Environmental Remediation of Contaminated
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Lecture - 42
Case Study: Solidification and Stabilization

Hello, everyone. So again welcome back to the latest lecture session. What are we been up in the previous session anyway, so we have been looking at particular case study, right I think it was with respect to site that was use for finishing or polishing wood and use for also preserve wood and so on and we looked at that particular site which was contaminated to great extent by among other contaminant dioxins, right.

And I believe a few heavy metals too, right. In that context we looked at the timeline of the relevant traditions at least as taken in the U.S. Again, we needed some particular study so where we had data and this is something that I could find, right. Again as you, as we saw anyway it took almost two decades from the time that the site was discovered or you know listed as requiring remediation to the completion of the relevant job, right.

So in that context we looked at preliminary or what is the relevant people to look at preliminary remedial investigation or feasibility study. Based on that they came up with different alternative then after few years and other what do we say relevant decision making let us say, right. People end up where record of decision again it termed used in the U.S. let us say, right where they finalize solidification/stabilization among the other options available.

I believe they also looked at bioremediation, incineration, excavation of the relevant soil and up to 120 feet and so on and so forth, right. And then we moved onto data looking at let us say the laboratory studies or the batch scale studies let us say, right. As in at this stage you know solidification/stabilization finalized to be the relevant remedial technique right. And then obviously to decide the relevant what do we say matrix let us say, the mixture of either cement, fly ash or any other additives.

Or in this context, I believe we also looked at or the relevant people also looked at let us say some proprietary add mixtures or binders, right. So to look at the relevant effectiveness and also obviously the cost and such you know, we looked at some data. So let us just start from there and take it from there.

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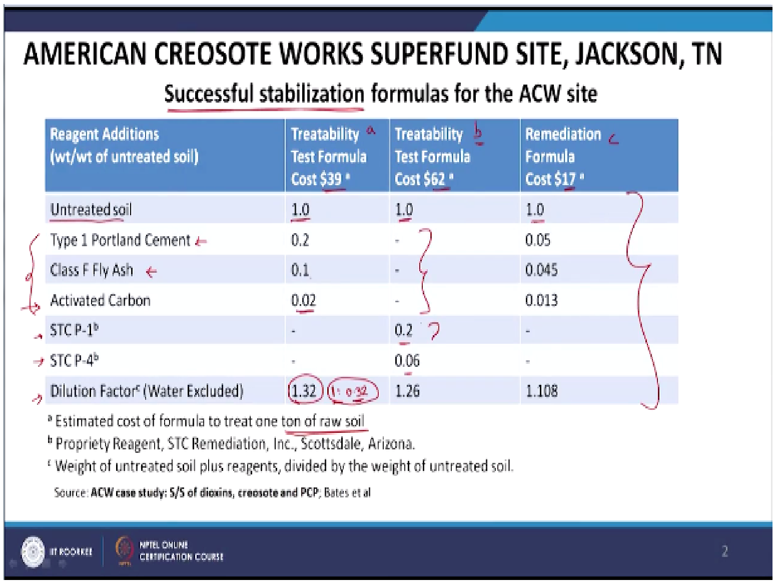

So here we looked at successful stabilization formula so again we are not going to look at the technical aspect here when you know, it is deemed to be successful stabilization formula we understand that the relevant and physical and chemical changes that we want to bring about you know, well successful let us say, right and again successful stabilization let us say and we looked at cases A, B and C let us say, right and one around 39.

What we say dollars per one ton of raw soil to treat cost of formula to treat what to say 1 ton or raw soil here at 62 and here at 17 the lowest. As we saw I believe the one that was selected but again let us just have a quick recap. So untreated soil, right and that is the reference here, right 1, yes and the ratios at which that was added let us say obviously as you can see 1:0.2:0.1 and here they also added activated carbon, probably because let us say if you have any other organic or such maybe not maybe typically activated carbon acts as a very good exacerbant let us say, right.

For hydrophobic compound and so on, so this could be one reason for addition of activated carbon. We already looked at addition of Portland Cement and Fly Ash, right. And then here they also looked at two proprietary items but that was only in case B, right. And Dilution Factor excluding water here, so what does it mean? So for 1 ton of raw soil they have to add 0.32 tons of the relevant binders now, right that is a considerable fined ratio.

Again with respect to B let us say, not B pardon me, option B, but here they did not look at these relevant aspects or the typical binders let us say, right. They try to look at some proprietary what do we say materials. Obviously, if I am trying to look at proprietary materials I need to either have a trade off with respect to what you say cost effectiveness or what do we say effectiveness with respect to the relevant immobility or the degradation, right. Like say binding two years and so on and so forth. We will look at some data later.

So they looked at some particular what do we say, proprietary items and here though you still see that for 1 ton you still have to add 0.26 tons of the relevant binding materials which obviously is relevantly you know, high amount or volume pardon me or mass and thus the cost obviously as you would have expect is relatively higher, right. So that is something out there. And let us look at; look at the option that was selected in a bit more detail.

Again 1, which is reference here and 0.5 when almost the same amount of fly ash, cement and fly ash almost the same amount and so on. But here as you see, obviously they decrease the relevant fractions of what do we say the fly ash, cement and activated carbon. Thus, obviously the savings in sense that you know, for 1 ton you only need to add 0.1 ton or the relevant binders and add mixtures here, right. So that is the one particular aspect. So obviously, here you know looks like at least to meet the threshold.

Let us say A, B, C options did well and obviously because the cost was remarkably less for this particular formulation and also the volume of the particular treated soil is not going to be greatly you know, remarkably great or high compare to the initial value. As in here as see or at least the weight and thus I am presuming the volume 2, right. Here 1.32 after treatment here 1.1, after treatment right, so that is something to take into account obviously because let us say if I need to look at disposal or such to, right.

And that is one aspect let us say. So let us move onto looking at in detail this particular aspect.

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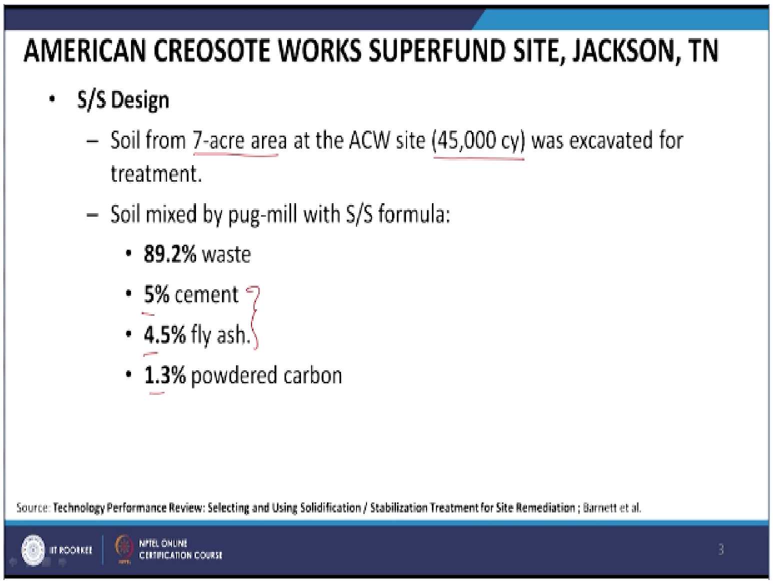

So 7-acres and as we mentioned earlier 50,000 cubic yards and option c where you know they chose cement, fly ash and activated carbon. As we saw cement and fly ash at almost the same what do we say fractions let us say and considerable fraction of powdered carbon. But obviously as you see here 90% of the relevant mixture the total the final matrix is made up of waste itself, right.

So that is something to keep in mind, it is 90%. Because, typically you know that way to the high value as we have seen even in the couple of examples we have looked at let us say, I think 70% or 80% waste is what we have typically looked at and the final what do we say mixture now. So here we see it is around 90%.

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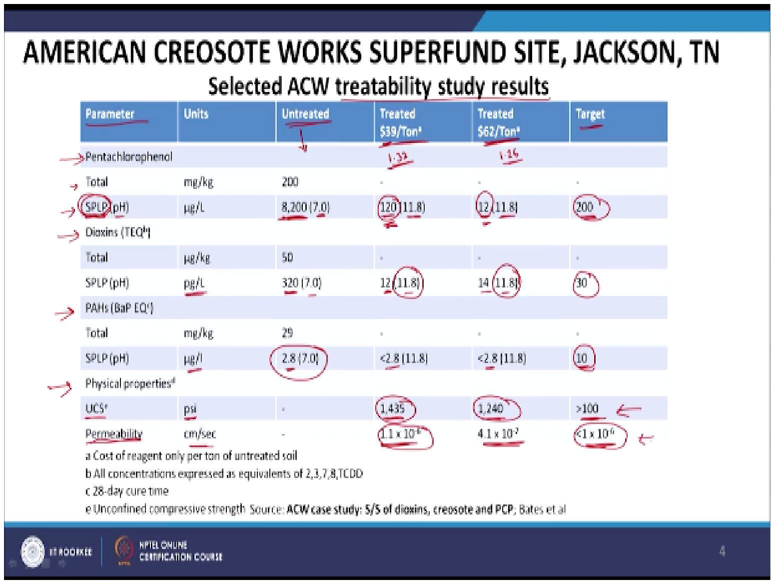

AMERICAN CREOSOTE WORKS SUPERFUND SITE, JACKSON, TN

Selected ACW treatability study results

Parameter	Units	Untreated	Treated $39/Ton[a]	Treated $62/Ton[a]	Target
Pentachlorophenol					
Total	mg/kg	200	-	-	-
SPLP (pH)	µg/L	8,200 (7.0)	120 (11.8)	12 (11.8)	200
Dioxins (TEQ[b])					
Total	µg/kg	50	-	-	-
SPLP (pH)	pg/L	320 (7.0)	12 (11.8)	14 (11.8)	30
PAHs (BaP EQ[c])					
Total	mg/kg	29	-	-	-
SPLP (pH)	µg/l	2.8 (7.0)	<2.8 (11.8)	<2.8 (11.8)	10
Physical properties[d]					
UCS[e]	psi	-	1,435	1,240	>100
Permeability	cm/sec	-	1.1×10^{-6}	4.1×10^{-7}	$<1 \times 10^{-6}$

a Cost of reagent only per ton of untreated soil
b All concentrations expressed as equivalents of 2,3,7,8,TCDD
c 28-day cure time
e Unconfined compressive strength Source: **ACW case study: S/S of dioxins, creosote and PCP**; Bates et al

So let us move onto more data here. So some other treatability study results just for our particular understanding here, so let us look at what we have here. So obviously, we have different Parameters here, different compounds, Pentachlorophenol, Dioxins, Polycyclic Aromatic Hydrocarbons and then the Physical properties, right. So here we have total, right. And then we have this I think synthetic or you know this is kind of a leaching procedure test. You know, straightly different from the TCLP test.

I think here it; this SPLP test tries to mimic the condition and thus particular what do we say waste let us say or the solidified waste as expose to acid rain. And that is the SPLP test. They looked at the slightly different test not the TCLP, right. And I think that is what we have. Here obviously, the units here right and untreated, this is the untreated site. So treated one option with respect to the 39 ton where we had 1.32 after what do we say treatment of 1 ton.

And here again where the 62 per ton site where they use the proprietary materials I think they are on 1.26 after treatment, right. So let us; and the target was obviously as you see different values out here. So let us just look at this data after leaching let us say. So 8200 for untreated, so after treatment by this particular 39 per ton or 1.32 option we have 120 or they ended up with 120 pardon me and then what we see now, here it is 12.

Here as in the case where they used or tried or the trial was done with the proprietary material you see that the relevant concentration after leaching is almost 10 times lesser than the one where they just use cement and fly ash, right. But obviously, the cost is considerably higher, right almost 80% higher. But the key is that you know both of them are lesser than target. The target concentration was suppose to be 200 microgram per liter.

So you see that even the one with 39 per ton now just the cement, fly ash contraction let us say is good enough to suffice or meet the needs of these particular targets. And again how about these targets arrived at, if you remember let us say, they looked at 10 to the power of -4 Lifetime Cancer Risk and then looked at what are the different targets for different compounds, right. And here let us say pH, so it is untreated here.

Obviously, after treatment has you, we witness that you know, we understand from our logical reasoning tool they are trying to beat this test here in other than TCLP they are trying to SPLP test right. So again here they are trying to raise the pH and again that is why you see from pH initially of 7 or initial pH of 7 they now ended up with pH of around 11.8, right. So that is something to keep in mind.

So again same case with Dioxins, but here maybe relatively lesser level of removal probably, so 320 here and then after treatment let us say by just the cement and fly ash mixture 12 and 14 not a great deal of distance and both the relevant options are less than 30, right. So obviously here it is pictogram per liter is the units here or the units. Again obviously pH it is increasing here after treatment that is the something that we see here, right.

Moving onto the Polycyclic Aromatic Hydrocarbons, right so we have it in microgram per liter so 2.8 initially and here I guess it is less than the method detection limits so they just mention that it is less than 2.8 and looks like the standards itself is 10, so even in the untreated waste the PAH was not considered, right.

So Physical properties, obviously what are the two aspects we typically look at, the unconfined compressive strength to look at the structural integrity of this mixture and the permeability or let us say depending upon you know the vendor hydraulic conductivity let us say right. So again pound square inch, right. Typically, we said at least 50 pounds per square inch was good enough, here they looked at 100, right.

But looks like obviously both the mixtures are remarkably what do we say, doing pretty well in this particular aspect right. They are meeting the standards, right. And again permeability, so it has to be less than 10 power -6 centimeter per second, right. I guess this does not do a great job in that regard right. This yes to some extent, right. But this is not of the relevant standard by a great though. Again why do we want the permeability to be less?

The reason is that let us say if you have this particular matrix let us say surrounded by the relevant soil or such let us say and you have water coming down, let us say here they were looking at acid rain let us say, think of rain though. And if there is rain and let us say you know, this template the soil cap and so on. If your permeability is less it will flow around a over and around this particular mixture rather than through the mixture right, that is obviously one of the reasons why they look at trying to minimize the permeability, right. So that is something to keep in mind.

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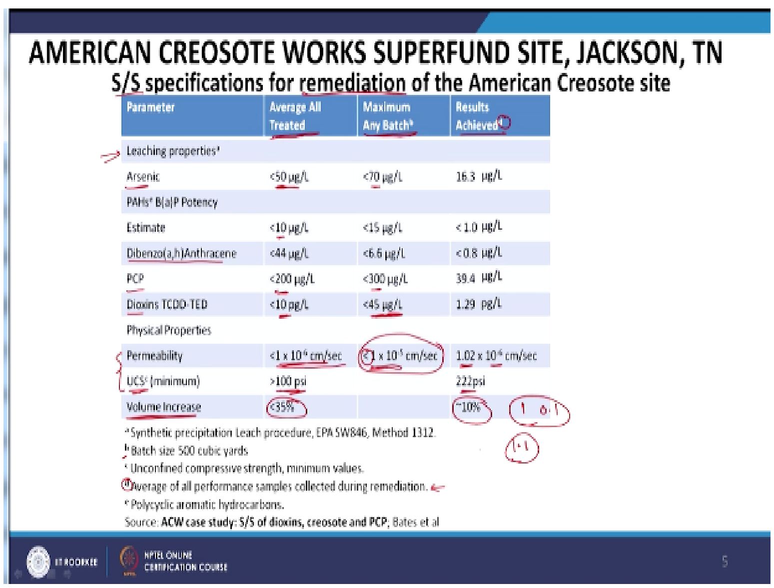

Let us look at some other data here. So here you know, solidification and stabilization specifications for remediation let us say, right. After remediation this is after remediation, right.

So this is after application of that particular kind of method that we talked about where they looked cement fly ash and activated carbon. But the ratios and the fractions were relatively less, right. So let us look at the leaching properties let us say.

So leaching properties we are looking at Arsenic, Dibenzo Anthracene, PCP, Dioxins and then again Physical Properties let us say and Volume Increase as I mentioned earlier obviously volume increase is something that remarkably relevant let us say. So let us look at the different options here. This is the average of all the treated what do we say, batches I guess, right. So maximum of any batch, right and here let us say batch size is around 500 cubic yards, so the maximum so they test different batches.

And this was the maximum they attain, this is the average and results achieved but we have a particular note here. Average of all performance samples selected during remediation, right. Again this is a average though, but all the performance samples related to performance they took multiple samples and when they results achieved it is the average of all those relevant samples, right. So let us look at the leaching properties, first let us say.

So again average is somewhere out here 15 microgram per liter, maximum slightly higher right. Let us look at anomaly let us say right. You know, here let us say 10, 15, 44, 6.6 that is seems to be anomaly obviously, 200 and 300 here. 10 pictograms, so this is an anomaly because it is pictogram here and here the maximum is almost remarkably high, 45 microgram per liter, right. And let us look at the permeability.

So here finally though as you see the permeability is less than what they were trying to look for, that is the average initially it was less than 1*10 power -6 and maximum here is less than 1*10 power -5, right so that is something that to be considered because the permeability remarkably high almost fact of 10 high.

Though they do say just less than 1; the issues is that let us say our mixture let us say and they are looking different batches and getting these, right. So even if let u say cluster of batches are having relatively higher permeability let us say, what can happen now, you can have seepage of that particular rain water or let us say the leachate through that particular batch. Because at least though say it is less than 10 power -5 we do not know as if it is what do we say 10 power -5 or how close to 10 power -16 or such it is.

There is uncertainty factor almost of 10 right. So you know this can be a critical aspect can be anyway but obviously if you are capping it and again using a relevant what do we say Geosynthetic clay liner you know, that is going to limit or you know increase the effectiveness of the system even though you have batches that have greater permeability, right. But that is something to keep in mind.

Obviously, the average is again around 1.0*10 power -6 closure to their particular requirement of 10 power -6 into; I mean 10 power -6 centimeter per second. So the average of all the treated, Unconfined Compressive Strength results were greater than 100 psi and again here it is 222 psi right. So again Volume Increase was less than 30%; 35% so looks like different batches they observed different levels of increasing the volume.

But as we looked at it, in our case let us say, in our in earlier we saw that the fraction was 1 ton there was there in I think 0.1 ton, right. So a total of 1.1 let us say initially when we had only 1. So around 10% but obviously we are looking at we need to consider the density, but that is something to keep in mind here, right.

So again genially did but again something to keep in mind is that because of cost effectiveness obviously you can obviously mean why you can obviously go much lower because people look at what do we say the feasibility cost obviously plays a role and time plays a role too, right. So keeping this two aspects in mind obviously though we have standards you know people look at the overall picture it is not that you know, we are going to you know be very picky let us say with respect to one or two variables.

Obviously, some other relevant the more what do we say variables or those variables that have more weightage let us say in terms of risk or the criticality let us say, you know obviously are we are going to look at that. But we are not going to be very picky with respect to all the relevant aspects though. But again as you see here, there is a variation between the average and the maximum and again that is something to keep in mind here, right. So let us move on.

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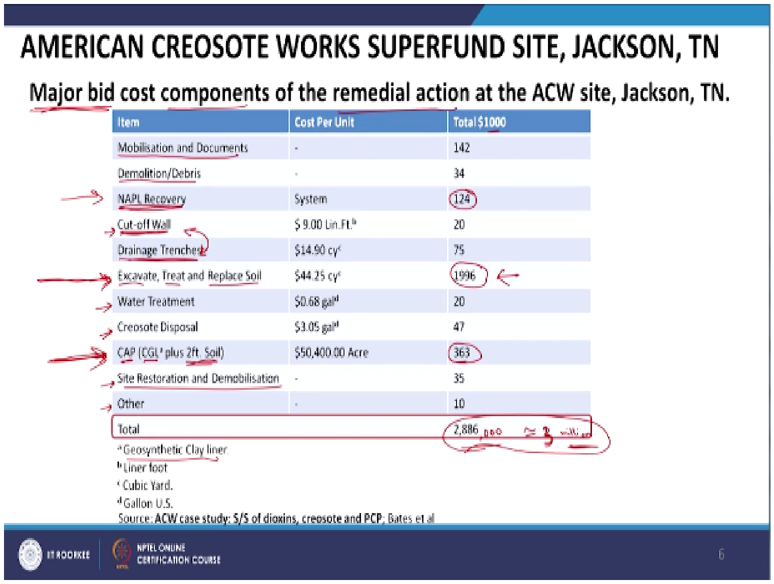

So let us look at you know for the final site let us say. Major bid cost components for the remedial action, right this is for the major bid. So let us look at what are the aspects that are leading to the relevant you know, or you know require resource in the first case. So paper work, mobilization and documents, right that is something, so first Demolition and Debris of the existing you know, are you clearing the debris of the existing structures if any.

And there is already some NAPL present and that needs to be recovered that is adding to the cost. So a Cut-off Wall and again when do we use this Cut-off Wall obviously now, let us say here this is playing the role of the containment or the barrier now. If you remember in one of the earlier examples with respect to solidification and; not solidification pardon me, remediation of the relevant segments we talked about aspect and we talked about Cut-off Walls.

Obviously, being use in conjunction with other techniques. So again what its role, it is containment let us say. If you do not want this particular contaminant to what do we say we transport it over wider distance or area pardon me. So they have a Cut-off Wall here. So Drainage Trenchers again, you know going in conjunction with cut-off walls you want to drain now the relevant ground water let us say.

So here is the major aspect Excavate, Treat and Replace the Soil, right. They are going to excavate it, treat it and replace it with the either treat a mixture or what do we say or typically you know fresh soil or uncontaminated soil. And contaminated water treatment, right, the Creosote, right looks like it requires what to say specific disposal.

And the Cap, cap again so after your particular what do we say solidification/stabilization you are also going to or these people also looked at, if you remember the record of decision a cap, soil cap and then a Geo synthetic clay liner that is what you see. So synthetic what do we have here Geo synthetic clay liner and 2 feet of soil that is the cap here and then once they are done with it site restoration and demobilization and you know other petty aspects right.

So the total seems to be, that was almost 3 million, right. Let us look at what is the major components in here, right. Obviously, as you would have aspect Excavation, Treatment and Replacing the Soil is major component almost 2/3rd of the relevant cost, right almost 2 million out of the 3 million, right that is from Excavation, Treatment and so on. Other aspects obviously are the major aspects are the Cap, right and obviously NAPL Recovery let us say, right. So these are the major aspects again.

Again as you would have expect the solidification/stabilization the relevant excavation as we looked at earlier I think we looked at one case for excavation of the more are the (()) (19:53) site and how much amount you know money it would cost. Excavation, Treating and you know replacing the soil is major aspect here.

But obviously there are other aspects that you know add up to considerable fraction too, right. But I believe if you look at the relevant initial estimates you know this particular estimate either met that particular estimate or was lower than the relevant estimate for this particular site. This is from the major bid though, right from the bid for this particular site again let us move on.

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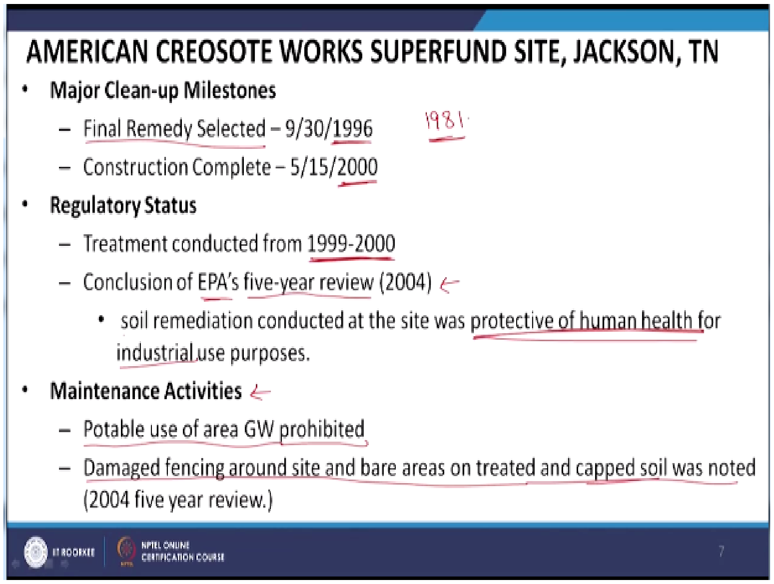

So let us just look at the timeline again for our understand let us say. So Final Remedy was selected in 1996 but keep in mind that they started what you say looking at the site from 1981, right. Obviously, you know what I am trying to impress upon the relevant people here is that you know remediation is with time consuming what do we say process, right. Either with respect to being able to let us say commit enough resources and also being able to come up to a worthwhile conclusion not conclusion let us say alternative pardon me, right.

To come up with a alternatively, right. That is something that is very important. Because, let us say you know I come up with a wrong alternative, right, I am going to mess up the relevant situation it is going to take more resources more time to be able to what do we say, assess, not assess remediate this particular site area, right.

But what do people do, they take temporary measures such that you know this containment does not spread out during that particular time it could include some of those extraction trenches let us say, or cut-off walls and so on. Or you know some cap in the mean time, mean time as in two decades as you see. As you see, we started out at 1981 and it was completed in 2000 now, right. So let us say long run process.

Obviously, whenever possible we would like to have what you say look for prevention, and so that is something that at least we should strive for in the Indian context, I mean we are only now you know moving from agriculture economy to an industrial economy. Obviously, there are going to be issues, right you know, people trying to make money, enforcement lagging behind and such. We are never going to have the ideal case scenario.

But as you see right you know, there are going to be legacy issues as an even after the site is close you are going to have issues what you say issues for decades and you know decades and decades, right. So that is something to keep I mind. And Regulatory Status, we looked that they; the treatment was for only a period of two years I believe 98 to 2000 or 98-99 to 2000, so that is something to keep in mind.

But the decision-making and the relevant process let us say and also the relevant studies, primarily the risk assessment and the preliminary remedial investigation and feasibility studies they obviously take time, right. So and then after that again EPA or the U.S EPA has the policy of five-year review for all these contaminated sites.

So that is again something maybe we can; we need to learn from some of the relevant aspects out there let us say or about how to do things or how not to do things too, right. So again, so soil remediation was conducted at the site was protective looks like the five-year review says that, you know it was during the job as in you know, we looked at 10 power -4 threshold what do we say Lifetime Cancer Risk, it was able to meet that particular objective too which was for the industrial use purpose.

And what else needs to be done, looks like they said that Potable use of area for you know the Ground Water cannot be used for Potable what do you or for drinking water, right. That is something that they mentioned. And looks like also you know, fencing around the site and bare areas on treated and capped soil was noted let us say.

As in, what I am trying to say here is that you know, that we cannot just let us say be done with remediation and let it be obviously we need to conduct periodic reviews now, right. Why is that? Obviously, to see whether it is performing as you would as you designed it let us say or as you estimated it to be, and secondly let us say there are going to be other aspects you know other variable at play.

For example, here they looked damaged site and a damaged fencing. Damaged fencing as in now the people can, you know people, children or any other you know can access this site that something we do not want to what do we say happen let us say, right. And so let us say there are some capped soil let us say that seems to be damaged out. So obviously, that is something to keep in mind right. So what are the relevant conclusions here?

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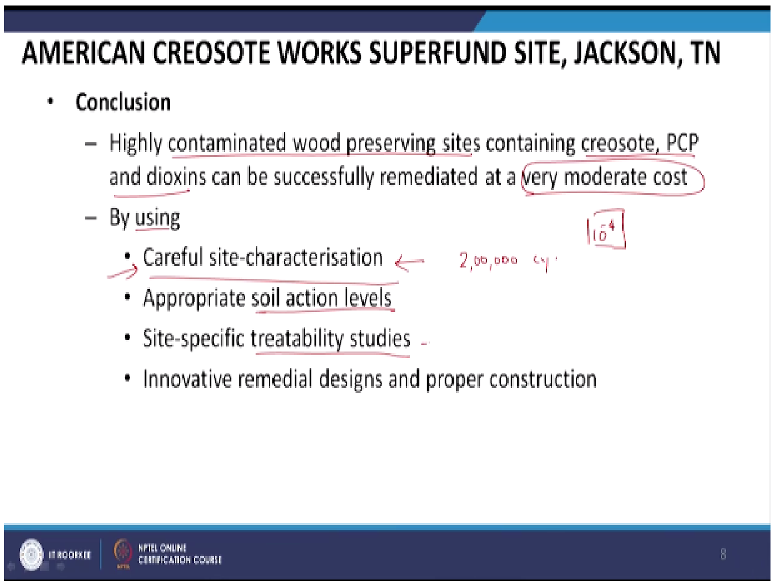

So highly contaminated the site let us say containing a variety of contaminants can be successfully remediated more importantly a moderate cost. The key is that moderate cost and that is one of the reasons why solidification/stabilization is relatively more what do we say widely used as we saw in that particular graph. This was the most widely used pardon me, technique, right. And what are the aspects?

So again one aspect was that site-characterization issue was in an issue, why is that? If you remember, initially they were trying to look at 2 lakh cubic yards, right. And then after decreasing it, it as in the threshold risk to 10 power -4 and more importantly good or better site-characterization to look at the critical areas. They could bring down this volume of contaminated soil from 2 lakh cubic yards to 50,000 cubic yards, right so that is remarkably important. Careful site-characterization.

So again soil action levels, let us say depending upon you know your particular objectives, right. And site-specific treatability studies as in obviously let us ay study with respect to the cement, fly ash and activated carbon any soil obviously does not work out, we need to look at batches from that particular site, right and that is something that is critically important. And again, you know some innovation in the remedial design and the relevant construction let us say, right. So let us move onto another minor case study and we will be done with that though.

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So here we are looking at PSA, let us say Pepper, Steel and Alloy let us say. This is again a Superfund site. Superfund as we mentioned is how the relevant U.S.EPA classified let us say highly contaminated or you know sites that are higher up the prior to list of remediation, right. So this is the relevant site out here. Look at what we have here. But again here, because of lack of time I am going to summarize this.

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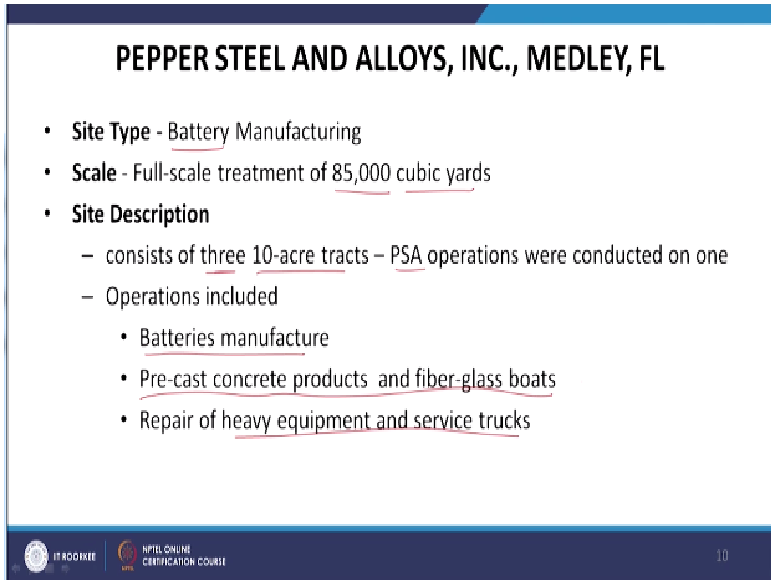

So for battery manufacturing typically heavy metals, right So full-scale treatment of 85,000 cubic yards was required. So 10-acres, the Pepper, Steel and Alloy these operations were connected on one let us say on one of these three tracks. Let us say operations including battery manufacture, heavy metal typically, pre-cast concrete products and fiber-glass boats, repair of heavy equipment and service trucks. So obviously, some issues from these two what do we say modes of usage but typically this could have let to the contamination, right.

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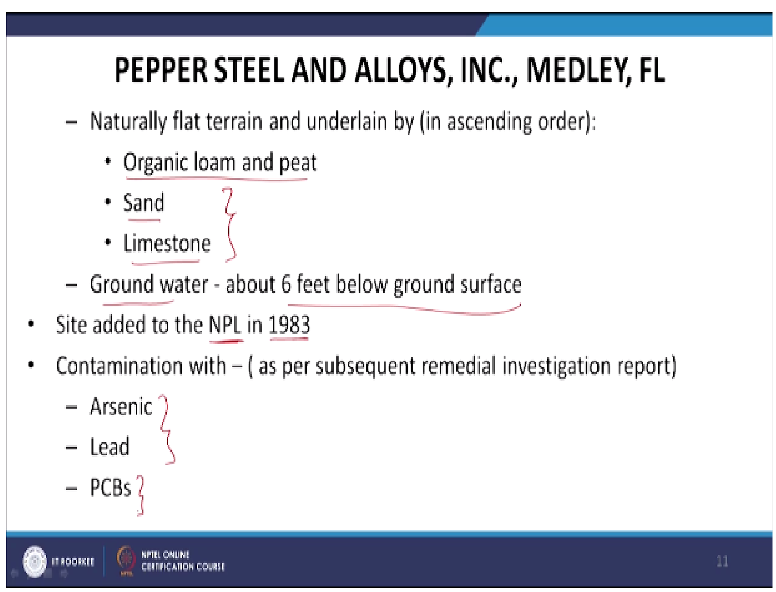

And what was it, what is the site here now how is the site here. So typically, organic loam and peat, sand and limestone. Sand and Limestone, keep that in mind because you know permeability is considerably high here. Obviously, we do not have the relevant thickness and such but you know; so ground water is relatively high about 6 feet below the ground surface so that is relatively high ground water level. So it was added to the National Priority List or U.S. National Priority List in 1983, right.

And as we mentioned heavy metals contaminated with heavy metals and also some PCBs, right. Again PCBs are remarkably toxic; Arsenic, Carcinogenic and Toxic, right. These are the heavy metals as we you know presumed they would be present because they would have used for or the site use for manufacturing batteries.

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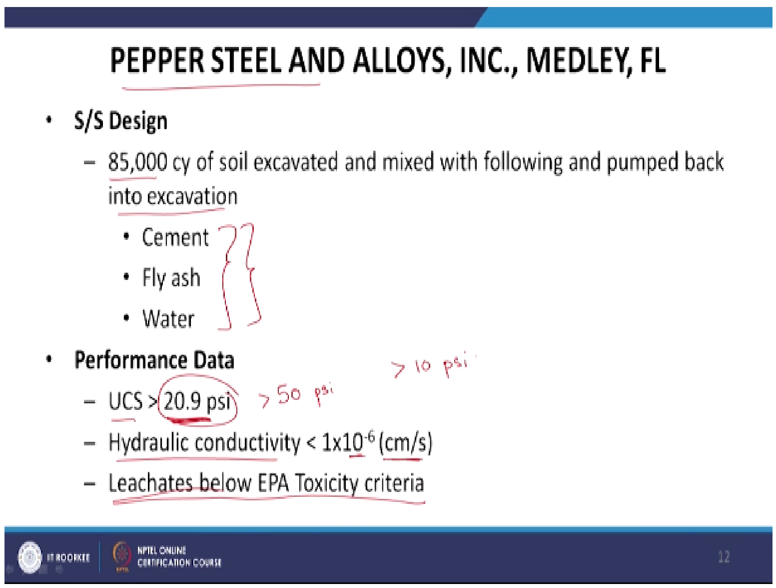

So what is the design here? They looked at as we mentioned 85,000 cubic yards. Again, the generic case cement and fly ash again, there is a particular reason why a most people use cement and fly ash. One is the cost and also the ease with which you can work with them and also you know it has been seen that for a wide variety of contaminants you know cement and fly ash and the relevant water you know, from the cemetrics is doing the job pretty well now.

So again I am just presenting this particular example to reinforce that particular aspect, right. And mix with the following and pump back into the excavation. So they are back wheeling with the same treated soil, right. So again compressive strength greater than 20.9 psi but if you remember typically we want or ideally greater than 50 psi, sometimes people are fine with at least greater than 10 psi, right.

So this falls within or between two ranges. Hydraulic conductivity as we mentioned earlier too less than 10 power -6 centimeter per second. And looks like the leachate is below the toxicity criteria, right. So let us move on.

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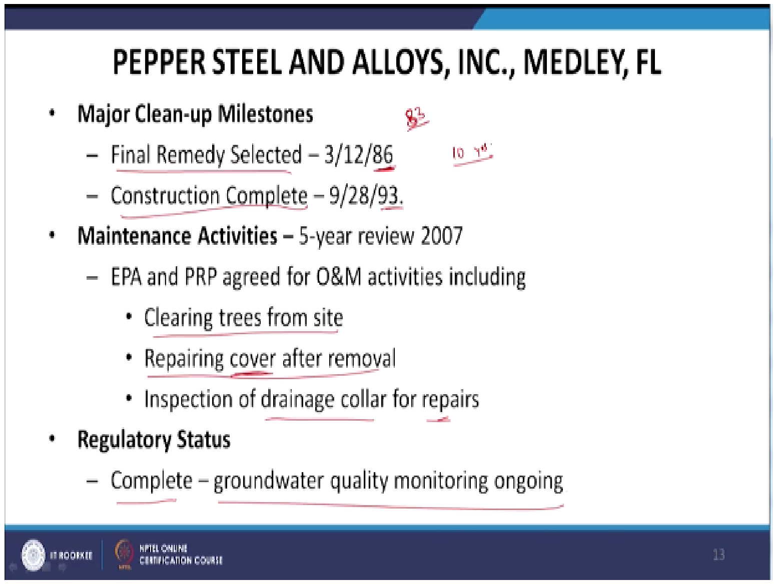

Again it was listed in 83'. Here it ended up the final remedy was started in 86, relatively faster. But the construction took time, right almost 7 years and was completed in 93' So almost here one decade or 10 years, right. That is again something to keep in mind. So maintenance activities again this is a critical aspect the five-year reviews.

So they said looks like trees, right trees from site. And the cover was damaged, this is an important aspect obviously though you have the solidified and stabilized mixture you want to take the extra precaution of let us say trying to see to that your particular mixture is not expose to rainfall or any other what do we say sources of water or leachate. So here repairing the cover after removal and inspection of drainage collar for repair.

Again, throughout the site you are going to have a drainage collar. As in let us say you have rainfall and you have cap right, so what is going to happen to this rain water, it is going to you know after run off it is going to be collected on site let us say. So thus, you need what do we say, drainage collar here.

And looks like you know, that is an issue out here, right. So regulatory status was complete and ground water quality monitoring is ongoing. Again keep in mind that the review looks at what are the issues that need to be addressed and also is the system behaving as it was suppose to be, right. So that is something we look at. And I am believe; I am, you know, ran out of timing today. So we will be done with this for today's session and move onto the relevant aspects in the next session. Thank you.