Simple Concepts Related to Single Macromolecule

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Lecture - 12
Reuse and Repurpose

Hello, we are in the second week of our course on polymers. And in this lecture, we will look at an aspect related to sustainability of polymers and, specifically reuse of the polymer. It is also referred to as the repurposing of polymers.

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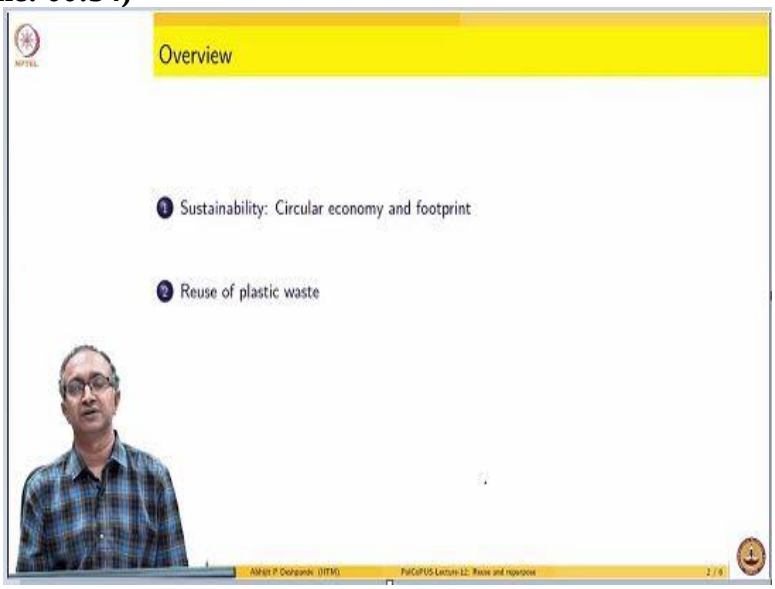

And we will do this by first looking at some broader concepts, which are related to sustainable use of polymers. This is especially important where we not only look at polymers from the point of view of their usage, but also from the point of view of their re-usage. Recycling is something which we are all quite familiar with. Recycling implies that, we reprocess the material, but reuse is something which is like what we do for a glass, we just wash it and reuse.

So, if materials can be reused, then they can function for a much longer period of time. So, is what is the possibility of reuse and in which way do we think about reuse in a broader context of sustainability.

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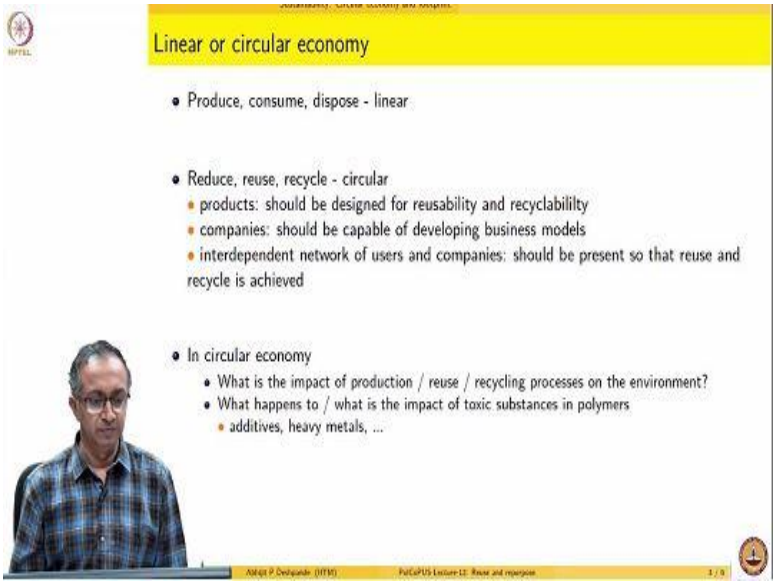

So, let us first look at this broad concept, which has become very important in the last few years related to circular economy. And, generally we are contrasting this with what we have done traditionally, in terms of linear economy, in which case we take a material, we produce, then it is used or consumed and then finally, we generate waste. So therefore, disposal has to be thought of.

So it is like a linear chain, where chain of processes, where each one is separately thought of. And this disposal then in the end does not lead to anything, how we started with the raw materials for the production itself. So that is why it is a linear progression of processes? Now in circular process, what we would like to do is to close and say that post disposal whatever materials are generated, can they become raw materials for production?

So, one of the aspects of thinking circular economy is also in terms of making sure that this disposal to production is also minimised. So, therefore, we think in terms of reduction, we think in terms of reuse, and we think in terms of recycle. So, all these aspects are combined, when we start thinking of materials and products in a circular sense. Because in this case we do not have end of life. End of life becomes beginning for certain other sets of processes.

And so if we think in terms of these circular economies, then product essentially should also be designed so that we can reuse them, and then we can recycle them or we can recover the raw materials from them. And so, we expect the companies that the business model has to be developed, so that this is made possible. And so, we need importantly for a circular economy

to function - an interdependent networks of users and companies, so that we can focus on trying to use the materials in a more sustainable way.

And, generally when we are thinking in terms of circular economy, questions which are very important are in terms of, you know, what is the impact of production, reuse, recycling processes? Because quite often we may think in terms of waste plastic, the solution is to just say that, we will recycle them. But we have to remember that a recycling process also impacts.

When we reprocess, we, there is input of energy, there is input of raw materials and there may be effluence. So, therefore, a recycling technique is good for repurposing the material and rather than having it disposed being again coming back into application, however, it does have impact. So, instead of recycling if we do reuse then the processing and fabrication associated with recycling can be avoided. So, in circular economy therefore, we think more broadly in terms of how can we minimise many of the aspects related to impacts.

And the other thing also we will need to think of is whenever we are doing recycling or repurposing or reusing, what is the impact of additional substances which are added as additives in case of polymers. So, many times we may use catalysts to polymerize as we seen already, we use additives for stabilisation for UV stability, for enhancing the flame retardant behaviour of polymers. So, what do many of these materials do when we try to reuse, recycle, repurpose of these materials?

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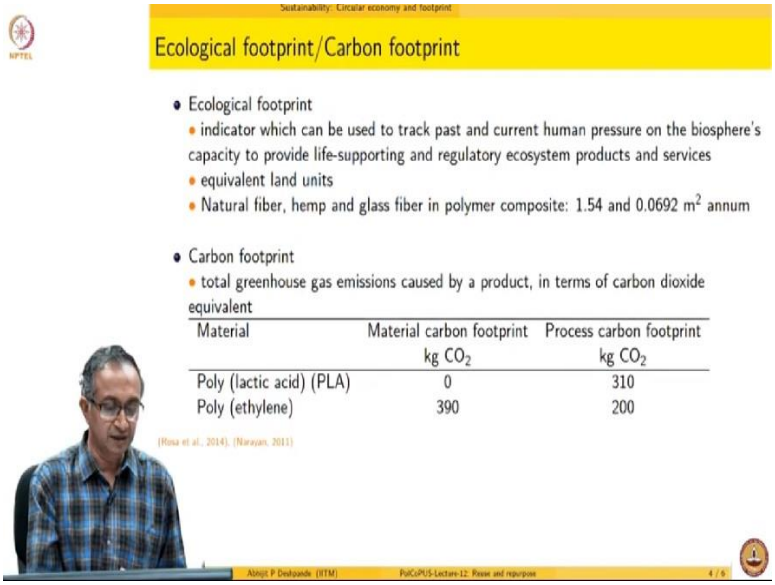

The other important aspects to think about when we think of sustainability of any material or any product or process is related to footprints. And we have a very broad term called ecological footprint, which is an indicator which can tell us about what is the influence of a particular material activity or a product on natural ecosystem. And therefore, it talks about the functioning of the ecosystem without getting disturbed by this product activity or a process.

And so, we generally think in terms of land units. So, when we are trying to fabricate something, how much land area would be required based on the amount of equivalent amount of energy that is spent or equivalent amount of impact that is had and so on. So, for example, let us say when we are using composite materials, we can use glass fibre or we can use a natural fibre. And quite often we will immediately tend to think that natural fibre is good because it is a renewable resource.

And yes, that is true. However, natural fibre can have a bigger ecological impact in terms of land usage. So therefore, ecological footprint talks about the overall sets of thing and one of the measure is also in terms of land usage. So land usage for hemp fibre is much more compared to glass fibre. However, there are several such indicators. One more indicator in this overall footprint calculation is carbon footprint.

So this is the total amount of emissions that are caused while making a product or doing an activity. And it mentioned in terms of what is the equivalent amount of carbon dioxide produced of whatever greenhouse gases that are emerging. So this is in the context of climate

change. So if we look at polylactic acid, which is a biopolymer, it is obtained from a renewable resource, like lactate, lactic acid lactite.

And so when we look at its carbon footprint from the point of view of material, it is not there, because we are using renewable resources. However, when we process it, because lactic acid or lactite has to be polymerized. So, to look at the process itself, there is certain carbon footprint involved. But if you look at synthetic plastic like polyethylene, then we have carbon footprint both in terms of raw materials itself, because we are using a non renewable petroleum oil based resource and then of course, process also.

And you can again see, interestingly, that polyethylene process might require less carbon footprint compared to polylactic acid. But if you look at the sum total in terms of material plus process costs, then in carbon footprint of polylactic acid is less. So, all of these questions are very important and complicated when we start thinking in terms of sustainable use of polymers.

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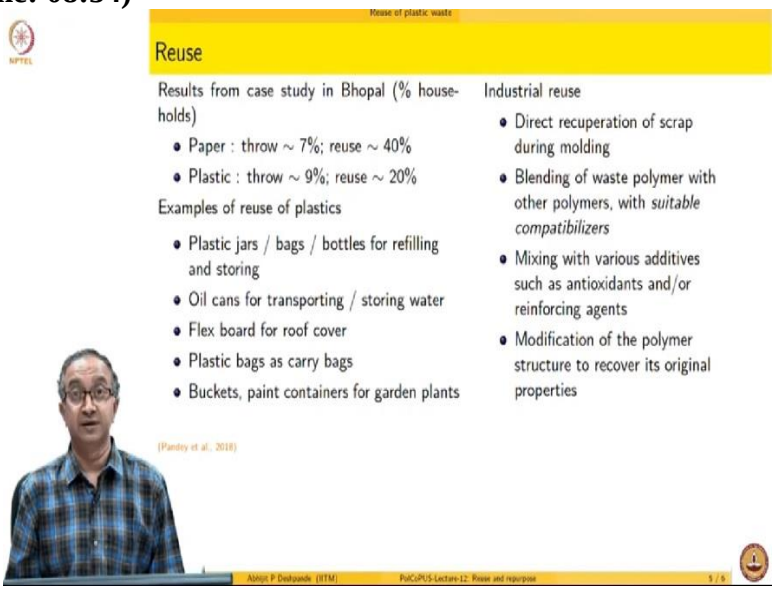

Let us look at reuse little bit more and that is why we will do this by just looking at a case study from Bhopal, where survey was done to figure out, you know, how are they using the materials there, whether it is metal or glass or paper or plastic. And what I am doing here is just showing you the data related to paper and plastic. And what households gave information on that they reuse fair bit of paper. But if you look at reuse of plastics, it is much less.

So in general, if we have to think of plastic material as a more sustainable material, then certainly reuse of plastics has to be increased. Examples of reuse of plastics, of course, we see a lot of this reuse. And I am also going to highlight that this can be a problem and we have to be careful while reusing. But we see that people using jars and bottles for storing and refilling. This is done in kitchen, household or industries or offices. We can use material which was made for polymer-plastic can which was made for oil but it can be used for storing water.

Something which was discarded from a public display board can be used as a roof cover. So, there are various ways in which we population already uses fair bit of plastics before disposing it. And one other important class of reuse is within an industry itself. So, while producing plastic, while producing, let us say automotive parts or chairs or aerospace products, we have a fair bit of plastic material which is generated during the process itself. So, therefore, this itself, this scrap can be directly again reused.

And so a lot of industries also tend to these days, reuse some of the material again in their production lines, so that the overall value of disposal that comes at the end is much less. And many of the times the reuse and repurposing in industry might have to be done by some clever adaptation of alternative strategies. For example, we may blend the scrap polymer with other polymers.

And this is where I want to just highlight and you to remember the word compatibilizer. Whenever we mix 2 materials, one polymer with another a polymer with fibre for composite, we might need to think of compatibilizing. So, we have to always think in terms of these 2 materials and their interactions and can we make those interactions favourable. So, we also of course, have to add properties enhancers, so, antioxidants to improve the stability or reinforcing agents and we may have to modify the structure.

We will see that when we reuse the polymer again and again in an industrial process such as a moulding operation, maybe molar mass will decrease because of chain scission, chain breaking down reactions, as we saw in the lecture related to depolymerization. So, then we might have to do some modification to the polymer chain, so, that molar mass decrease is negated in terms of whatever is the overall performance of the part.

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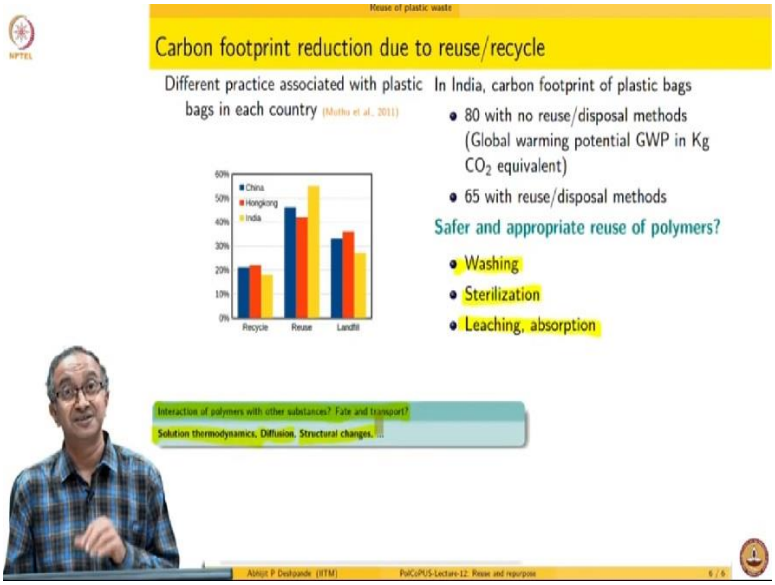

Just to continue with this reuse aspect and why reuse should be done, again this is some study which is trying to highlight you know how reuse pattern is different in different countries. And this is data from 3 countries, China, Hong Kong and India. And what you can see is reuse is significantly higher in the Indian context for plastic bags. So, this is something positive in terms of the Indian survey, at least this was the data from 2011, and we have no reasons to believe that we would have changed our behaviour significantly.

If at all, in fact, we have become far more aware in terms of reuse of many of these plastic materials. So the other quantification of some of these sustainability aspects of polymers can be done. So in this work, they highlighted that if you include reuse then the carbon footprint decreases. So, it is 80, if you say that we are not going to use, reuse, or we do not have proper disposal methods, but as soon as we start having reuse and proper disposal methods, then carbon footprint comes down.

So polymer can become lot more sustainable if we incorporate strategies of reuse disposal recycling into its overall usage. One key thing that we as polymer scientists and engineers have to remember is reuse - is it safe and appropriate? Why do I ask this question? Because polymers, when they are in application are interacting with the surrounding environment other materials and this interaction is it changing to any change in its properties, is it changing its chemical and physical nature also.

And when we now reuse it later on, will that have an influence on the reuse? For example, whenever we are reusing, of course, we put to washing. So, how good is washing? Is it really

washing away something which was considered not so good and therefore, we are doing the washing? So, is the washing really working? In case of applications where there are health influences, sterilization may also be important.

So, is sterilization effective? Two key things that phenomena which we have to be very careful while reusing plastics are related to leaching and absorption. Leaching is something where material from a polymer let us say, we can think in terms of a PET bottle which is being reused. So, something which is there in PET can leach out to whatever we are storing. So, we are storing water in PET bottle something can leach out from PET to the water bottle or inversely, we can have absorption.

So, something if you are storing let us say, medicine in a plastic bottle, can some of the active ingredient of the medicine go and get absorbed in the polymer. Then therefore, they are not available. Or other ways to think about it is initially the plastic can is used for oil storage. Now, can some of the oil molecules go absorbed in polymer and plastic can? Now, later on we throw the oil is used up we wash the plastic can and now we use it for water storage.

So, now the oil which is there in the plastic can, can it leach out to the water and when we use the water will it be possible that it will be consumed? So, therefore, these absorption and leaching phenomena are also very important while reuse of polymers. So, generally interaction of polymers with other substances and fate and transport of small molecules and macromolecules over long term exposure is something that we always have to think of.

And so, whenever we think in terms of sustainability of polymers, we have strategies such as reuse, recycle, but there is always caution in terms of safety and appropriateness of these strategies. And scientifically to address these of course, we need to be aware of phenomena such as absorption, leaching, mixture, thermodynamic behaviour of one substance with other, how do molecules move around when there is a concentration gradient diffusion, is there a structural change when absorption happens?

So, all of these are fundamental scientific issues, which are very important in addressing sustainable practices such as reuse and recycle.

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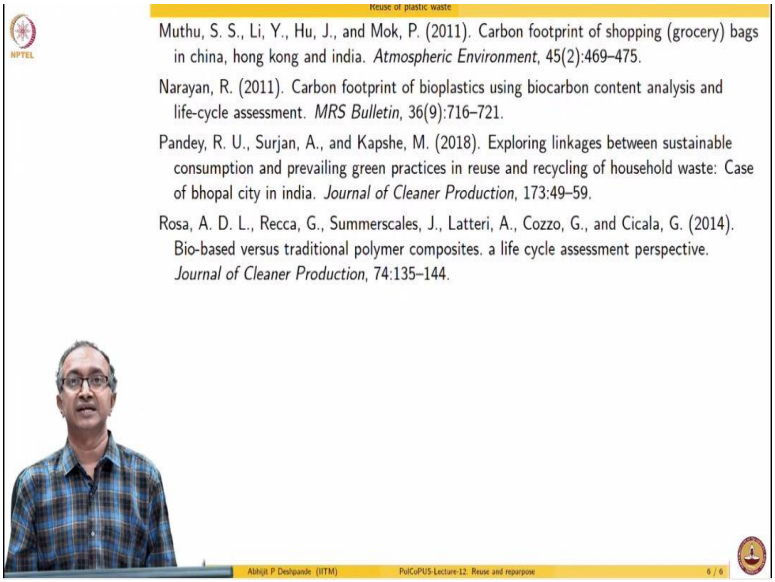

So, with this, we will close this lecture on reuse, and continue our discussion related to single macromolecules for the next 2-3 lectures. Thank you.