

Course on Integrated Waste for a Smart City
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Module 12
Lecture No 60
E-Waste Management (Contd.)

So hello welcome this is the last module of the lecture material. After this you will see me again at least once when we will be reviewing all those survey questions results that I had giving you during earlier weeks. So you will I you will have that video up pretty soon after this week.

So it is a looking at electronic waste management, if you remember from the last video, what we did? We were looking at recycling, how the recycling is being practised globally and today will continue that discussion, we will talk about how the recycling is being taken up not only by the companies of electronics manufacturer but also by some of the urban local bodies. In many countries in the world the municipalities are looking at the possibility of making money out of electronics as well.

If you remember from the rule that we talked about from the Indian context, we were saying that in India for the e-waste management rules we want our electronics producers to setup a recycling centre, they should be authorised recycling collection and that is one way of doing recycling of e-waste, that is you saw some example of similar things being done, either more in a cooperative way in Best Buy or office Depot and other place that I showed you in the video in the previous video, but some of the municipalities around the world is also looking at the possibility of, why do not we collect the garbage.

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Municipal Government Collection

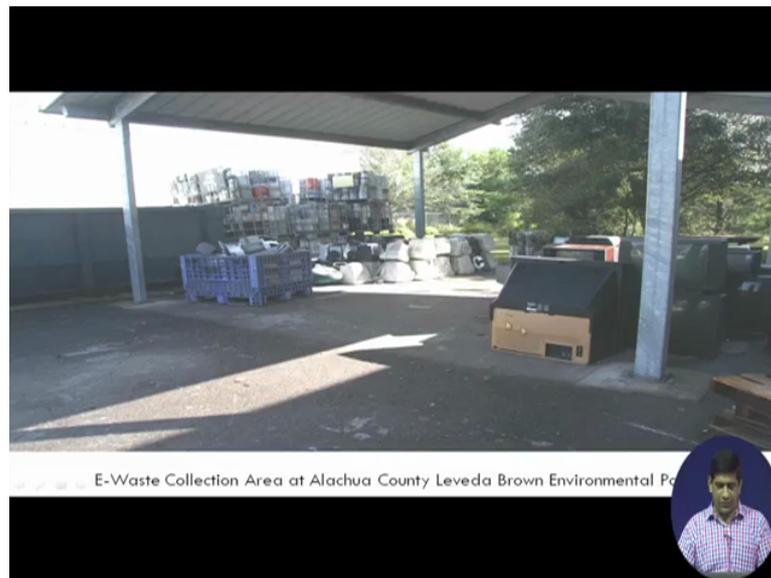
- Household collection of E-Waste for recycling is not common, but many municipalities provide free drop-off services for residents.
- These are often coupled with household hazardous waste recycling facilities.
- Multiple studies have evaluated optimal methods for WEEE collection, processing and reverse logistics.



You this type of signage is kind of becoming common these days, where you see that municipalities are looking at household collection of e-waste for recycling is not common, but many municipalities what they are doing, they are providing free drop off service for the residents. What they are trying to do here, they coupled with household hazardous waste recycling facility.

So household hazardous waste collection is usually is not done, as we were talking in municipal solid waste part is not usually not done from a individual houses, what they do is? They put a collection centre where you and I can go and drop off household hazardous waste. Similarly where they can drop off household hazardous waste the thing is that why do not you drop off your electronic waste there as well? So what they have been looking at is they try to evaluate how to collect it, process it and look at an even try to make some money out of that.

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So for example, this is one e-waste collection area for one of the municipalities in Florida, where they are collecting this e-waste and if some of those workers working there also they are actually trying to look at some of this electronic waste and if there is something could be salvaged they can use it for that as well.

So there has been cases like I personally was benefited when I was doing my waste management research as part of my Ph.D., I did find I did find the TV there with just as a minor problem and then I brought the TV home and it was like a 25 inch TV and I am talking about early 2000, so it is a it was a pretty big TV at that particular time and that work that worked for my Ph.D. days. So it is a so things can be salvaged, can be recovered, can be sold off, some people are looking at making money out of that as well in terms of electronic waste recycling.

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Recycling Economics

- If WEEE contains valuable resources, why doesn't the market dictate in most WEEE being recycled?



In terms of the economics, they contain valuable resources that we talked about earlier. So in terms most times the market why does not the market dictate the most WEEE being recycled? It is the process of recycling to recover this valuable resource, that is actually very challenging, so will talk about some of this process your as well. So recovery of those is very challenging and many times what happens is actually you end up paying some money rather than getting some money.

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Recycling Economics

Detailed Recycling Price Guide (June 2011)

Note: Items highlighted in yellow are not accepted this year.

Item	Cost	Item	Cost
15" or Smaller CRT Monitors	\$10.00	MP3 Player	\$0.25
17" CRT Monitors	\$15.00	Major Appliances	Not Accepted
19" or Larger CRT Monitors	\$20.00	Media Drives	Free
Air Conditioners	Not Accepted	Microwave Ovens	\$10.00
Alarm Clocks/Clock Radios	\$0.50	Modems (Cable & Standard)	\$0.25
Answering Machines	\$0.50	Monitors, CRT type (15" or smaller)	\$10.00
Appliances - Large	Not Accepted	Monitors, CRT type (17")	\$15.00
Appliances - Small (Kitchen or Bathroom)	\$1.00	Monitors, CRT type (19" or larger)	\$20.00
Bathroom Appliances	\$1.00	Mouse	\$0.25



So here as you can see over for the different types of like a electronics depending on 15 inches smaller CRT monitors, 17 inch monitor, 19 inch monitor, air conditioner was not accepted, alarm clock, answering machine, appliances, bathroom appliances, MP3 player,

major appliances, media drive, microwave oven, modem, so there are different stuff and if you drop off one of these you actually have to pay this fees.

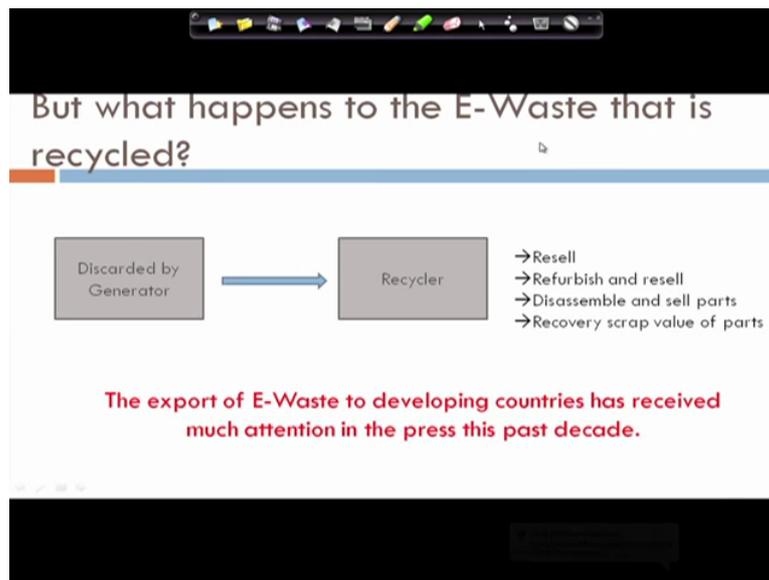
So there was actually a fee associated with that, because it takes an effort to recycle those it is not and it does make money, but if you want to do it as was trying to tell you in the previous module as well that, if you set up a plant which really works taking into consideration all the environmental health and safety into consideration it is very it is requires lot of investments. So to make that happen what we try to do is we are like to make that happen we have to find money from somewhere and that is what these money go for that.

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Item	Fee	Item	Fee
Batteries	Not Accepted	Movie/Slide Projectors	\$3.00
Big Screen TV's (Projection)	Not Accepted	Paper Shredders	\$3.00
Boombones	Free	PC's	\$2.00
Cables & Cords	Free	PDA's	Free
Cable Boxes/Satellite Receivers	\$1.00	Pocket Calculator	\$0.25
Calculators	\$0.50	Personal Music Player	\$0.25
Calculators (Pocket)	\$0.25	Power Straps	\$0.25
Camera	\$0.25	Powered Subwoofers	\$3.00
Car Batteries	Free	Printer (Dot Matrix)	\$3.00
Car Stereos	\$0.50	Printer (Laser)	\$7.00
CD Players	\$3.00	Printer (Inkjet)	\$3.00
Cell Phones (including battery & charger)	Free	Projector (Movie/Slide)	\$3.00
Clock Radios	\$0.50	Projection TV's	Not Accepted
Computer Speakers (per pair)	\$0.50	Rechargeable Batteries	Not Accepted
Computer Tower (CPU)	\$2.00	Record Player/Turntable	\$3.00

It is like a if certain type of as you can see over here depending on the type of waste that you drop off you have to be certain fee to drop off those waste. It is not a lot of money just a but it is a small amount of money but that money those money add up, those money add up and they help in development of recycling system.

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So and like how it is being recycled? What happens to it? Like in once it is discarded by generator it goes to recycler. Some of them could be resold, as I was telling you that if it is good, say if you have 3 bad computers out of that if you can make 1 good computer because of the some of the parts you can salvage and you can make one good computer out of that so that that is your day can be resold. You can refurbished and resell, you can refurbished and resell as well. Disassemble and sell the parts, some of the parts maybe working, then you can recovered scrap value of the parts.

So those are it is being done if it is done in a in a formal sector, but many of the as the things highlighted in red over here what is happening is? We have export of e-waste is happening a lot in terms of developing country. So lot of e-waste is being exported to the developing countries where we have e-waste making way to the developing countries in the past decades almost like two decades where things are going into the developing countries.

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You see some pictures here now and this is pictures from Ghana in China and those places. You can go on YouTube, you can find several videos of how e-waste is being improperly managed in Indian context, so that is also out there. So as you can see, e-waste is dumped along with the other waste over here and this is from Ghana.

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And you see all this electronic waste just piled up over there, so we have all this electronic waste all piled up which needs to be disposed, so that is that is over there. Here you can see the waste which says city of Los Angeles, state of California, so this they are and this waste was found in Africa, in China, in India, so even the waste so this basically shows that waste is travelling from the Western countries to Indian subcontinent, Africa and other places.

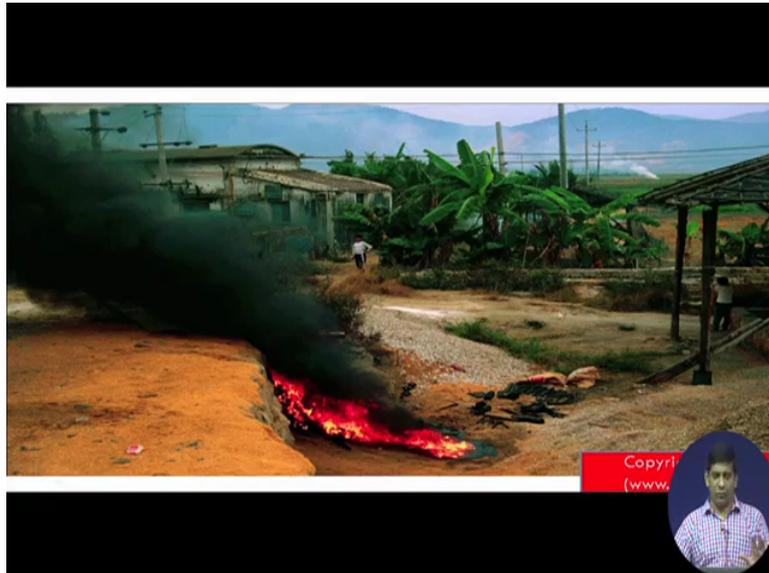
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This picture is like a classical picture, all this picture actually came from this ban.org, it is there picture, I am just using them they have for this lecture proposes you cannot please do not reproduce it without approval from ban, because I have been given approval for use it for the lecture material.

And so this is again this picture is from China, this is a very classical picture you will see you see this picture many times in different news report that this particular village there whole surface water source was got damaged or you can say became unusable because of improper management of e-waste.

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You see this here to recover some of these copper, these wires are being burned and you can see all these black fumes going into this that is all like a dioxins and furans because of those plastic coating on top of that. And this why this plastics wires are being burned? Just to recover some of those copper there, copper, aluminium which are little bit precious metal which they can sold off and but the amount of environmental and human health impact that is coming, the cost of environmental and human health probably is much-much more than the cost of the amount of gold or amount of copper or aluminium that is being recovered here.

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Here things are being used in this is you see all these stuff, they are aquaragia. Aquaragia is concentrated form of sulphuric acid and nitric acid which can dissolve lots of metals and these drums being used with aquaragia. And as you can see like people are just using this rubber boots, some sort of protection, lot of fumes, inhaling all these fumes and becoming sick and off course off course it is also contaminating the surrounding soil, water, air and all the different stuff.

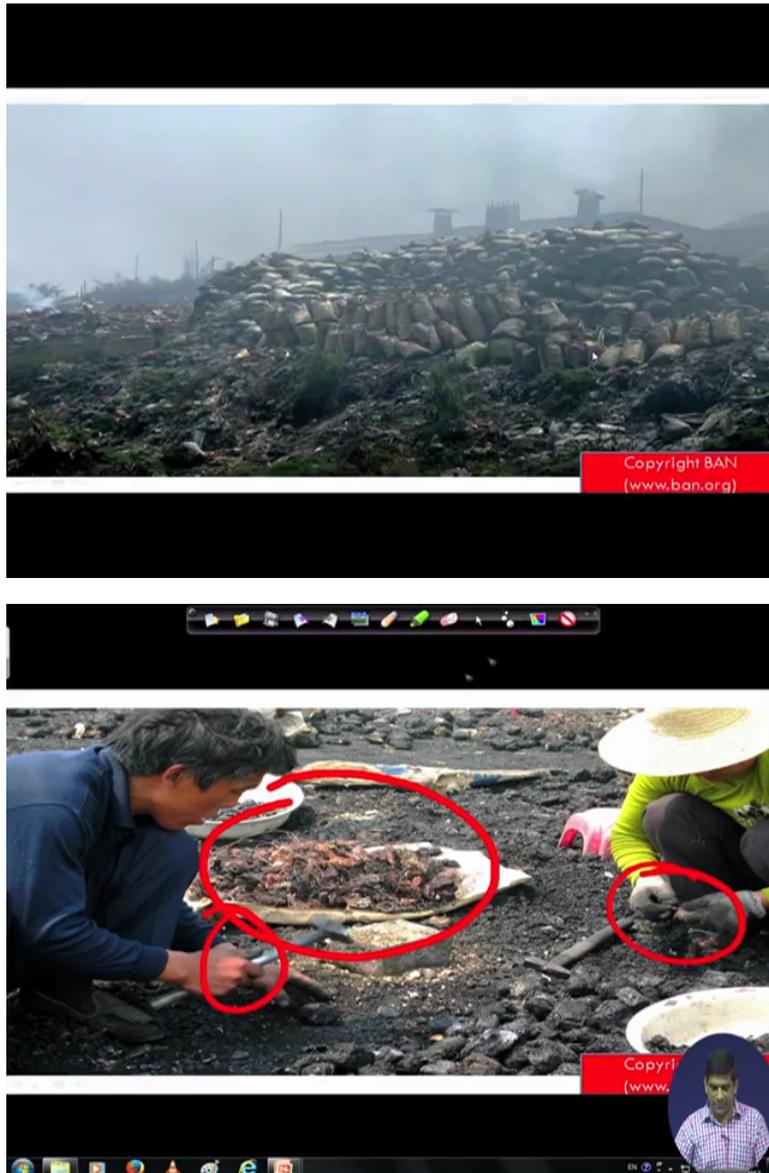
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Again things being burned up, things which what is the typical procedure they do, they dismantle, they try to recover whatever they could and many times whatever they could not recover because of it is difficult to do that, if they have plastic they just burn it. So plastic when burns goes away you have now they metals left, try to recover metals out of that. But the processes is so crude, the process is so informal without any environmental protection, without any personal care protection like personal protection, people are getting sick, people are getting affected with all these contamination.

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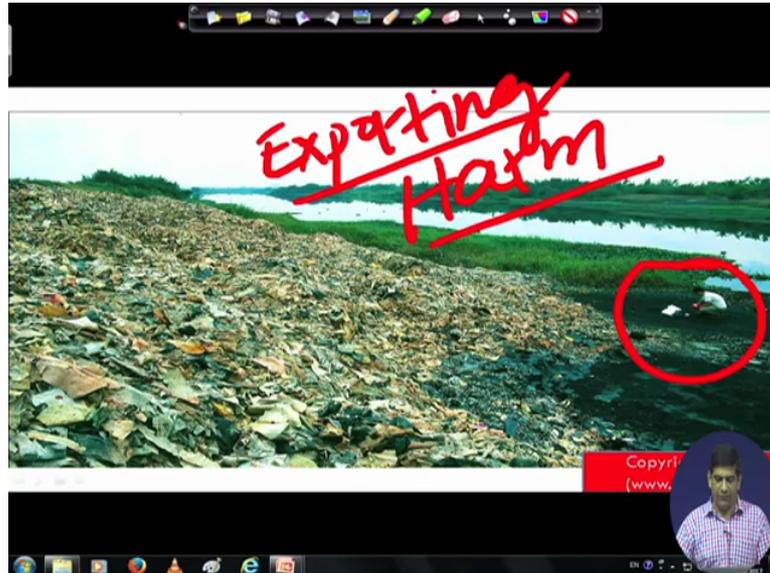


You can see another picture of lots of fumes and other stuff going in into the atmosphere, some more pictures from all this e-waste. Here now you can see people trying to just trying to recover some of this copper, trying to recover this copper from there. And so as you can see many crude way of working it, they are not it is not sophisticated those all we have these like a hammer and other stuff which is being used to do that.

So it is not very so we have as you can see it is being done in a very crude way. It is a all those hammer, chisel and no sophisticated equipment which will not be there if you set up a e-waste recycling facility. As we have seen in earlier slides, earlier video that in India also we have several e-waste recycling facility being set up, but they are not able to get electronics and the way the electronic is being managed is this. You go on YouTube you find several of these videos showing how the e-waste is being managed in Indian condition.

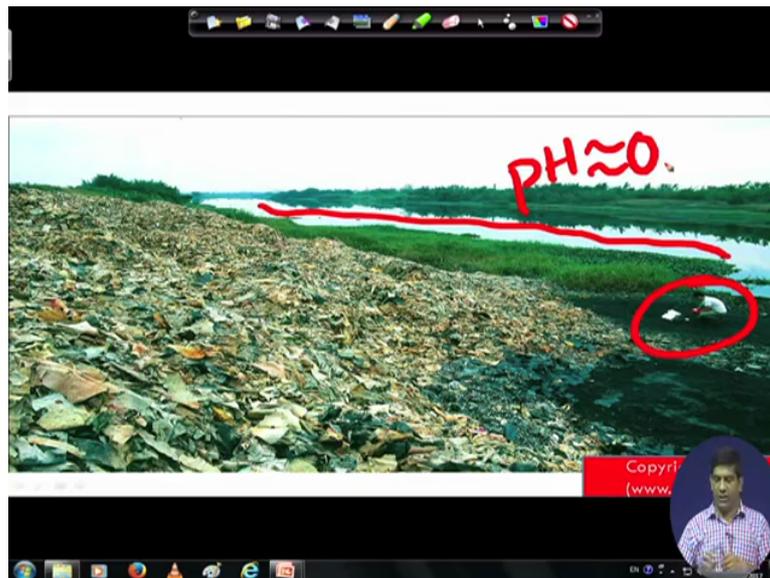
So just to recover some of this copper out there, just they are getting all these no protection, no protection here, no mask nothing. So as you can see getting possibly getting hurt, maybe getting some needles and others like things may they may get some other kind of problems as well.

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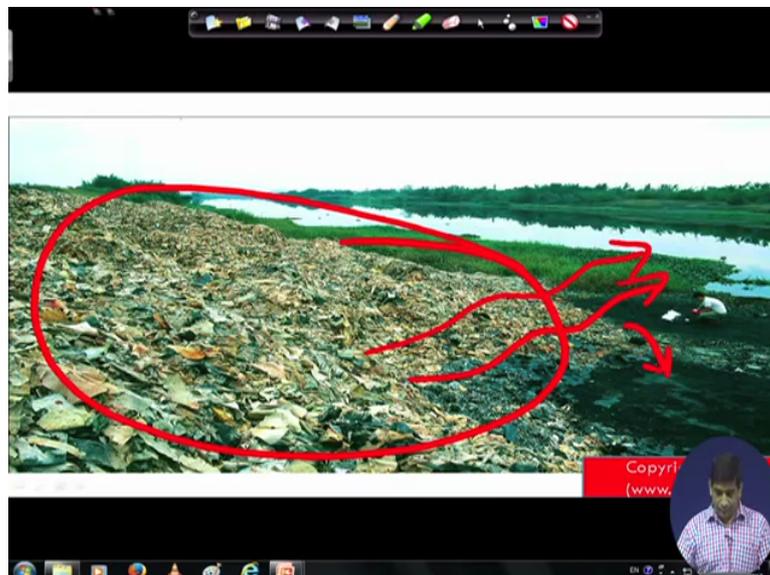
And this particular village that I was talking about, this is the water body they had and the water body here when the gentleman taking sample and this again this gentleman was from Basel Action Network and who did this there is a video actually out there exporting harm. If you go on exporting harm, if you go on YouTube and try to type this exporting harm and you will see this like a story behind this two pictures that you are looking at right now and this is a village in southern China, where they are basically destroyed that village groundwater surface water source because of the improper e-waste disposal.

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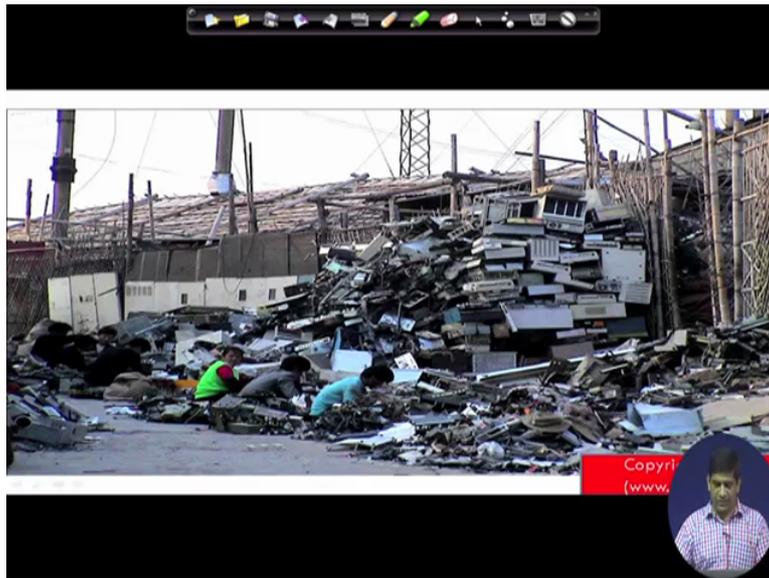
And this surface water which is over this surface water had a this gentleman is taking some soil, water sample, sediment sample and the pH was almost 0, like pH was close to 0 and less than 1 that is what around the pH meter it is came out to be very close to 0 and lead was almost 25 I think it is around more than 100 times than drinking water limit.

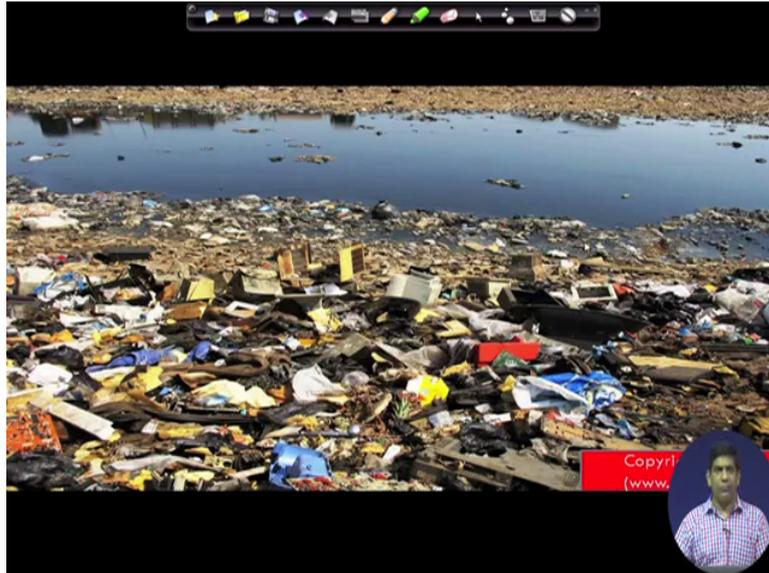
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So this water was contaminated, they cannot use water as you can see over here whatever they could recover they could. After this is the material which could not be recover and this is just dump on the side of the river and then things will keep on leaching into this river and getting into the sediments and becoming a problem for your soil, sediment and off course could things may go can get airborne as well.

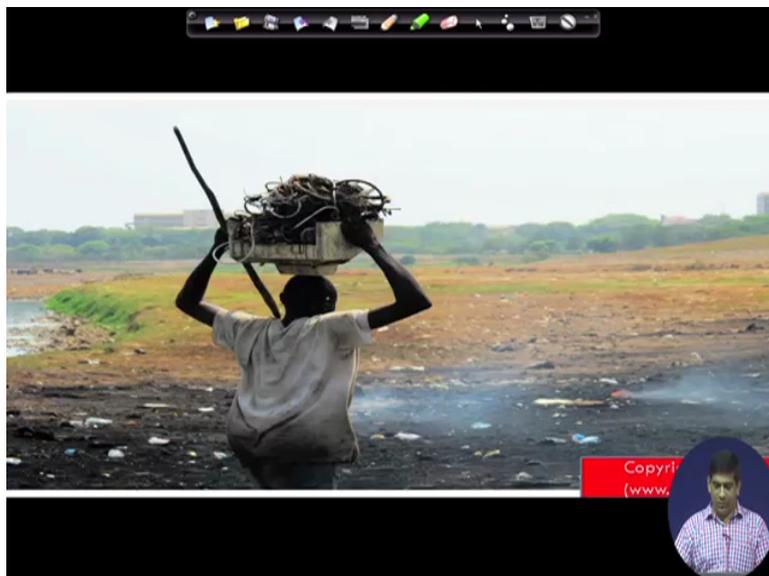
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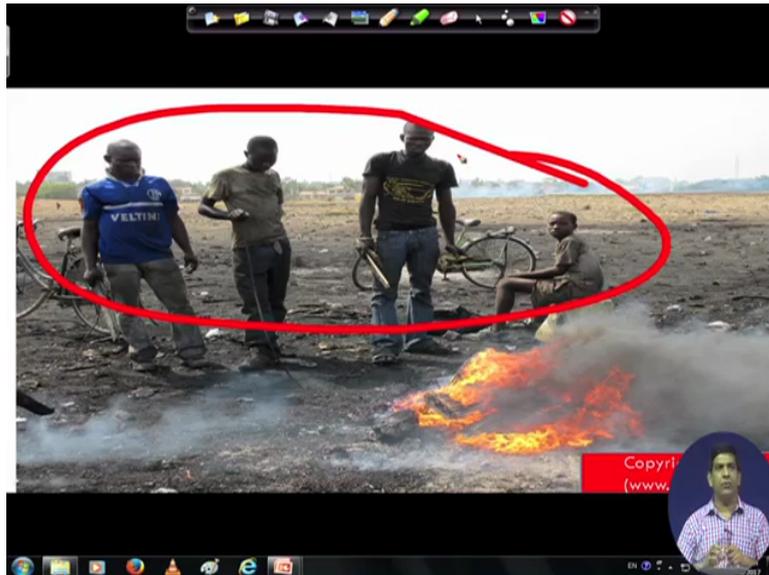




Again you see lots of activities going on in terms of electronics village after village. So that you see people are working on it and this is now in Ghana in Africa, as you can see things have been dismantled, again whatever could not be recovered just dump on the side of the surface water.

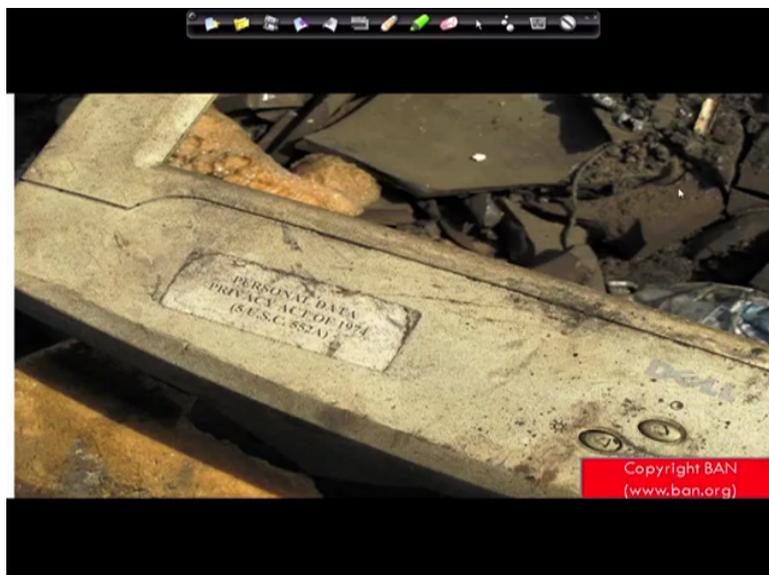
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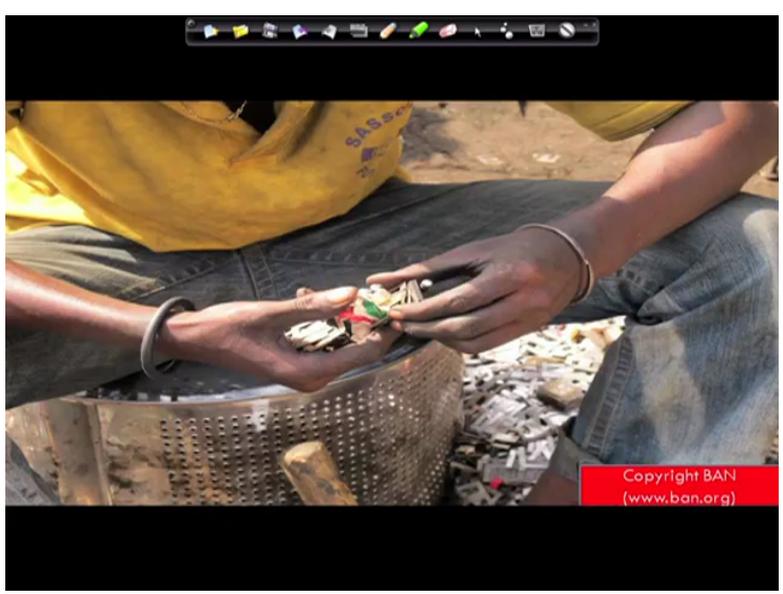
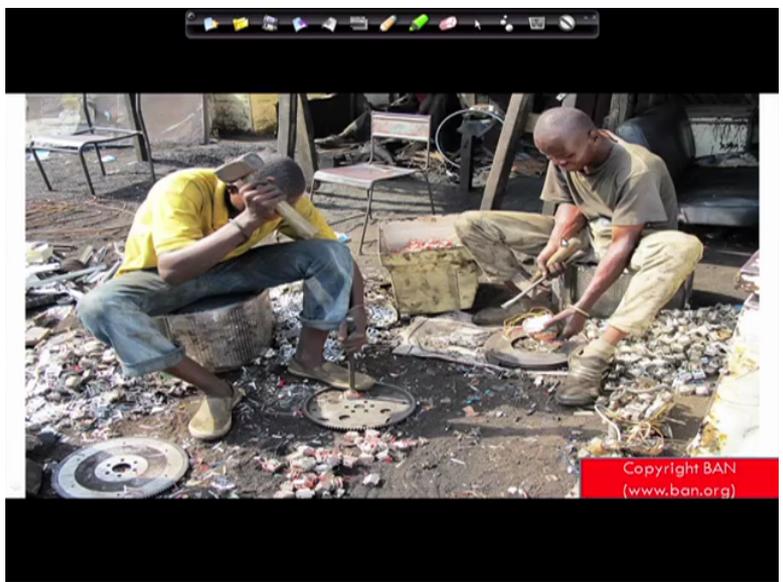
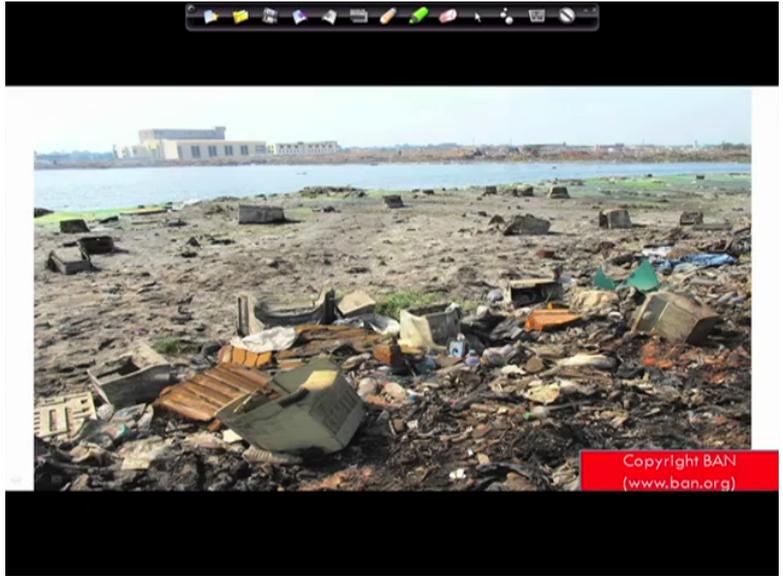


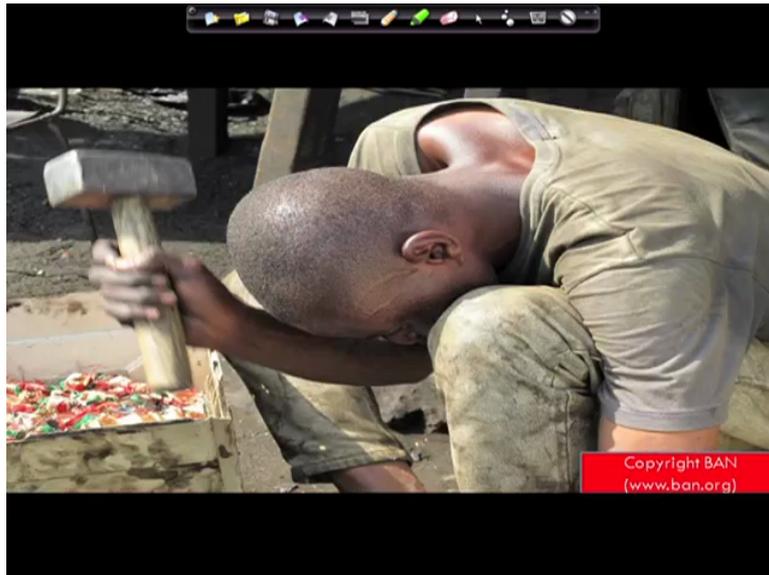


People taking at those wires and other stuff, they are going to burn it just to recover some of those heavy metals and all this peoples are getting exposed to all these fumes. So as you can see over here this peoples are getting all this peoples are getting exposed to all this fumes and thing about health condition of this people after being exposed to these kind of toxic fumes day in and day out for several days, so it is off course not good.

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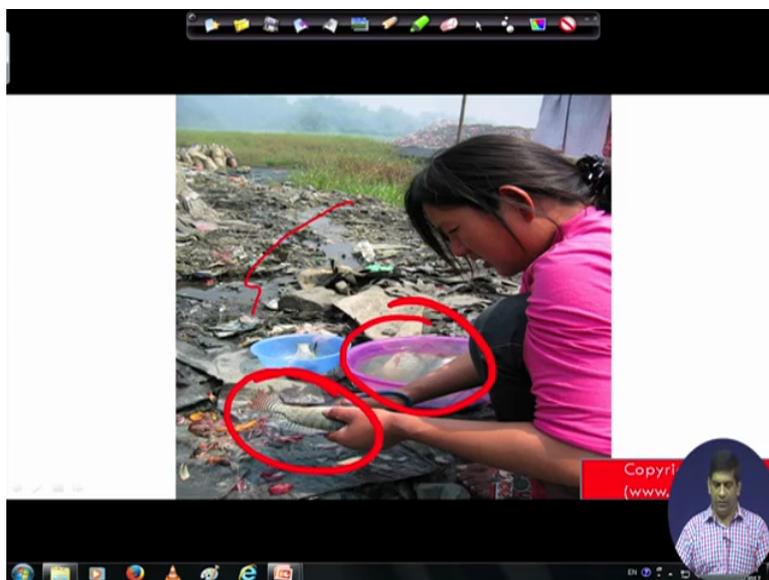






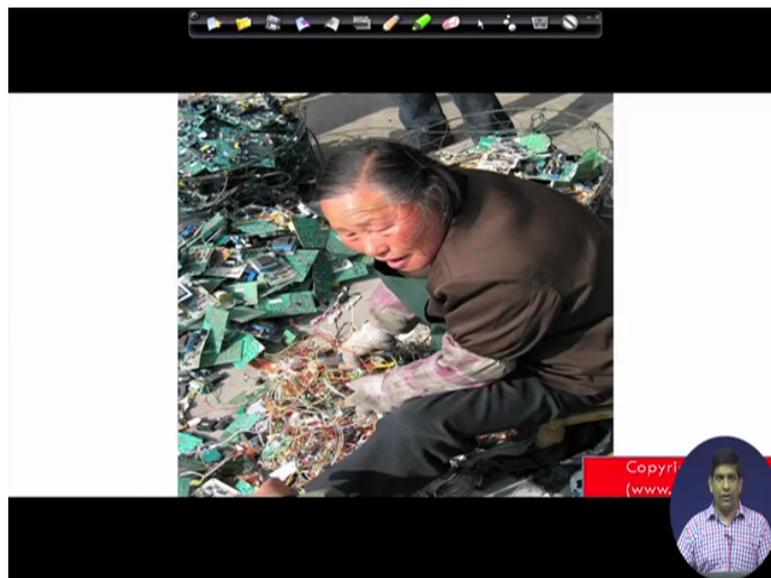
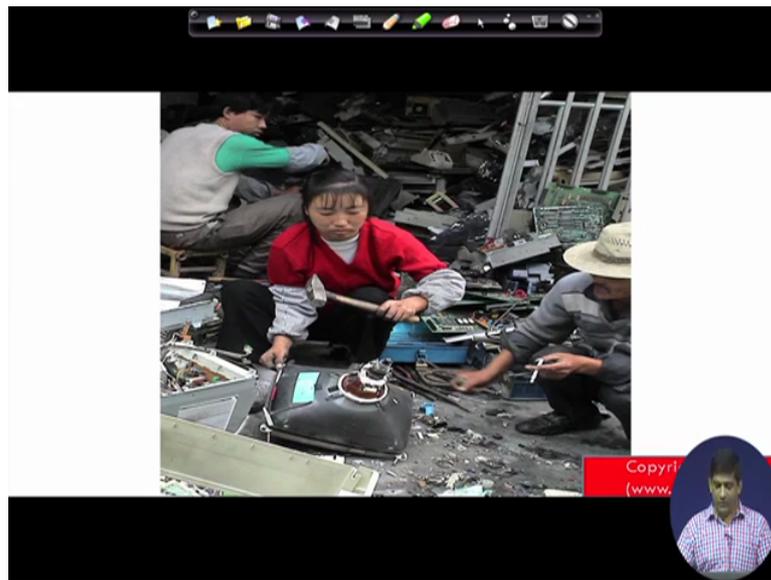
Again things coming from United States and other places. Such a nice water body, now lots of electronics and other things dumped on the side of the road. So it is kind of sad but this is what is happening. And then you see very crude way of trying to find out, try to recover some of those materials. See the people are trying to recover some of those stuffs and same way.

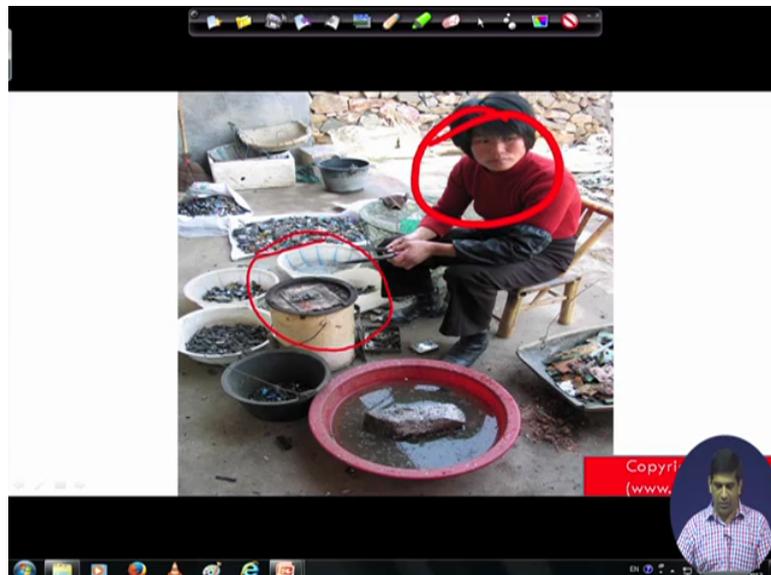
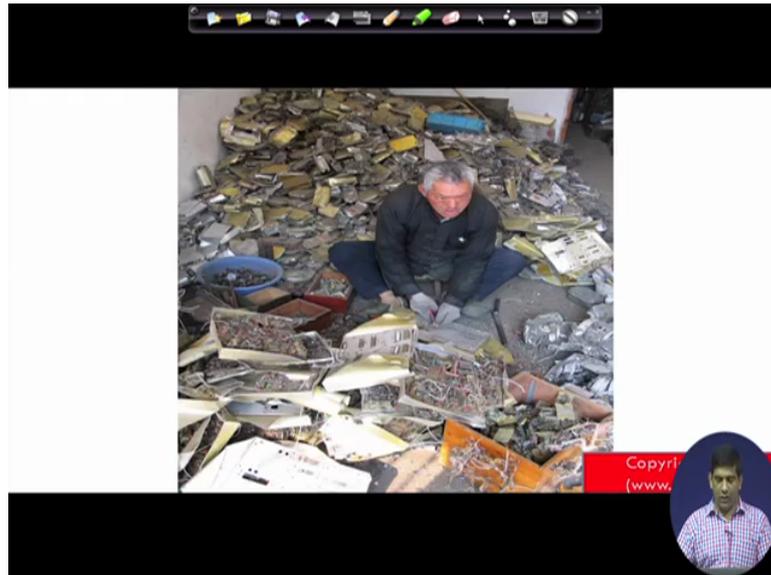
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And you see this water, e-waste all this electronic waste right there and same water coming in here and the this lady is using similar water washing the fish, so think about the quality of fish. So and what kind of contaminant the fish is there fish will carry to the food for the food table, on your dinner table or in the lunch table. So those things and it leads to human health impact so that is.

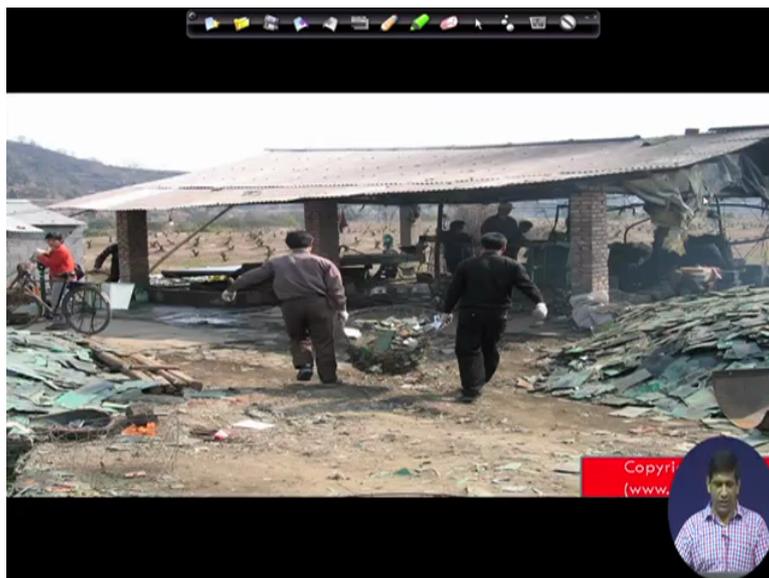
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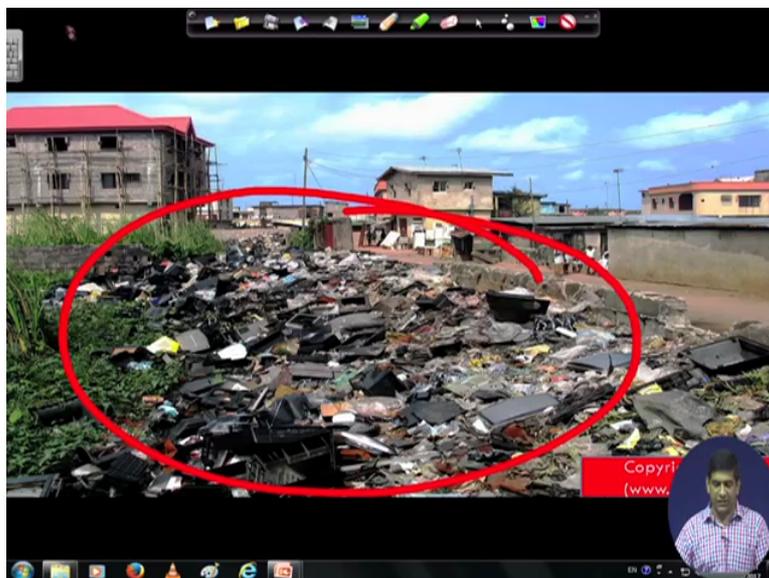




Again here doing some stuff using crude way trying to get all those wires, again they will try to burn it going through the electronic waste. Again working with aquaragia , again this lady is trying to burn some stuff to take those what we call it chips out and in the process is burning using some acid and that acid will create some fumes and she does not have any personal protective equipment, so she basically getting all those fumes coming into her.

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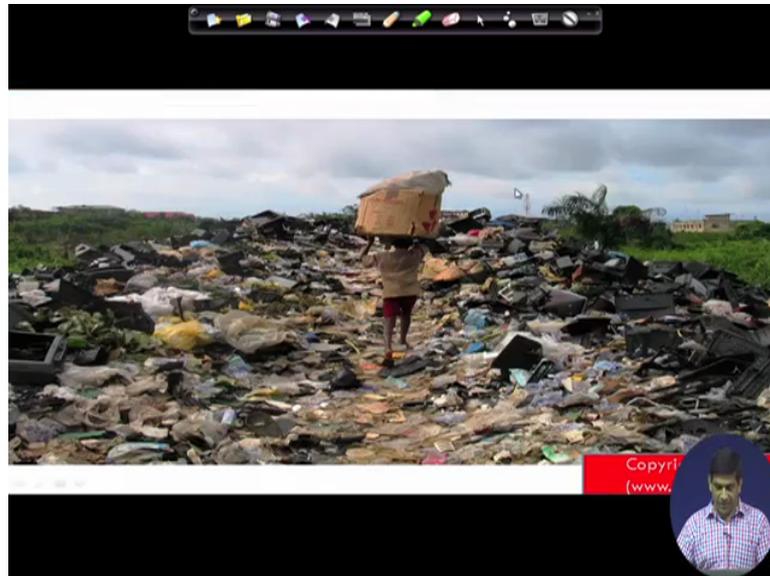


So those again another picture, so there are lots of pictures and we can go over that pictures after pictures actually you can see people are just being exposed to all these different stuff, so much of waste. So on one hand we as a society we have been so much after electronics, now what iPhone X is there iPhone 8 I do not know whether it is launched in India or not I have not seen anybody with iPhone 8 yet but we live in not that Hi-Fi place.

So but anyway so it is a iPhone X is there, then there would be some other, then would be some other and doing puja there would be some other models coming up and then Diwali there would be other model, so it is the problem is with a consumerism we are forced to buy things, we buy things just because it is cool, but we do not think about and after it is all done once this waste goes into the disposal this is what is happening with it, this is what is

happening with it and that is how it is contaminating the water, contaminating the air and all that stuff.

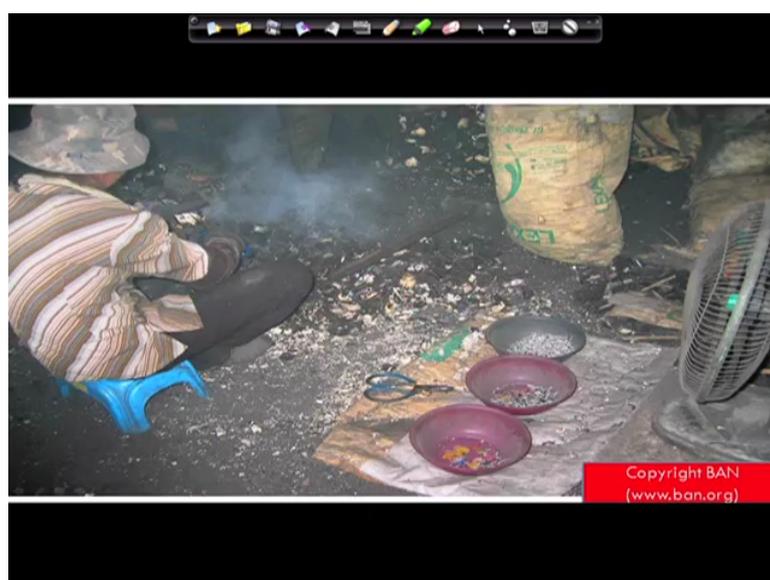
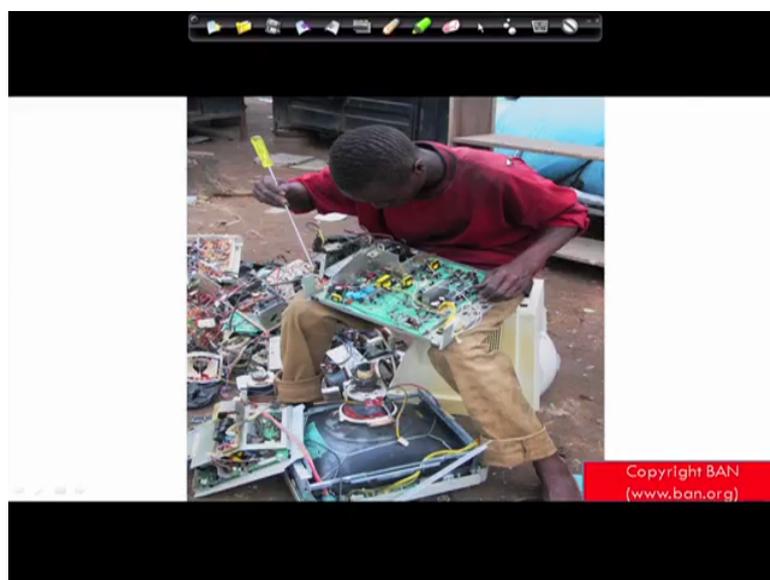
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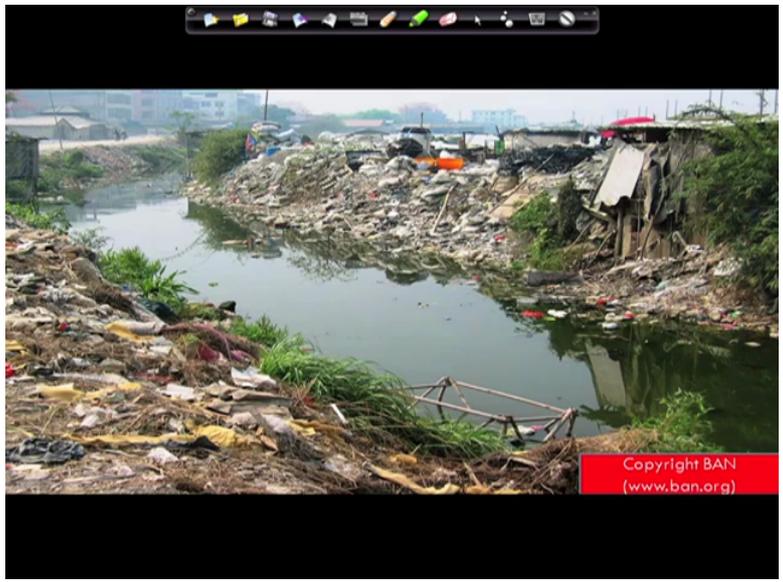
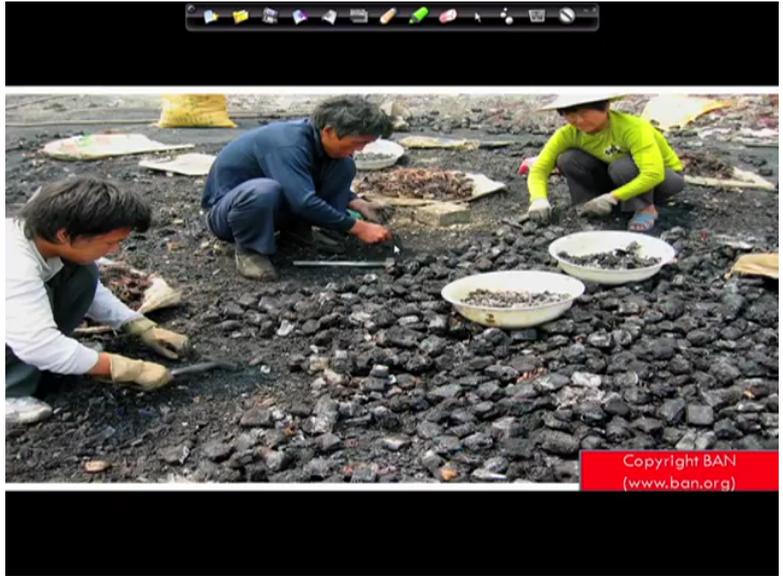


Some more pictures we will try to go over that really quick and as you can see people and thing is that since that it is so the country the African country so poor compared to the other places, so this the electronics that is coming in here it is a livelihood. So it is not that the it is not only that problem of the Western world dumping it is of course there are people in Africa, there are people in India who wants those coming so that they can take some livelihood of the out of that. Off course at the cost of they make a livelihood for a few years and at the cost of the health, at the cost of the environmental health but that does.

So it is basically our system needs to we need to get this people at least some scale, as that is what I was talking about in the solid waste management class as well. All this program there are lots of program announced by government of India recently, but all this programs can be used for example skill Indian. Let us just give skill to this kind of people who can do these electronic waste recycling in a better way and let us formalise them, bring them with the formal sector, merge the formal and informal sector, help them come up with the economic model. That is where government has to play its role I think, without government playing its role it is it will be difficult to achieve it.

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Pollution from Uncontrolled WEEE Recycling Operations

- Pollutants include:
 - Chemical originally present in WEEE
 - Heavy metals (lead, cadmium)
 - Flame retardants (PBDE)
 - Chemicals resulting from the processing of WEEE
 - Polycyclic aromatic hydrocarbons (PAH)
 - Dioxins and furans (PCDD/F)



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Again some more pictures things are being taken away. There are different kind of material, again things burning in Indoor kind of very closed environment getting all the fumes, going through all these different kind of stuff, things on the side of the water is very-very common. So what we are talking about you looks at you saw lot of pictures, what we are looking at the pollution from uncontrolled WEEE recycling operation.

And what kind of pollution we are looking at? We are looking at heavy metals, lead, cadmium, we already talked about that, why they are bad, flame retardants PBDE's. Then chemical resulting from the processing, so we have to PAH because uncontrolled like a incomplete burning, PA polycyclic aromatic hydrocarbon, then dioxins and furans. So these are all nasty stuff and this is what is coming out in terms of pollutants when they are in uncontrolled WEEE recycling.

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Pollution from Uncontrolled WEEE Recycling Operations

□ Elevated concentrations of pollutants have been encountered in:

- Air ✓
- Soil/Sediment
- Biomass
- Water
- Humans ✓

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So there have been studies have been done where they have found elevated concentration of pollutants in air, soil, sediments, not much work we see from the Indian context, right now we are trying to do one work, I have a Ph.D. student who is trying to do some work in Kolkata, Patna and Delhi area for elevated concentration of pollutants in where we try to do some soil, sediments, biomass, we are also trying to do some water, humans like a human in terms of urine, blood, nails, hair and those samples.

So because we are seeing elevated concentration of pollution that have been encountered, so region for our studies is to kind of showcase that it it is a high time that we start implementing our e-waste management rule and somehow we need to make it possible to

implement that, because it is impacting, improper management of e-waste is impacting lot of human like a impacting the human health, impacting the environment in a big way, there is we all know about, but we do not have a good data from the Indian context. The research that we are doing we hope to produce some good data, so that that can be used by the policymakers.

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Documenting Environmental Impacts

- There has been a flourish of recent papers on the human and environmental impacts of these uncontrolled recycling

Location	Year	Concentration	Reference
China	2008	110,000 mg/kg	Leung et al. 2008
China	2007	22,600 mg/kg	Wong et al. 2007
China	2009	90 - 2,850 mg/kg	Ha et al. 2009
Florida	Reference	400 mg/kg	Florida risk level

So there has been a flourish of recent papers on human, environmental impact, many of those you see from China. As you look at this slide in a little bit detail as you can see over, most of the work that has been reported actually came from China and you see that lots and lots of elevated concentration much higher than the safe levels has been reported.

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Example: Lead Concentrations

- Leung et al. 2008
 - Workshop dust = 110,000 mg/kg
 - Road dust = 22,600 mg/kg
- Wong et al. 2007
 - River sediment = 28.6 – 590 mg/kg
- Ha et al. 2009
 - Soil near WEEE facility = 90 – 2,850 mg/kg
- For reference, Florida risk level = 400 mg/kg

For example here Leung et al. 2008, workshop dust and these are lead concentrations, 110000 milligrams kilogram, where as you can look at a risk level is 400 milligrams per kilogram, so you can think of so much high. Road dust 22600 and another one 28.6 to 590. Soil layer WEEE facility 90 to 2850, where the risk anything more than 500 milligram 400 milligram per kilogram is actually not good for human health.

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The image shows a presentation slide with a black header and footer. The title 'Restrictions on E-Waste Exportation' is centered in a light blue bar. Below the title is a list of five bullet points, each preceded by an orange square. The first bullet point is 'Debate about whether to completely ban exports or not is heated at the moment.' The second is 'Signees of Basel Convention have agreed not to export hazardous waste to developing countries.' with a sub-bullet 'Room for interpretation of what is a waste and what is hazardous'. The third is 'The US is not a signee of the Basel Convention.' The fourth is 'In US, CRT glass export is regulated.' The fifth is 'Many companies and governments pledge only to sell to "safe" recyclers.' In the bottom right corner, there is a small circular video inset showing a man with dark hair wearing a red and white checkered shirt.

Restrictions on E-Waste Exportation

- Debate about whether to completely ban exports or not is heated at the moment.
- Signees of Basel Convention have agreed not to export hazardous waste to developing countries.
 - Room for interpretation of what is a waste and what is hazardous
- The US is not a signee of the Basel Convention.
- In US, CRT glass export is regulated.
- Many companies and governments pledge only to sell to "safe" recyclers.

So there has been a there has been a debate about restriction on e-waste exportation, there people were talking about not to export e-waste, but it is still happening to some extent. There are certain rules and regulations in terms of Basel Convention's, few countries have signed it, some countries have not, US has not signed Basel Convention, so still things are coming into this the developed countries sorry developing countries from developed countries in terms of the e-waste.

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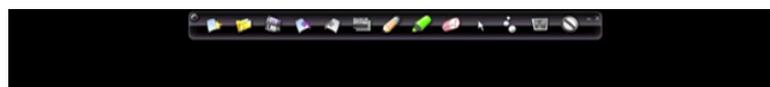
Proper Management of Recycled WEEE

Discarded by Generator → Recycler

- Resell
- Refurbish and resell
- Disassemble and sell parts
- Recovery scrap value of parts



Let's Take a Look at Typical Recycling Operations in US



Best Option: Resell for Its Intended Use

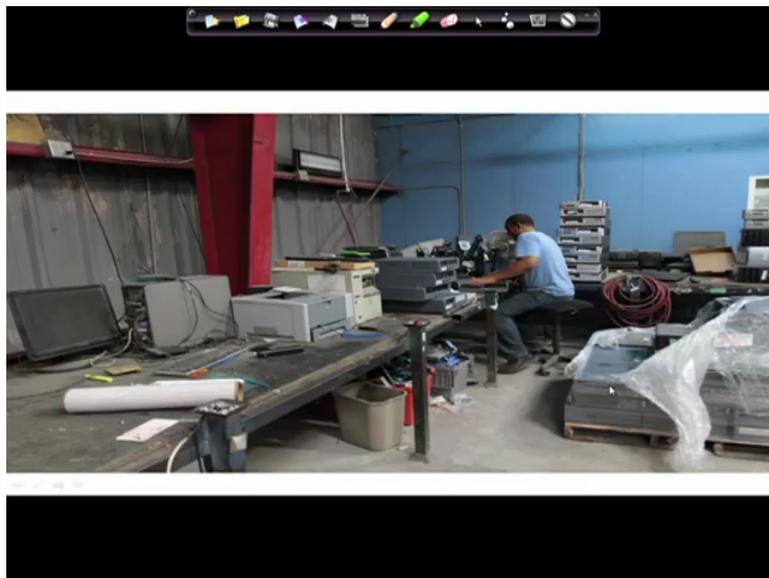


Facilities will have testing areas to determine whether devices work or not.



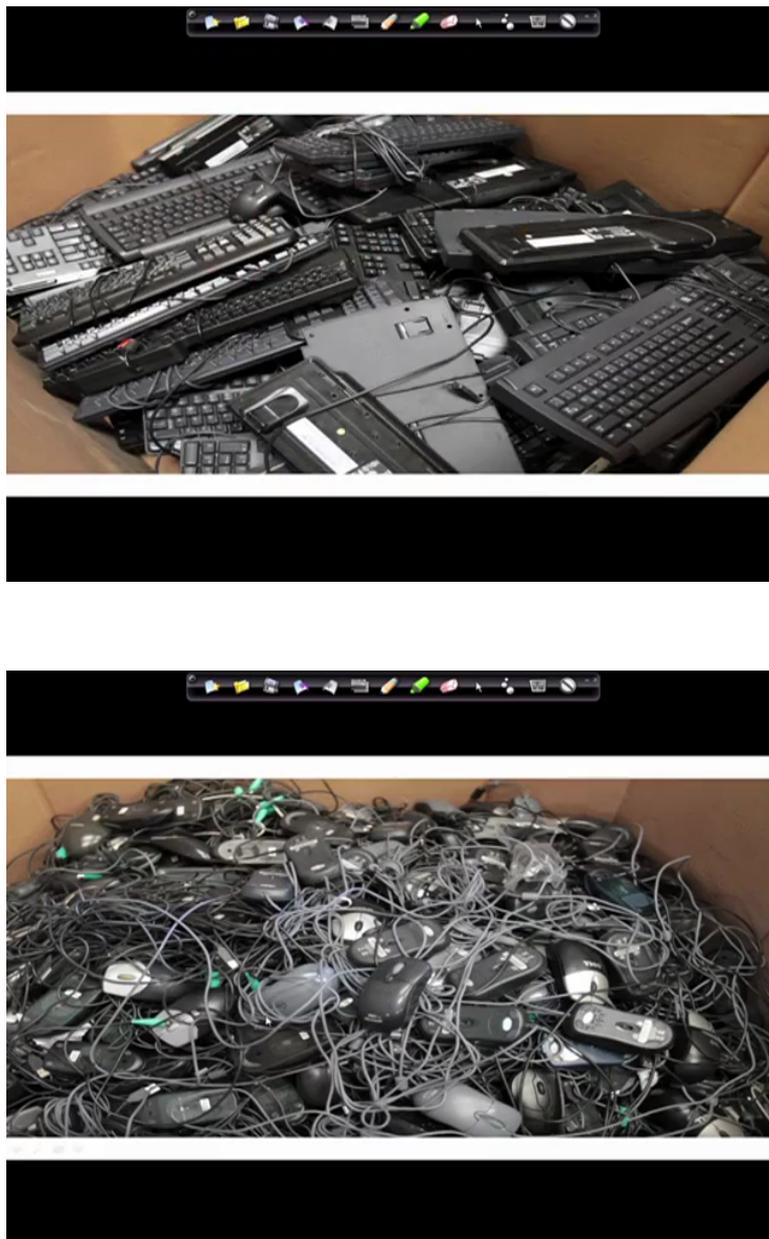
So when it is properly managed, what we saw so far was improperly managed, because that is what human health and environmental impact. When we do the properly managed, you like a typical recycle. This is what we expect to happen in Indian context, if you look at the typical recycling operation the e-waste will come in best option is resell for its intended use if it is still working. Facilities will have a testing area, where it is tested out, whether it is working or not, if it is working it could be sold off.

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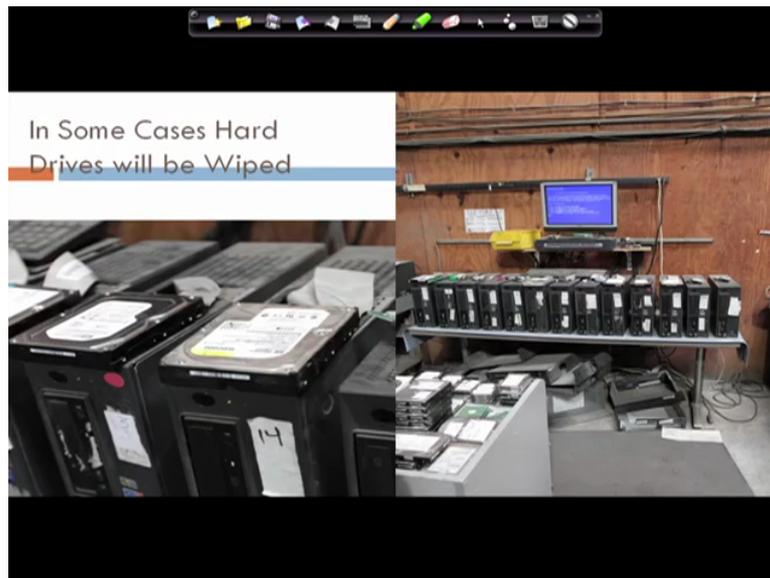
Many times people specially in the in the rich countries they just dump off their old electronics because they do not want to use it anymore. It is they are it is still in a good working condition, may not be very superfast, may not be this top-of-the-line machine for them now, but it was a good machine a 5 years down the 5 years before, but they do not want to use it, but somebody else like a poor family can you still use it for a small like a web surfing or Microsoft office kind of application, so it can be sold off into the market, so those kind of market also exist.

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So here they have been tested out, then you separate it out like you have this keyboards, most of this keyboards looks okay to me and similarly mice, most of this mice are there which actually looks much better than many of the mice I see here in our offices, so hopefully they might be still working. So it can be tested out and if it is working can be sold back into the market.

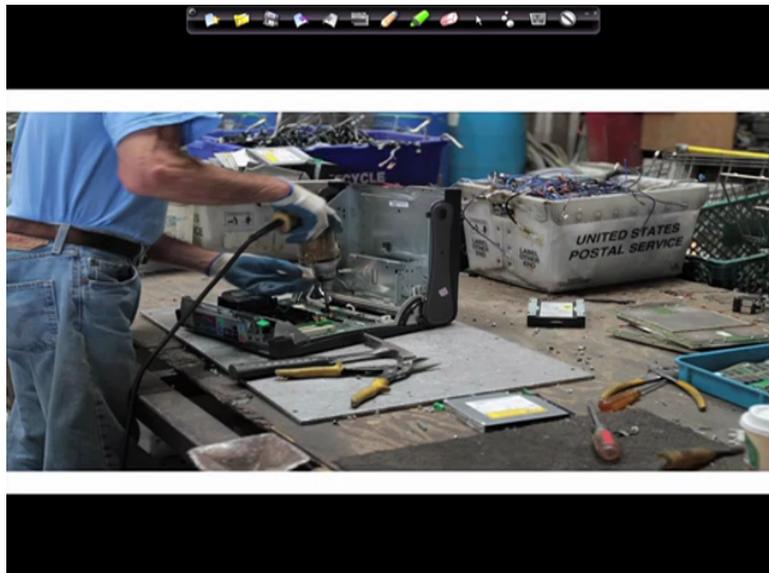
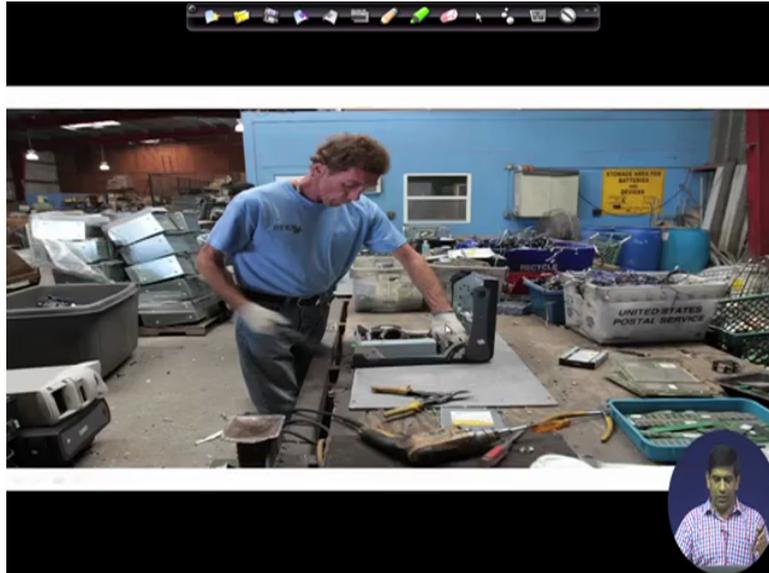
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And hard drive, in many in some cases the hard drives will be wiped, because people do not want hard drive people will have their own personal information, maybe income tax return, some personal family photographs, other person files or any files that people do not want that to go to some other people's hands, so they want it to be wiped off to be cleaned of before it can be used.

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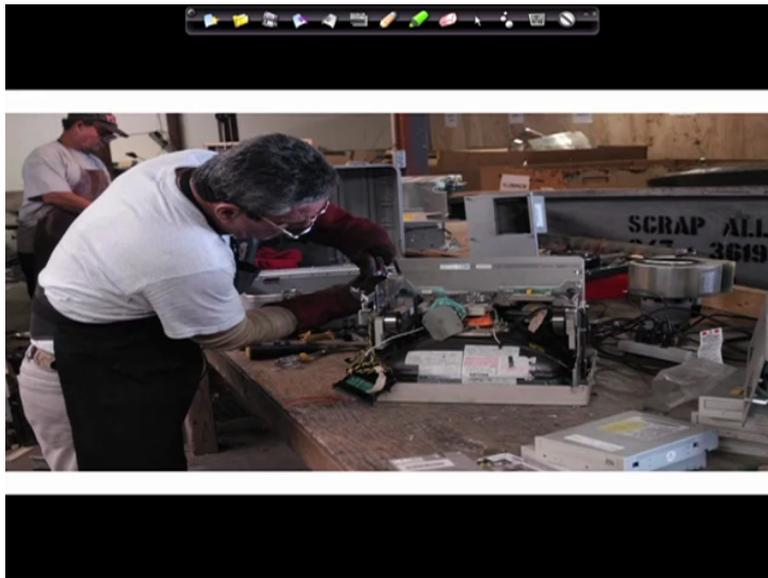




Then it can be disassembled, electronic e-waste could be disassembled and this is how the disassembly is done and different components. So plastics and other stuff can just go into the plastic recycler, here as you can see it being done in a as a proper control he just he is just using a screwdriver right now to opening it up and taking things apart and in a ventilated environment.

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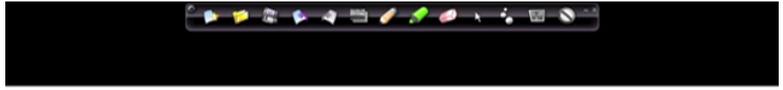




And some of the stuff being done outside as well, it can taken off, different containers, different types of material going into different drums over here. And again taking it apart, so those things as you can see over things are being done with a whatever protective equipment needed for that.

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What do you do with the re-furbished computers or the intact components?

- Put materials on the market for bid just like any other commodity.
- Some will stay in US




And so again dismantling another for the dismantling part things are taken it part with different materials going different like a container and after you do that what you do put materials on the market for bid just like any other commodity. So these are all now materials, so if they are materials so for example these when tested good LCDs, so this could basically go back into the market somebody will buy it.

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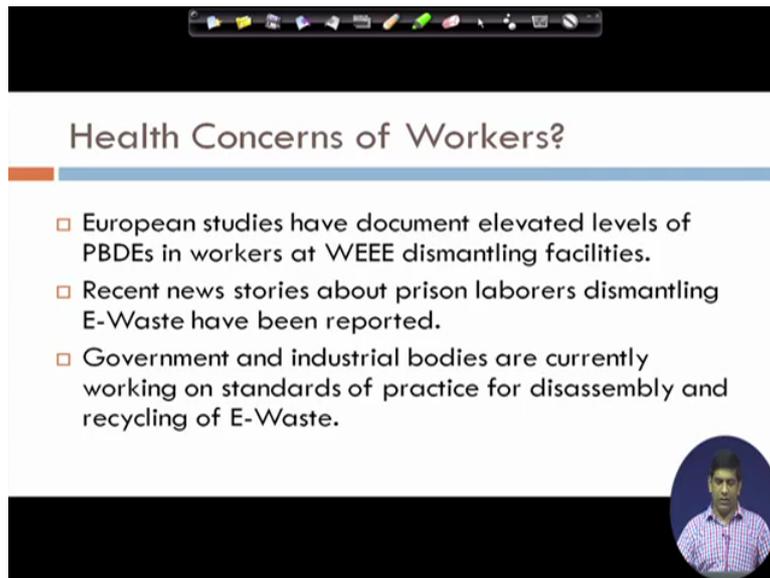
It is becoming more common for municipalities to pre-process their E-Waste to get the highest value





So and if which one it is becoming more common for municipalities to pre-process. So what municipalities do is they try to pre-process this electronics, as I was telling you earlier and that basically gives them the value, because you separate different fractions and those fractions could be sold off.

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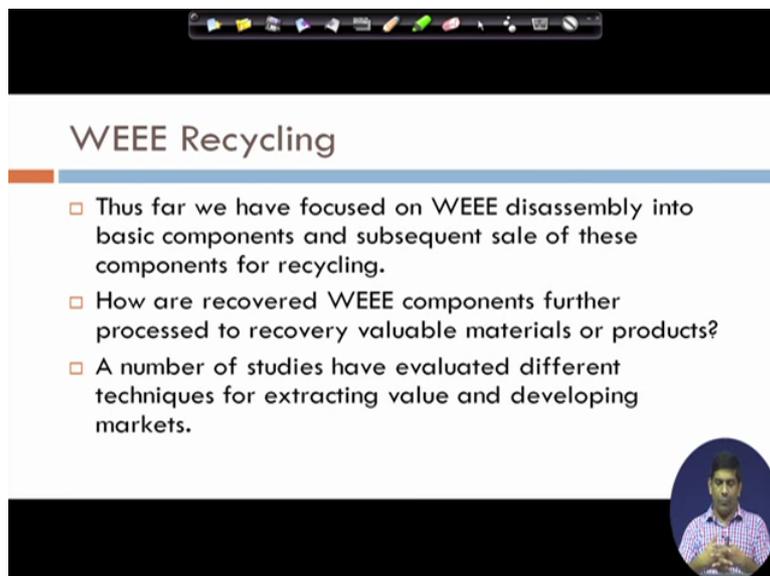
Health Concerns of Workers?

- European studies have document elevated levels of PBDEs in workers at WEEE dismantling facilities.
- Recent news stories about prison laborers dismantling E-Waste have been reported.
- Government and industrial bodies are currently working on standards of practice for disassembly and recycling of E-Waste.



So health concern of workers is there. There have been some studies the documented high elevated level of PBDEs in the workers. The recent about prison labourers dismantling e-waste has been reported. Government and the industrial bodies are currently working on some practice for disassembly in recycling of e-waste.

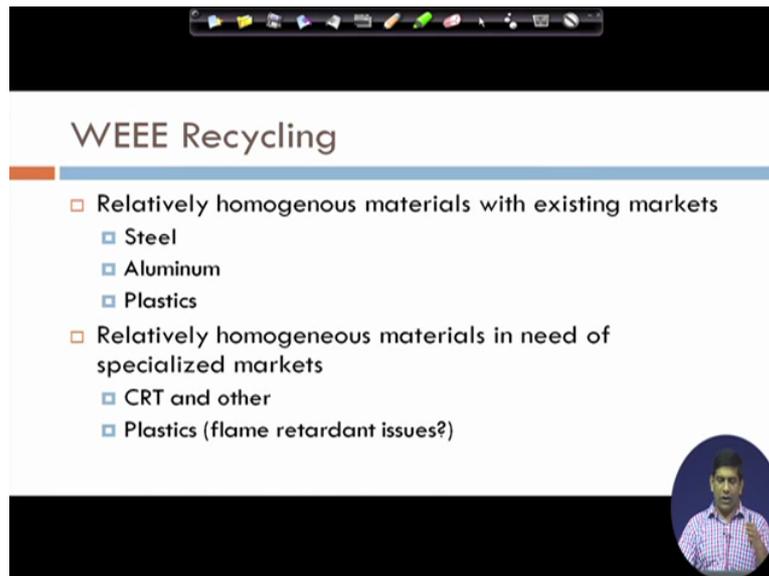
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WEEE Recycling

- Thus far we have focused on WEEE disassembly into basic components and subsequent sale of these components for recycling.
- How are recovered WEEE components further processed to recovery valuable materials or products?
- A number of studies have evaluated different techniques for extracting value and developing markets.





The image shows a presentation slide titled "WEEE Recycling". The slide content is as follows:

- Relatively homogenous materials with existing markets
 - Steel
 - Aluminum
 - Plastics
- Relatively homogeneous materials in need of specialized markets
 - CRT and other
 - Plastics (flame retardant issues?)

In the bottom right corner of the slide, there is a small circular video inset showing a man in a checkered shirt speaking.

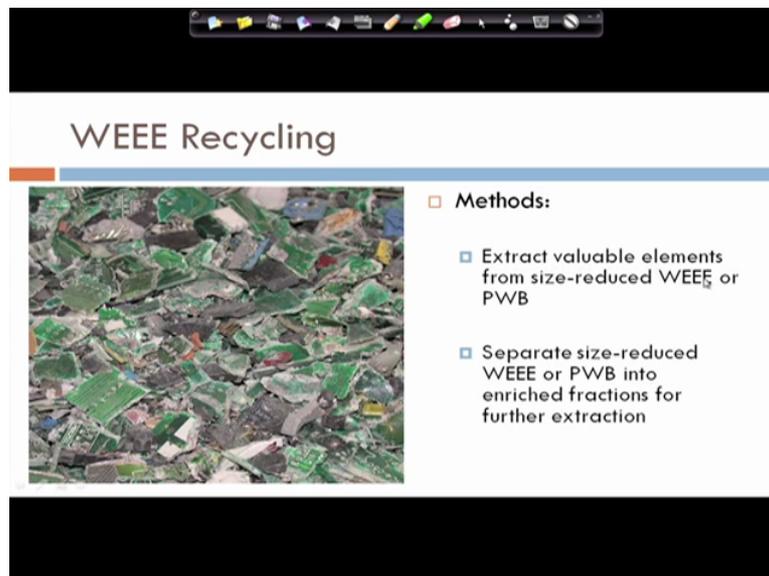
Thus far so disassembly into basic components and subsequent sale. There could be further processed to get recover valuable and there have been number of studies looking at different extraction. In terms of extraction, relatively homogenous material for example steel, aluminium, plastics as for MSW we have recycling market for that, there is a recycling process for it, so it basically goes there.

And for the stuff which is not but not that present in other stream of MSW. So relatively homogeneous material is there, but in terms of specialised market CRT and plastics some of those plastics, because thing with electronic waste is the plastic is a mixed plastic, it is blended together, as I was showing you in the previous video. So it is very difficult to it is not PET, like HDPE or like a many times it all blended together like you see your phone or the remote, those plastics are actually blended plastic and it becomes difficult to recycle them.

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The slide is titled "WEEE Recycling" and features a blue header bar. Below the title, there is a bullet point: "A major focus in on the processing of shredded WEEE, most particularly printed wire boards". To the left of this text is an image of a shredder's internal rollers, and to the right is an image of a pile of shredded electronic waste, including green printed circuit boards.



The slide is titled "WEEE Recycling" and features a blue header bar. On the left side, there is a large image of a pile of shredded electronic waste, including green printed circuit boards. To the right of this image, under the heading "Methods:", there are two bullet points: "Extract valuable elements from size-reduced WEEE or PWB" and "Separate size-reduced WEEE or PWB into enriched fractions for further extraction".

But a major focus on the processing is what we do is a printed wire board, printed wire board is try to recover some of the material so you shred them, you shred them make it a smaller pieces. So what you try to do is, you extract valuable elements from size reduced separate size reduce PWB to enrich fraction for further extraction.

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The slide is titled "WEEE Recycling" and features a diagram of a separation process. A central circular chamber contains a rotating arrow. Above the chamber, an arrow labeled "Separation Technologies" points down. To the right of the chamber are two electrodes: an "Ionizing Electrode" and a "Static Electrode". Below the chamber, three collection bins are labeled "Non-Conductors", "Middlings", and "Conductors". To the right of the diagram is a list of separation technologies:

- Separation Technologies
- Screening
- Density separation
- Magnetic separation
- Eddy current separation
- Electrostatic separation

H.M. Yelit et al. / Waste Management 25 (2005) 67-74

Now what kind of things you will use? So you can use screening, density separation, magnetic separation, Eddy current, electrostatic separation, so all the different technology that has been used in other places as well, same thing technology could be used for electronics recycling as well.

So screening, density, density based on the weight of that, magnetic based on like magnetic charge, Eddy current, electrostatic separation based on the charge. So those things are done as you can see over here, so we have ionising electrode, we have static electrode, so basically conductor, non-conductor, so it is kind of get separated into different fractions right there.

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WEEE Recycling

Extraction Technologies

S. Iyas et al. / Hydrometallurgy 101 (2010) 135-140

- **Pyrometallurgical**
 - Smelting
- **Hydrometallurgical**
 - Cyanide leaching
- **Biometallurgical**
 - Bioleaching

Disposal Concerns

Discarded by
Generator

What are environmental impacts of co-disposal with MSW?

Then there are some Pyrometallurgical, Hydrometallurgical, Biometallurgical, like you can do some bioleaching, cyanide leaching, smelting, so all the different things are used in terms of the extraction technologies. So those are in terms of extraction, in terms of recycling in a proper way, now if it goes to the disposal, if it goes to a landfill, so we already talked about recycling.

If you remember we already talked about the recycle part and then we also talk about returning to manufacturer that was done in the previous video just now we finished this recycling part, now we will look at what will happen if it goes to the landfill or waste to energy plant.

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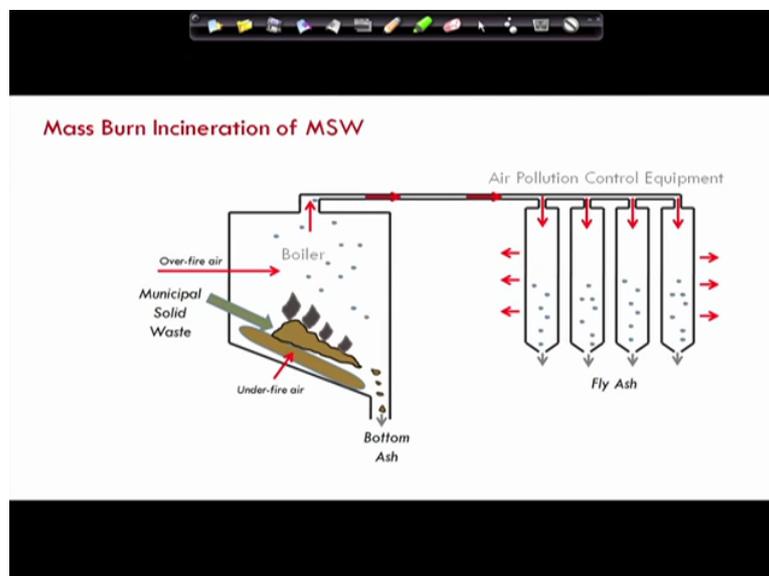
Fate of WEEE in WTE Systems

- Potential concerns
 - ▣ Metal accumulation in the ash / APC residuals
 - ▣ Dioxins and furans as a result of flame retardants

The slide includes a photograph of a large industrial waste-to-energy plant and a small circular inset of a presenter.

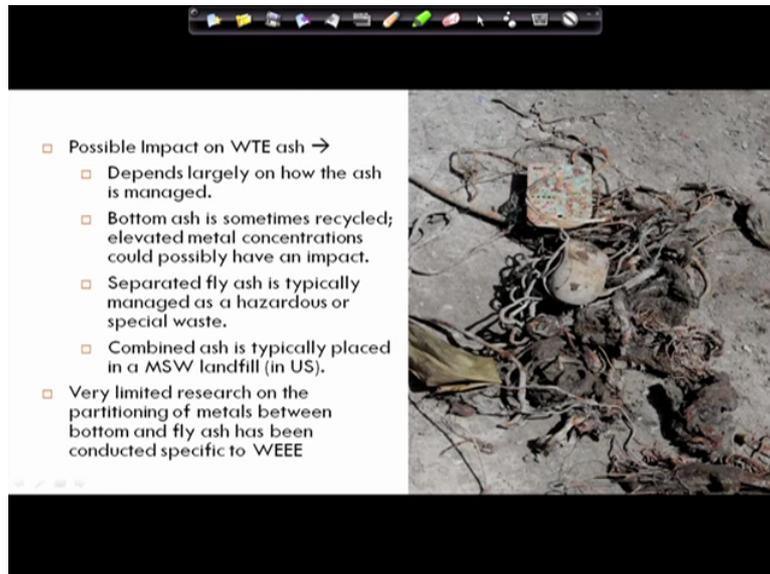
So in that case let us look at in terms of waste to energy plant, fate of first waste to energy plant. Major concern here is the metal will accumulate in the air pollution control or in the ash and that dioxins and furans can also form, but if it is done in a very high temperature, dioxin and furan should not form but just at a lower temperature chances of there.

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Mass burn of incineration of MSW, you have this over boiler, municipal solid waste is burning, you get the bottom ash, we talked about that in the incineration chapter. You have the air pollution control, you have the fly ash over there. So in bottom ash as well as fly ash you may have traces of electronic waste contaminants showing up, so that is that is there.

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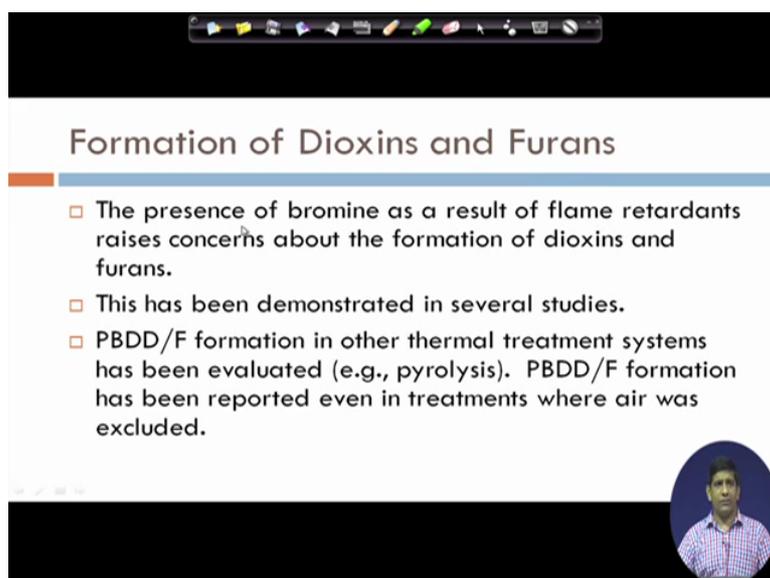
□ Possible Impact on WTE ash →

- Depends largely on how the ash is managed.
- Bottom ash is sometimes recycled; elevated metal concentrations could possibly have an impact.
- Separated fly ash is typically managed as a hazardous or special waste.
- Combined ash is typically placed in a MSW landfill (in US).
- Very limited research on the partitioning of metals between bottom and fly ash has been conducted specific to WEEE

The slide includes a photograph on the right side showing a tangled mass of wires and debris, likely representing WEEE (Waste Electrical and Electronic Equipment) components.

So depends largely on how the Ash is managed, if it is there in the ash it is depends on how the ashes will be managed, bottom ash is sometimes recycled, so elevated metal concentrations could be a concern. Fly ash is typically managed as a hazardous waste. Combine ash it goes to MSW landfill, if it goes to the MSW landfill and again it may be question in terms of how it will have impact on the leachate quality. So but there are not much research has been done in terms of partitioning of metal between the bottom ash and the fly ash when they specific to WEEE.

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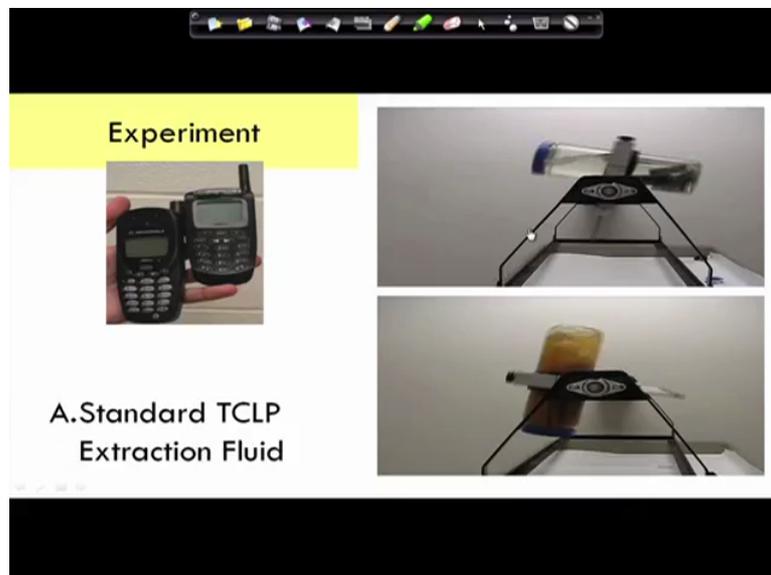
Formation of Dioxins and Furans

- The presence of bromine as a result of flame retardants raises concerns about the formation of dioxins and furans.
- This has been demonstrated in several studies.
- PBDD/F formation in other thermal treatment systems has been evaluated (e.g., pyrolysis). PBDD/F formation has been reported even in treatments where air was excluded.

The slide includes a small circular inset photo of a man in the bottom right corner.

Dioxins and furans can form because of presence of bromine, flame retardants raises concerns about the that is this has been documented in several studies. It is formation in pyrolysis also been evaluated it is even has been reported even treatments where air was excluded, so even in the in absence of oxygen as happens in pyrolysis that there also dioxins and furans have been formed, so in that that concern is there.

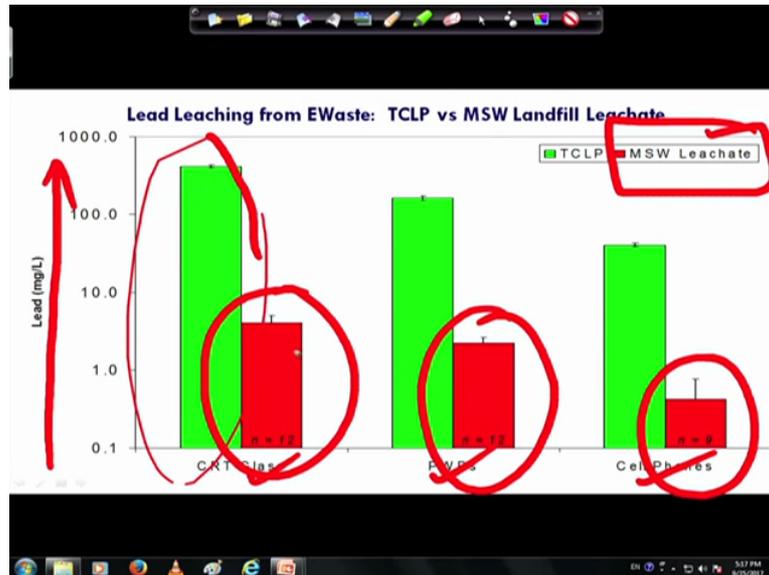
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In terms of going to the landfill, as we know modern landfills are lined, as you saw this picture both this picture earlier as well. And the leachate is collected and treated. So one of the concern that we have in terms of in terms of electronics going to the landfill is, what the impact that it will have on leachate?

So as you remember earlier we talked about this TCLP test which predicts the worst-case leeching scenario in a MSW landfill, so here also a standard TCLP fluid could be used which we can do a electronic can do the sorry you can do the TCLP test on a electronic and then what you get out of you get the lead concentration coming out.

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So as we talked earlier in the previous video or maybe 2 videos before, that electronics, lead in presence of TCLP fluid which is the acetic acid, acetate. Acetate ions and lead they really like each other, they make this lead acetate solution which goes makes a soluble complex and you see lots and lots of lead coming out, that is what you are seeing over here those green bars, if you can look at here these green bars are those like a TCLP on CRT glass, printed wire board and cell phones.

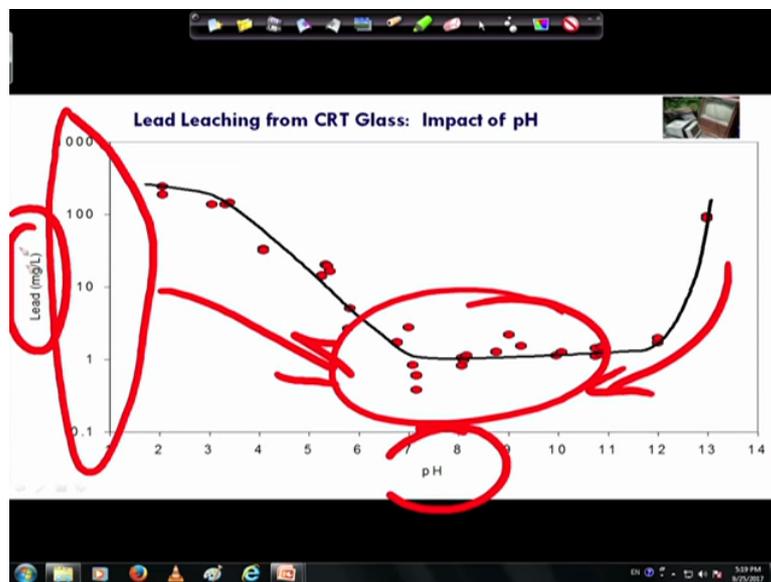
Now when you come to if you remove this TCLP fluid and you start and use this MSW leachate instead, you see the concentration going down and if you have not noted this is in log scale. This is in log scale so the concentration is much-much less, so when you go from for the same samples, same CRT glass, when we go from say TCLP fluid to MSW landfill leachate, so what has been done is rather than using TCLP fluid we are using landfill leachate as the leaching fluid.

Why we are doing it? Because as you know TCLP supposed to stimulate worst-case leeching scenario in a MSW landfill, but as we know that lead and acetate having a very good soluble complex formation, so we see a very elevated lead coming out to see that, do we see similar lead coming out in if you use that MSW landfill leachate as a solution because that is what

will interact with e-waste in a landfill. So we took some leachate from the landfill and we predicted this TCLP test again, only difference was the other than TCLP fluid here we used the MSW landfill leachate.

And we knew the background concentration of lead, so subtracting that what we got the lead concentration in these cases is much-much smaller than what you see in a TCLP fluid. So that detects that basically shows that TCLP actually over predicts in a what will happen in a landfill condition especially for waste containing lead such as electronic waste. So that was I that was trying to highlight so and which is

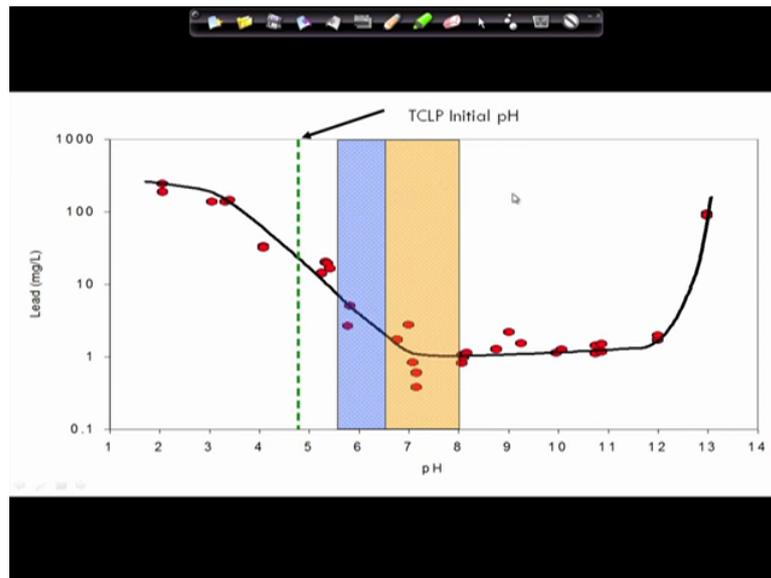
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But other thing is that as you see lead leaching from CRT glass, if you look at the function of pH, as you can see at the lower pH and a very high pH. Y-axis here is the pH sorry x-axis here is the pH and the y-axis x-axis. So x-axis here is the pH and y-axis is the lead concentration, again lead concentration is in log scale. So as you can see, as you go from like a lower pH towards neutral as well as the higher pH towards neutral you see that concentration leachability is much less.

Mind it you should look that this is a log scale, so this is log so concentration is actually much less, several order of magnitude lower when we go towards the neutral pH. So and so this is what typically happens at neutral pH we do not see that much leachability happening, most of the leachability happens at very low pH or very high pH.

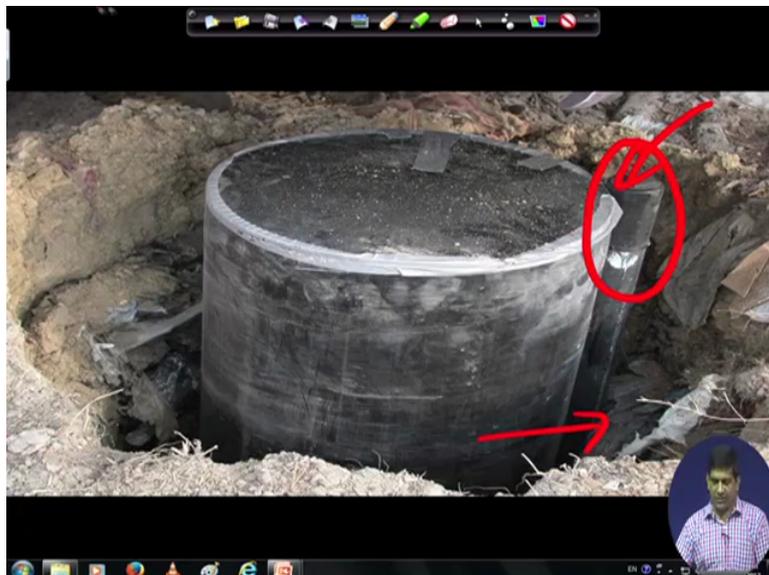
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So typically leachate pH is in this range which is around 6.5 to 8, so that is your typical pH which is a very low leachability as opposed to that. And TCLP leachate pH in the acid forming stage will be somewhere here between 6.5 to 5.5 and our TCLP pH is here. So although TCLP will over predict because this is because it is at lower pH, if you can look at the as a pH being an impact on leachability, but as we go towards neutral conditions the leachability actually goes down.

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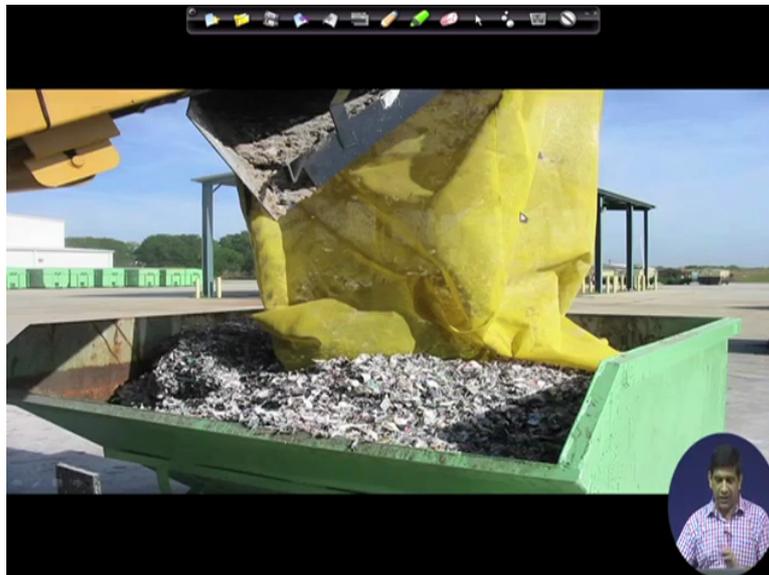




So that is in terms of the batch leaching, but there are always a debate that, what will really happen in a landfill condition, so to stimulate that very quickly I will go over a landfill test which was done. So here a stimulate landfill was actually constructed, where this is a 3 feet diameter, 16 feet long column and on the side you see a side pipe which was connected, this side pipe was connected at the bottom.

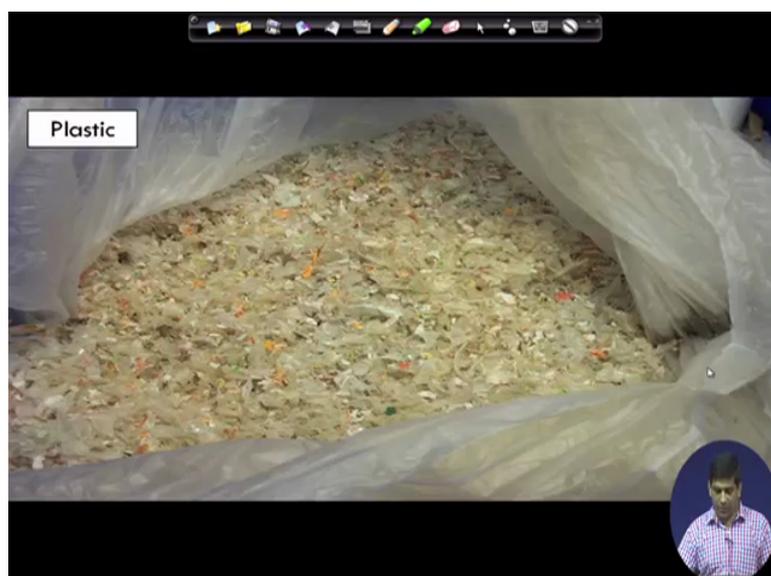
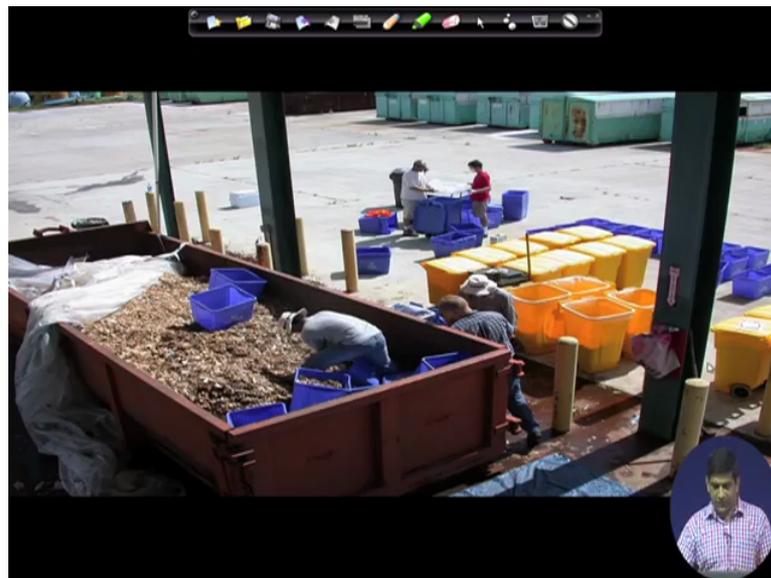
This side pipe is connected at the bottom so that the leachate will as you know the liquid will find its own level. So leachate will travel from this side to this side at the bottom level and then we can drop we can try to collect the samples from here by dropping a pump, so that is how the sampling was done from time to time.

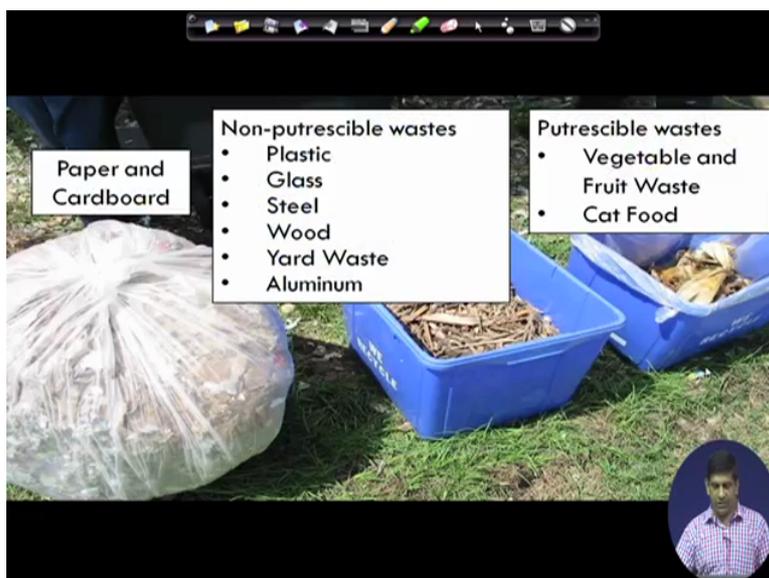
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And we here we basically made our all MSW municipal solid waste component. So different component, mobile grinder used for size reduction. This was a huge project many student helped where we were working on this project and you see several students helping out, these are all graduate students, masters and Ph.D. students and that is the good thing about many foreign universities, this was when I was working as a post and all these students were helping us on this project. So this is it is really a team work where because you cannot really do such a big project without having a teamwork.

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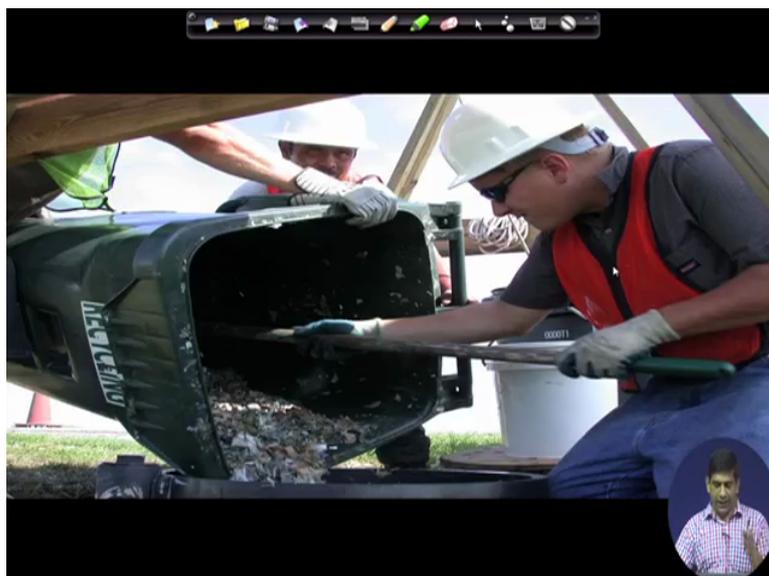
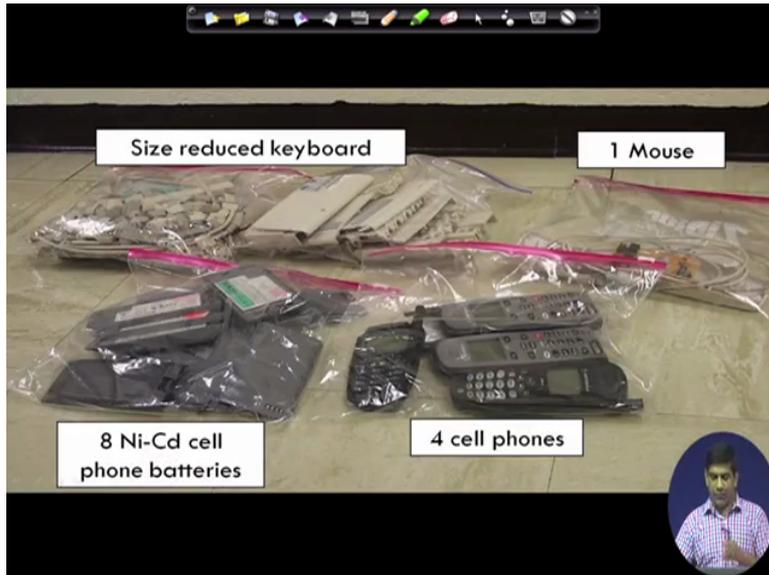


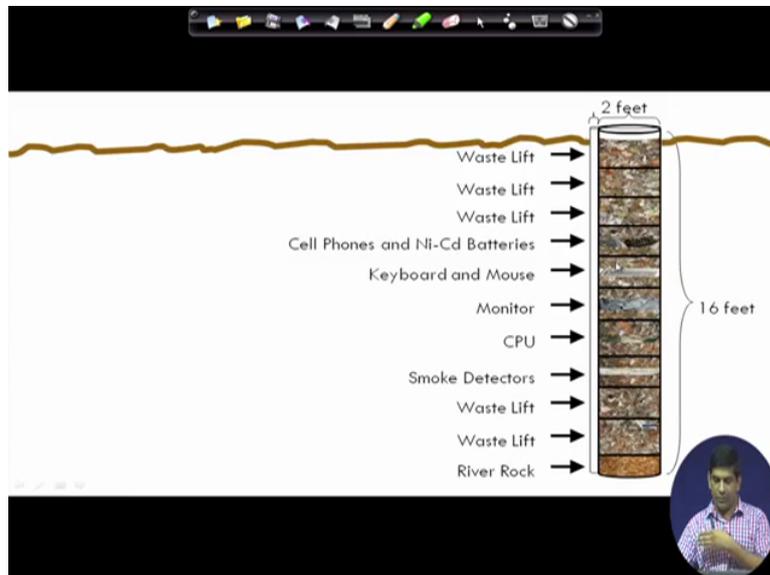
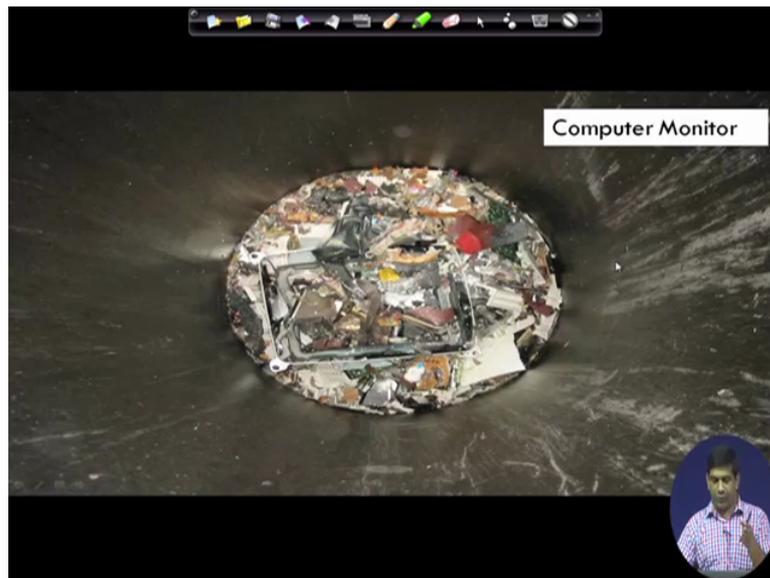


So these are all different types of waste we are collecting, so here you can see different types of waste being prepared plastics, food waste, a scale used to measure them. Then this different types of waste plastic, glass, metals, putrescible, non- putrescible, paper, cardboard and these are going into different containers.

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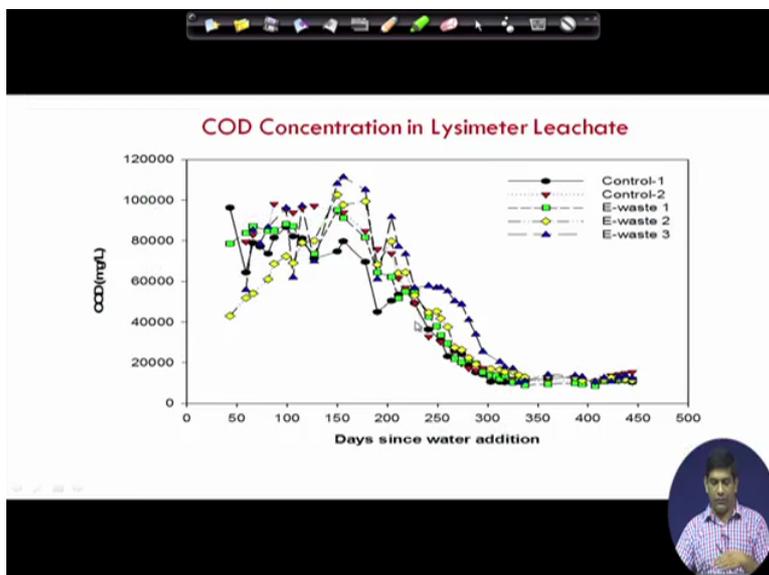
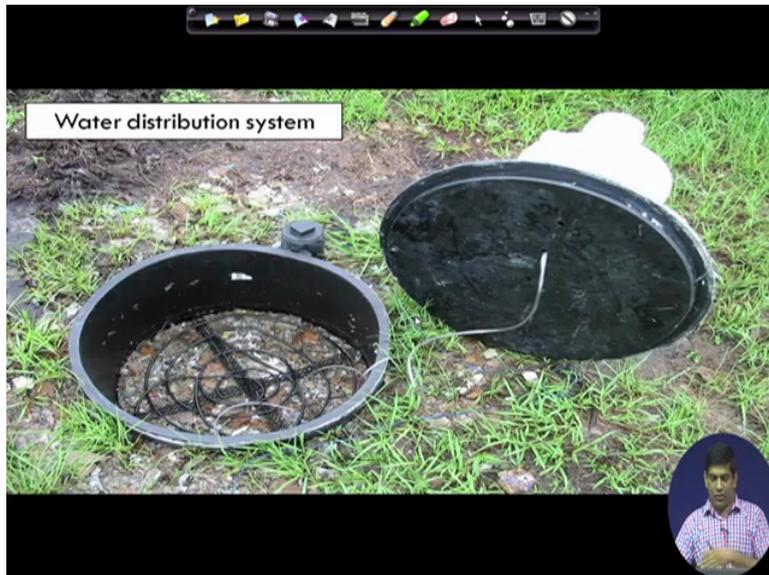


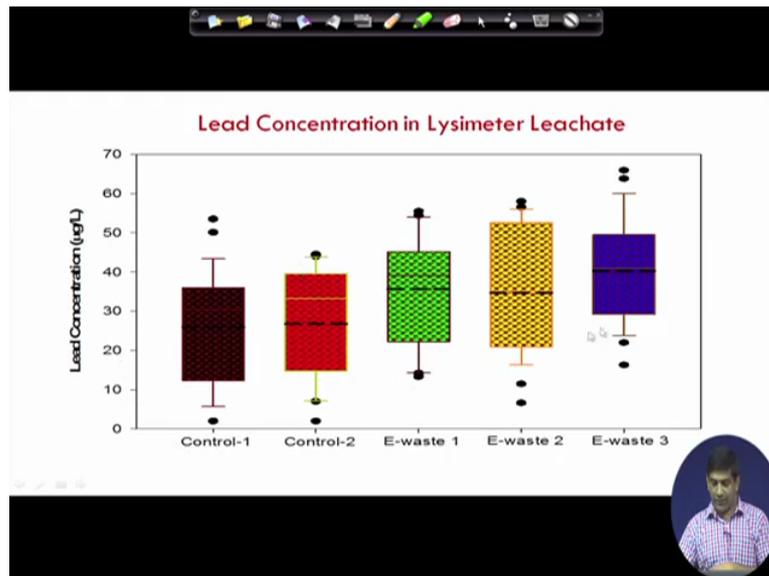




E-waste was disassembled, size reduced keyboard, mouse, cell phone, nickel cadmium cell phone batteries, disassembled monitors and everything was filled in, you can see computer monitors in one level, desktop computers. So different levels of the waste, waste has different level over there.

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And then we had a moisture distribution system so the water will go through. So we looked at all the typical parameters like COD, lead. So let us look at this if you look at these were the 3 control 2 control which has no electronic waste added to them and these 3 e-waste has electronic waste added to them and this is the box and whisker plot if you know what they are and this basically shows you the range. So if you do although these 3 tends to have a slightly higher concentration then the control but if you do the statistics on them they were statistically similar.

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Motivation for Recycling

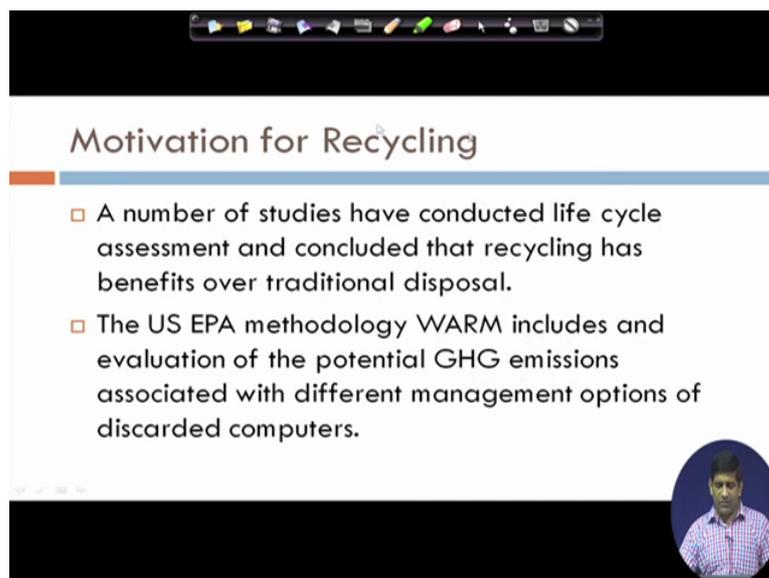
- When properly managed as part of a modern, controlled solid waste system, WEEE risk to the environment should be limited.
- Other considerations for separation and recycling
 - Resource management
 - Climate change issues

So what does that mean, was actually even if lead goes to the landfill it does not impact leachate quality, what does that mean it is good for the lead to go to the landfill, of course not because you are basically creating a huge lead environment in a landfill something happens

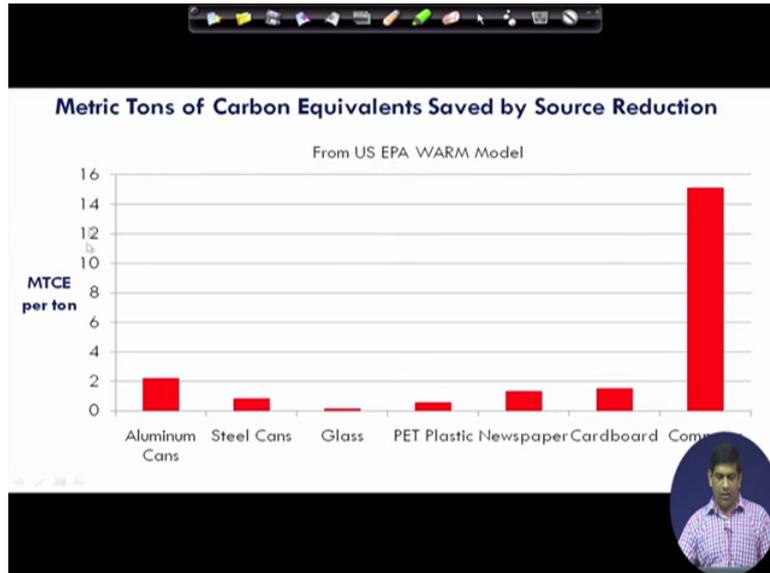
future God forbid like we had recently a incident in Ghazipur where the landslide was happened. So similar things happens because lead in a landfill environment in a reducing environment lead becomes with the sulphide, lead sulphide is formed, lead hydroxide is formed, they have a very low solubility products, so they precipitate out, so they remain in the solid form.

So if somehow it gets exposed to air, lead sulphide goes to the lead sulphate, lead hydroxide was to lead oxide things may start coming into the solution. So those I am not suggesting lead goes there, but if lead goes to a landfill it does not impact that much on the leachate, it remains inside the landfill, that is what we got from that particular study. So in terms of recycling, what is the motivation? Properly managed modern controlled solid waste, it is a risk can be limited, should be limited. Other (0)(36:56) we can resource management there are climate change issues associated with that.

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The image shows a screenshot of a presentation slide. At the top, there is a dark bar with a row of colorful icons. Below this, the slide has a white background with a blue horizontal line. The title "Motivation for Recycling" is centered at the top in a dark font. Below the title, there are two bullet points, each preceded by a small orange square. The first bullet point reads: "A number of studies have conducted life cycle assessment and concluded that recycling has benefits over traditional disposal." The second bullet point reads: "The US EPA methodology WARM includes and evaluation of the potential GHG emissions associated with different management options of discarded computers." In the bottom right corner of the slide, there is a small circular inset photo of a man with dark hair, wearing a checkered shirt, looking directly at the camera. At the very bottom of the slide, there is a dark bar with a few small, faint icons.



So number of studies have conducted life cycle assessment there was US EPA WARM model, greenhouse gas emission have been done as well. As you can see here metric ton of carbon can be saved by source reduction in terms of with computer we can save much more, if we can recycle those computers.

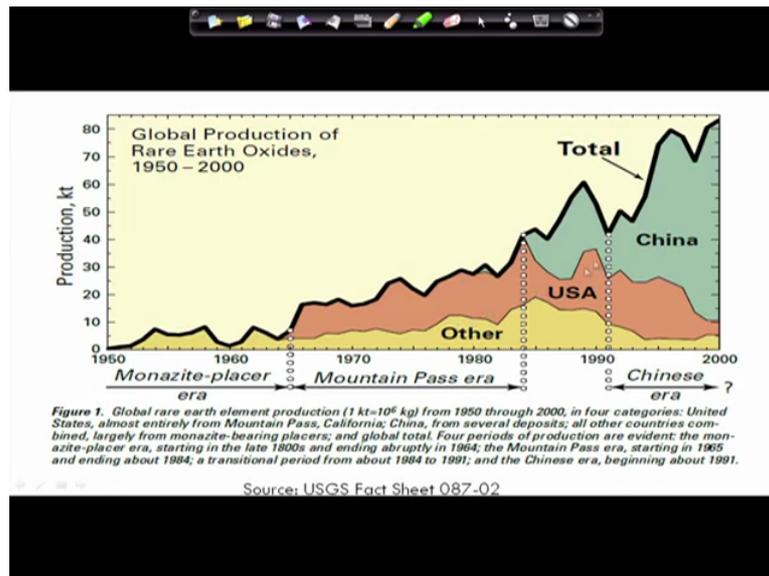
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The New York Times
Japan Recycles Minerals From Used Electronics
October 4, 2010

KOSAKA, Japan — Two decades after global competition drove the mines in this corner of Japan to extinction, Kosaka is again abuzz with talk of new riches. The treasures are not copper or coal. They are rare-earth elements and other minerals that are crucial to many Japanese technologies and have so far come almost exclusively from China, the global and dominant supplier.

Besides gold, Dow's subsidiary, Kosaka Smelting and Refining, recycles rare metals like indium, used in liquid-crystal display screens, and gallium, used in wafers for semiconductors. The company is trying to develop ways to reclaim the harder-to-mine minerals included among the rare earths — like neodymium, a vital element in industrial batteries used in electric tools, and dysprosium, used in magnets for hard disk drives.

Kohmei Harada, a managing director at the National Institute of Materials Science, and an enthusiastic supporter of recycling efforts like the one in Kosaka. Apart from rare metals and earths, Mr. Harada estimates that about 6,800 tons of gold, or the equivalent of about 16 percent of the total reserves in the



There has been a study that Japan recycles minerals from used electronics. About 6800 tons of gold or the equivalent about 16 percent of the total reserve in the world can we recovered from electronic waste, so just from Japan. So those things are there. And global production of rare Earth oxides going down, we do not have much rare Earth oxides left. USA, other countries do not have it, it is the China who has the most. So at some point of time is to we have to start recycling, otherwise we are just using up all these resources.

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Summary

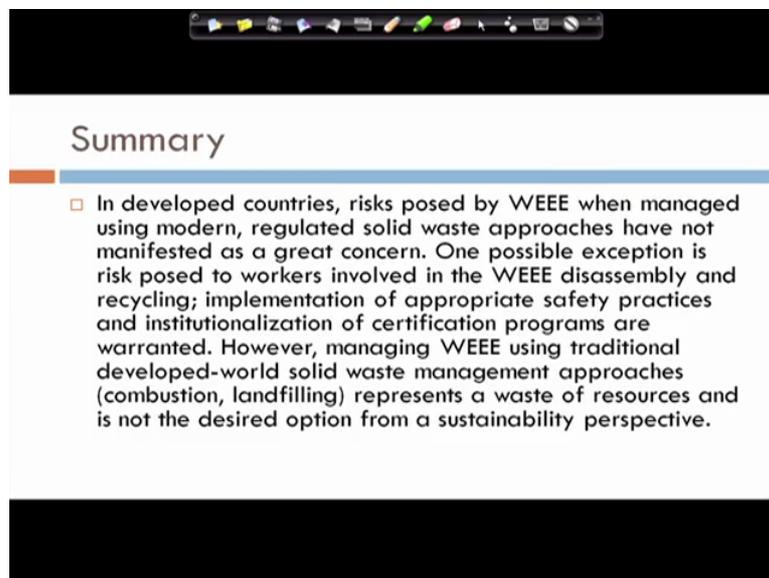
- The magnitude and growth potential of WEEE, coupled with the myriad of different chemicals potentially present, justify the recent interest focused on this waste stream and call for additional time and resources to be invested. Managed poorly, WEEE can pose a sizable risk to human health and the environment. Managed wisely, WEEE represents a considerable resource.

So in terms of summary, the summary for the entire e-waste lecture that you had, is the magnitude and growth potential of electronics waste couple with different chemicals potentially present, justify that we need to it justify the interest that we have on this waste stream and additional time and resources are needs to be invested. So if managed poorly, this

can be a big problem for the environmental health, but if managed wisely it represents a considerable resource.

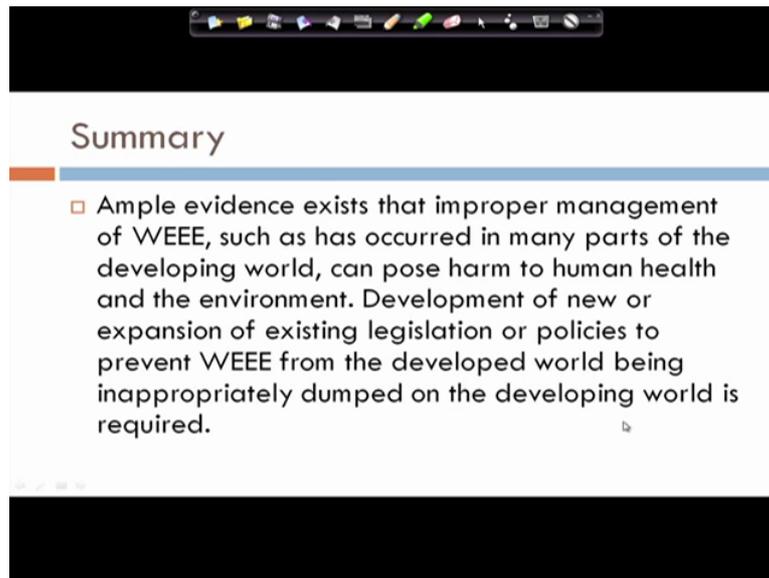
So in this particular course we could just do a very quick overview of electronics, but we will like near future will try to come up with at least a maybe a 4 week course on just on electronic waste management, just because this topic is so important in Indian context right now where we can discuss some of the this stuff that we talked about today and some more stuff some in more detail rather than me trying to rushing out things as we had to do some in some of the videos.

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So in summary again in developed countries risk is when WEEE when managed using modern, regulated solid waste approaches have not manifested a great concern. One possible exception is risk posed to the workers who are doing it because there have been some reports that. However managing using traditional developed world solid waste management approach combustion, landfill represents a waste of resource and not the desire option from a sustainability prospective.

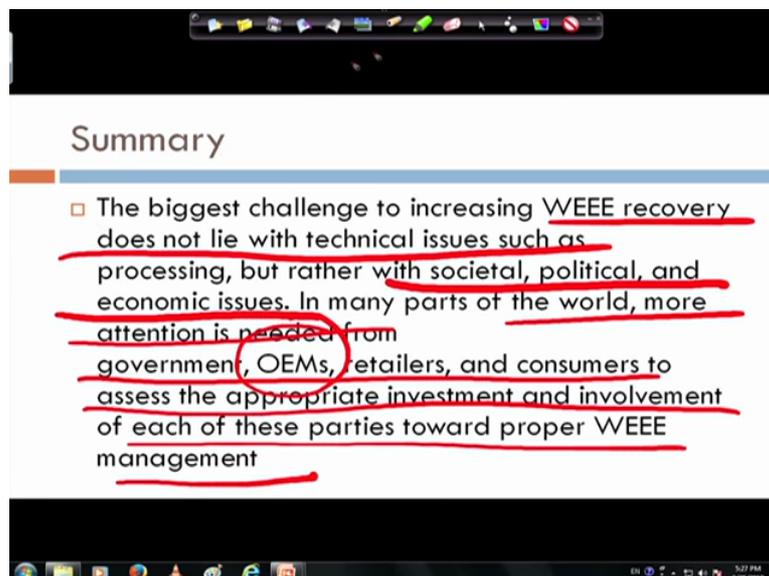
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The screenshot shows a presentation slide with a black header bar containing a toolbar with various icons. Below the header, the word "Summary" is written in a grey font. A blue horizontal line separates the title from the content. A single bullet point, marked with a small square, contains the following text: "Ample evidence exists that improper management of WEEE, such as has occurred in many parts of the developing world, can pose harm to human health and the environment. Development of new or expansion of existing legislation or policies to prevent WEEE from the developed world being inappropriately dumped on the developing world is required." The slide has a white background and a black footer bar.

Ample evidence exists that improper management of WEEE in countries like India or similar countries, has just occurred in many parts of the developing world, it can cause a significant human health impact and environmental impact. Development of new and expansion of existing legislation, in Indian context we already have a new legislation 2016, off course it needs of the refinement and legislation is always a work in progress, as you learn you refine and you make it better and you major thing is in the Indian context is the implementation of that regulation. So legislation or policy prevent WEEE from developed world being dumped into the developing world is also required.

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The screenshot shows a presentation slide with a black header bar containing a toolbar with various icons. Below the header, the word "Summary" is written in a grey font. A blue horizontal line separates the title from the content. A single bullet point, marked with a small square, contains the following text: "The biggest challenge to increasing WEEE recovery does not lie with technical issues such as processing, but rather with societal, political, and economic issues. In many parts of the world, more attention is needed from government, OEMs, retailers, and consumers to assess the appropriate investment and involvement of each of these parties toward proper WEEE management". The text is underlined in red. The slide has a white background and a black footer bar.

So the biggest challenges to increasing WEEE, actually it is not a technical issue. Again as I was telling for the municipal solid wastes as well the technologies are out there, we do not have to reinvent the wheel, technologies are out there in terms of recovery of heavy material, in terms of the recycling, but the problem more is in the societal as with the societal, political and economic issues.

So that is where the problem lies, it is not the technical issue that WEEE recovery does not lie in the technical issue, it is a societal, political and economic issues. It is it will more attention is needed from the government or the manufacturers, retailers, consumers to assess the appropriate investment and each of these parties towards proper WEEE. So it needs a opt all the stakeholders needs to come together and look at these things in more frugality.

So with that let us close this video I think it becomes little bit longer than typical 30 minutes but that is okay. So with this we covered this entire 12 weeks material, I hope you enjoyed this course so far and many of you have I think registered for course, registered for the exam. So all the best for your exam, there will be another two videos of salt problem which will be up pretty soon and then at the same time we have giving you 2 surveys 1 on MSW and 1 is on e-waste and we will compile the results from those 2 and I will do a quick maybe 20 to 30 minutes video depending on how the results comes out.

So with that again thank you very much, I hope you enjoyed it, I enjoyed teaching this course, I hope you learn something and in overall the goal of doing helping one of the major goal for offering this course, why I offer this course is to help the cause of Clean India Mission, the Swachh Bharat mission. So I hope you have around 7000 some people who have registered for this course, you have learnt some material from this course that you will be able to wherever you go just talk about that, what is the best way of managing the waste.

Because that is the one thing we need, wherever in whatever capacity you are, wherever in whichever forum you can be please spread the message, so that that this is the way to manage it and this is not the way to manage it, these are the things we should talk about it. So I have tried to highlight several times in the presentation over the last 12 weeks, so with that, thank you, thank you very much and I look forward to meet you again sometime in person, sometime online and if you have any if I can be of any help, anytime feel free, right now use the discussion board, later on you can send me email, thank you.