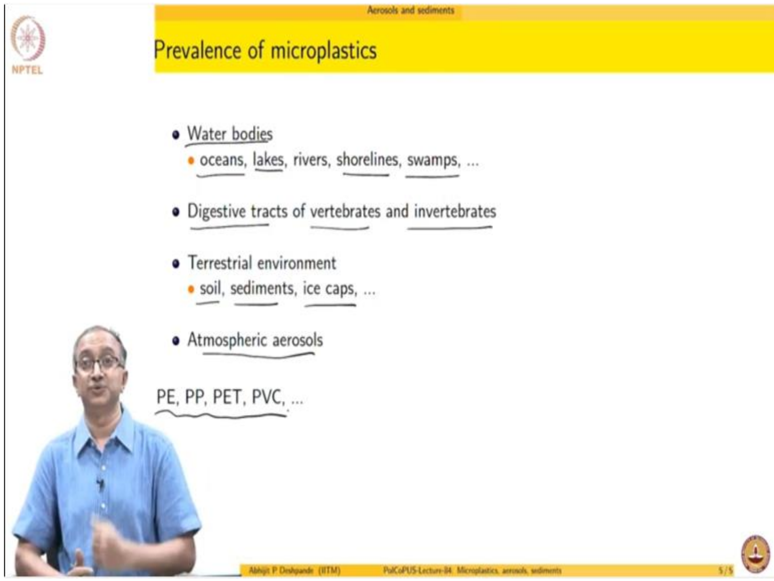
So it could change for example, the concentration of different species it could also change things like oxygen availability in case of. Let us say aquatic systems where oxygen availability is required for multiple species and these polymers can act as barriers and they can therefore influence how oxygen is getting transferred in different parts of the aquatic medium. So, therefore it can change the properties of the surrounding other important effect that these microplastics can have is through ingestion.

So from small animals like fish to much larger animals we can influence the overall health of these fauna, because they get ingested and then these are not part of our usual food items and so what happens? What is the overall long term impact, do they get accumulated in the body, if they get accumulated in the body what is the overall consequence. If they do not get accumulated in the body, do they influence the functioning of our digestive tract?

So several questions to which a lot of answers are being generated over the last few years and so just to give you an idea how this can also be in case of ocean what is known is that there is about 18 kg per kilometer square of polymeric materials and but it is much higher it is in the beds. So even though we think in terms of disposing of plastics and given that their density is low, they would float and move around but there are processes which are happening at times which lead to basically agglomeration and settling of these.

And again this is a long term phenomenon. So therefore ocean beds have accumulated much larger amount of plastic and so any plastic amount that is visible to us on the surface is just an indication what could be out there. And, given again the limited bio degradation of polymeric materials their half life or their lifetime in the environment is quite high and so they will remain as in ocean beds and again if it forms a film over some of this existing species there, then you can again see that how it will lead to a significant impact in terms of the life and sustainability of those species.

(Refer Slide Time: 16:05)



So the prevalence of microplastics is there in water bodies, we just saw example of how this there in oceans but lakes, shorelines, swamps, marshes where there is a lot of water,grass vegetation along with fairly loose soil, so in all these situations microplastics are present. There are also been reports, in fairly large number of reports of them being present in various species. They are also present in soil in as sediments in ice caps.

So there has been investigation of ice caps in polar region or Antarctic region and so we have seen that you know the microplastics are present there and they are also present in the form of aerosols again because density is low and if size is low then they can become airborne and they can again depending on wind speed get transported across long distances and we of course know, that there are aerosols of biological origin also either from plants or from bacteria or other living species microorganisms.

So, therefore we have in as part of atmospheric aerosols even these polymeric materials and generally when most of these studies have been done it is not a surprise that the polymers which feature in many of these microplastics pollution are polyethylene, polypropylene, PET, polystyrene, PVC basically the set of polymers which we have seen in this course have excellent properties.

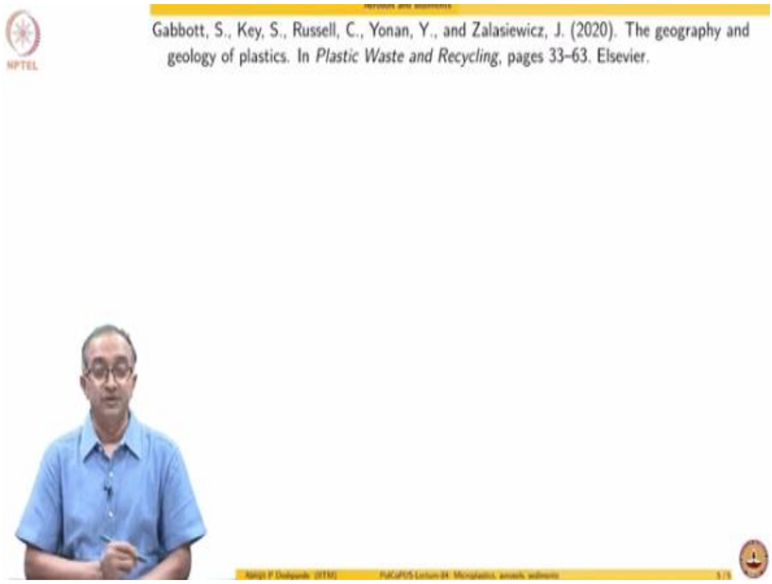
So their use is very widespread and given their now disposal and interaction with the environment large amount of microplastics from these polymers have formed and they have permeated through all these different places in the environment and that is what is causing concern and significant amount of work is going on in terms of analyzing fate and transport in the sense where is the origin of this microplastic?

How are these microplastic being generated? How are they getting transported? So that we can understand and try to reduce the influence of these microplastic reduce their migration. This is one direction and second is of course in terms of their effect on any of the flora and fauna where these microplastics have come in. So both of these directions we are significantly studying one of course large question that could be thrown at us as polymer scientists and engineers is why are these microplastics given a chance to be generated?

Why cannot we have polymeric systems, which do not generate these microplastics or even if these microplastics get generated they should be biodegradable like so many other material systems that are part of the bio geochemical cycles. So that is a valid concern and that is what a lot of work right now in polymer science and engineering is going on towards trying to see, whether we can try to look at those polymeric systems which will lot lead to problems like this.

So, in terms of the waste due to macro plastic has been known for 30, 40 years. It is only in the last 10 years, we have become aware that the macro plastic which is disposed off can also lead to such problems.

(Refer Slide Time: 19:37)



So with this we will stop here and in a few lectures we will look at the biodegradable polymers, the phenomenon of biodegradation, as well as a few examples of biodegradable polymers. Thank you.