Environmental Remediation of Contaminated
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Lecture - 41
Discussion of TCLP Approach Contd.
and Cost Estimation for Solidification

Hello, everyone. Again, welcome back to the latest lecture session. Again a very quick recap, so we have been looking at very quick example relevant to the TCLP based approach right for designing solidification/stabilization mix. So let us look at that one example here again.

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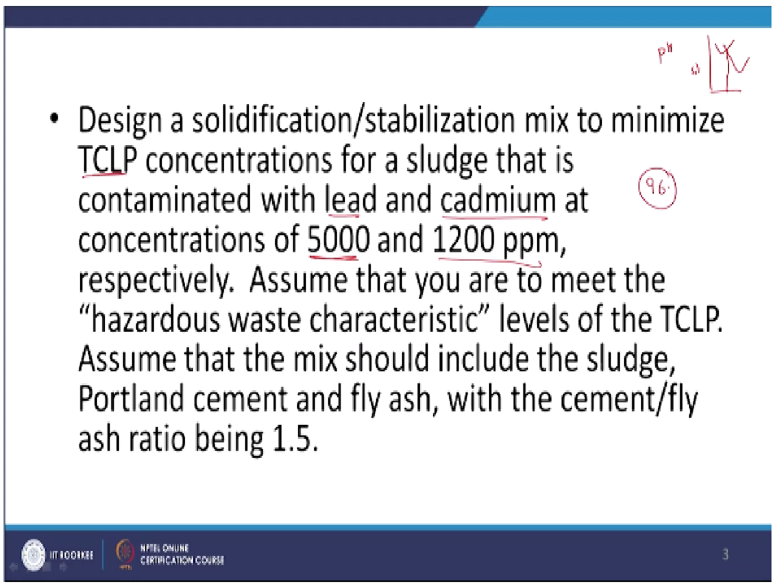

So TCLP, right and here we had both lead at 5000 ppm, cadmium at 1200 ppm right. And we were trying to design the relevant matrix or the different fractions right. In that context obviously we needed the design pH, right. So for that we looked at the solubility, right and we chose you know some such pH out here, right. But again different trials were required there to choose the relevant variable, relevant best suitable variable to be able to choose the optimum pH.

But obviously there is no particular way as you, as looked at it there are different ways, sometimes cost consideration can come into play so on and so forth. So it depends upon the relevant aspects or variables. For example, you might want to give greater weightage to let us say the toxicity of that particular heavy metal and such you know want to concern yourself with maintaining the relevant concentration of a particular heavy metal at a lower concentration let us say, right.

Again, different aspects, so in that context we end up with pH of 9.6 now. So let us move onto that acid neutralizing capacity test based table.

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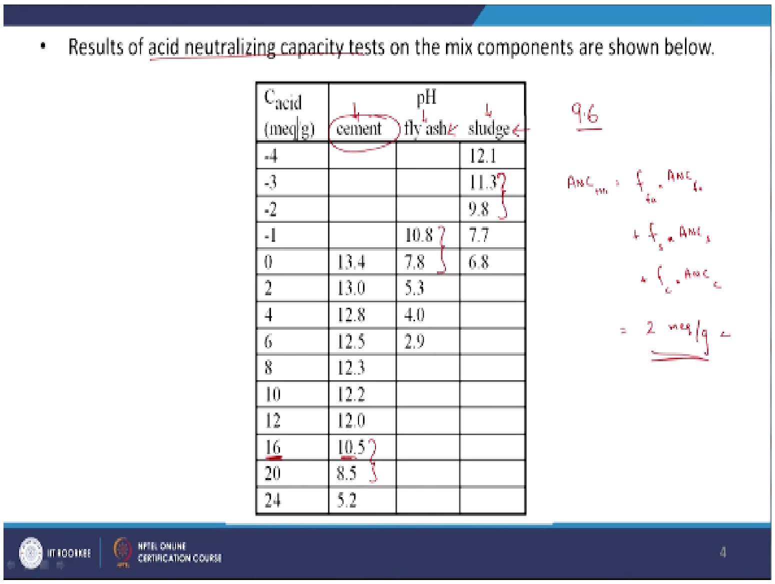

C_{acid} (meq/g)	pH cement	pH fly ash	pH sludge
-4			12.1
-3			11.3
-2			9.8
-1		10.8	7.7
0	13.4	7.8	6.8
2	13.0	5.3	
4	12.8	4.0	
6	12.5	2.9	
8	12.3		
10	12.2		
12	12.0		
16	10.5		
20	8.5		
24	5.2		

So as we see for fly ash and now the design pH is 9.6, right. So it is somewhere out here, right between these two. So as you see at 10.5 the acid neutralizing capacity for cement is 16 and what is the relevant range for fly ash 9.6 is between these two values here. And as you see here now the most probably this particular acid neutralizing capacity is going to be negative, right, as in this particular fly ash itself at what do we say 9.6 is going to be what do we say as an acid if you can say so, right.

And same case with sludge at pH of 9.6 right between these two ranges right. That again does not have any acid, cannot neutralize the acid but it itself act as you know an acid in this particular range let us say, right. And that is something that you can see out here. So by linear interpolation right between these three sets of values for cement, fly ash and sludge, right. why is that because we are trying to go into look at finding the acid neutralizing capacity of this particular mixture, right.

And what is that equal to obviously fraction of the fly ash * acid neutralizing capacity or flay ash + fraction of sludge * acid neutralizing capacity of the sludge + fraction of cement * acid neutralizing capacity of that particular cement. And obviously all the cement to be equal to 2 milliequivalents per gram, right of your particular what do we say per gram of your mixture, right.

And obviously here there are obviously assumptions that even when we mix this stuff that you know, the acid neutralizing capacities are going to be what do we say obey the relevant what do ready to rule if I may call that, that we are looking at here, right. So again, and also you can obviously add more what do we say relevant of this relevant constitutes such that your acid neutralizing capacity is greater than 2 milliequivalent per gram.

But what is that means? As you can see sludge does not have any acid neutralizing capacity neither does fly ash at pH or the design pH so what is it mean? You need to increase the cement content. But obviously cement content to crease that you need to what to say, put in more resources or money. So thus, typically people try to design in such a way that you more or less meet the acid neutralizing capacity requirements from the TCLP point of view, right. Again, that is something that we look at, right.

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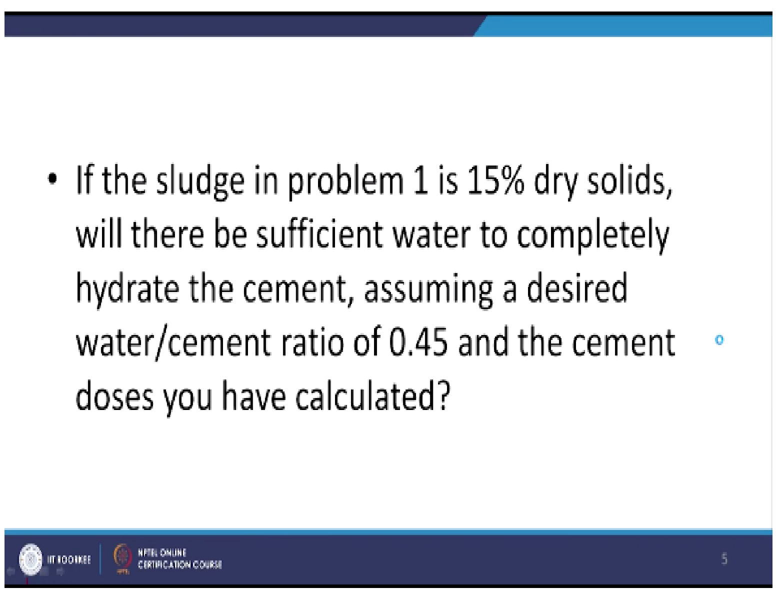

So let us look at the relevant cases and again the relevant aspect of problem 2.

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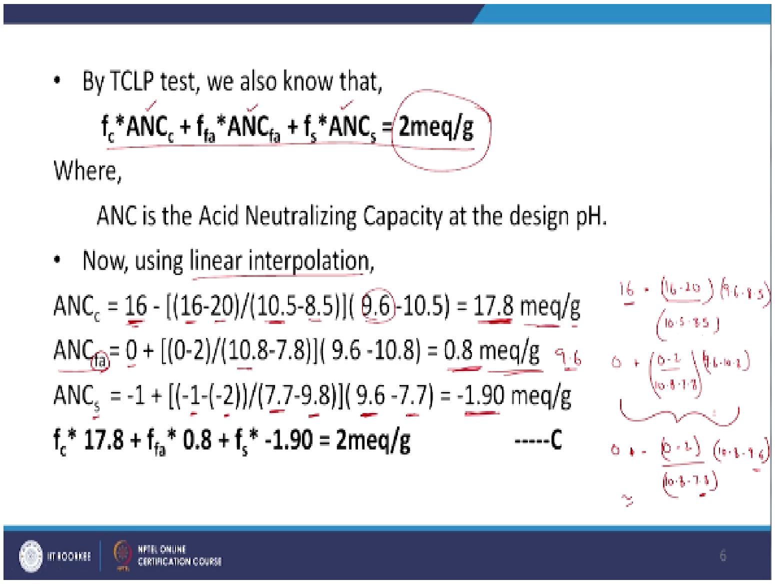

So this is what we have here, right 2 milliequivalent grams. This is the amount of acid that you put in per waste in the; per weight of waste in the TCLP test, right. So moving on let us see. So again linear interpolation, so based on 16 right at 16 we had what do we say at pH 10.5 we had 16 and that is something that we see out here.

And at pH 8.5 we have 20, I believe right. And we are trying to find what it set at 9.6. So it is nothing but linear interpolation to just writ it in a better format 16, 16-20/10.5-8.5 or you can say the slope at the rate at which it is changing into; the actual range that you are looking at was 9.6-8.5, right. So 16 is the one obviously at pH 10.5, right. 16 is the acid neutralizing capacity at pH10.5, right.

So, need to because 8.5 or 9.6 is lesser than that, but obviously the acid neutralizing capacity is greater or increasing with pH that is why you obviously see that at pH 9.6 I end up with what do we say acid neutralizing capacity for cement there is something that I end up with as 17.8 milliequaivalent per gram. Then for fly ash as we obverse let us say, I thought it might be negative but let us say it is not.

So 0, right at pH of 10.8, right. What do we have here, 0+0-2/10.8-7.8*9.6-10.8 right. So again we have a linear interpolation here. So other than expressing in this way we could have also you know we can also express it as 0- let us say 0-2/10.8-7.8, right and then what is this here 10.8-9.6, right. Again looks like we end up with the value of 0.8 milliequivalents per gram. For fly ash anyway at, the design pH of 9.6.

That is your design pH here, right. So that is what we have out here. Yes. And then moving onto this acid neutralizing capacity of the sludge, what do we have, same approach, right. So if we can look at that pH 7.7 looks like the acid neutralizing capacity is negative 1 and pH 9.8 it is obviously negative -2 and then we are trying to calculate it at 9.6 right and that is why we look at range here, and we end up with what do we say an acid neutralizing capacity of -2 or -1.9 for the sludge right.

Again what is the one we, what do we say matrix here or which compound is really to acid neutralizing capacity of the mixture, you see that it is only cement. Both, what do we say fly ash and sludge obviously cannot neutralize the acid but actually you know contribute to the SD content let us say at the pH 9.6. That is something that you see out here, right. So now I can plunge in the relevant acid neutralizing capacities, right for this individual relevant what do we say mixtures and then I can solve for this particular setup.

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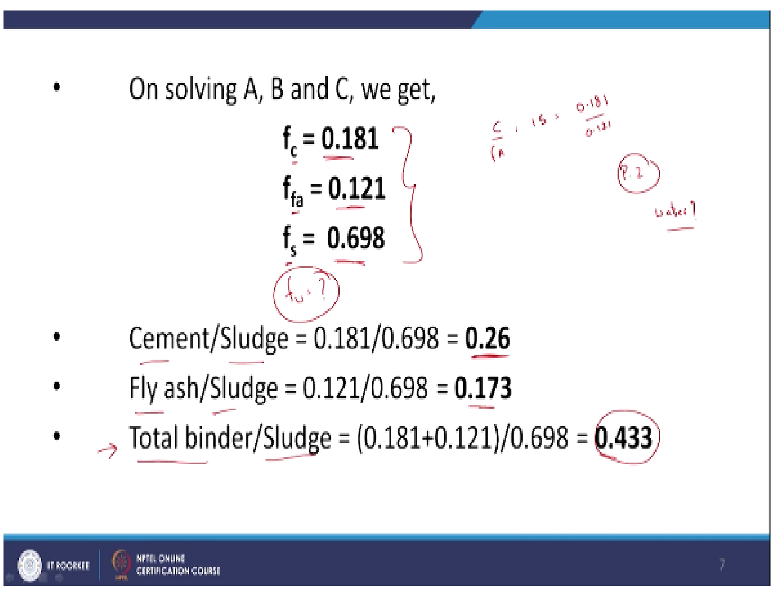

So solving for that looks like the amount of cement is 0.18, fly ash is 0.12 and sludge is 0.698 right, obvious, cement/fly ash right. And I think we mentioned that it had to be 1.5 and that is what you see here 1.0.181/0.121 so that should be hopefully the in the ratio of 3:2, right. I think divided by 6 and so on and let us say you can get the; and obviously the sludge here I guess. So let us look at the total binder content let us see.

Okay, cement/sludge that is something to look at. So let us look at, we are adding what do we say 0.26 adding cement pardon me in the ratio of 1:4 so with respect of sludge area, right. So the other aspect, obviously fly ash sludge 0.173 that is obvious, right. And total binder to the sludge, this is something that we are typically concerned with.

So as you see I am adding what do we say 0.433 of what do we say or it is almost half let us say, the total binder is almost as you know if not same almost the same as your particular relevant waste here slightly lower that is something that people look at. Why is that obviously because to minimize your cost you want to have greater what do we say value of your particular waste right and lesser the value of your lesser the content of your binder here, that is something to keep in mind.

Now we are going to move onto the problem 2 and there obviously you are trying to look at is there enough water content present, right. As you know seen here; here we did not consider any water content here, right but obviously we need water. Why is that, you know it is going to be apparent why we have not consider that here let us see, right. Let us look at what we have.

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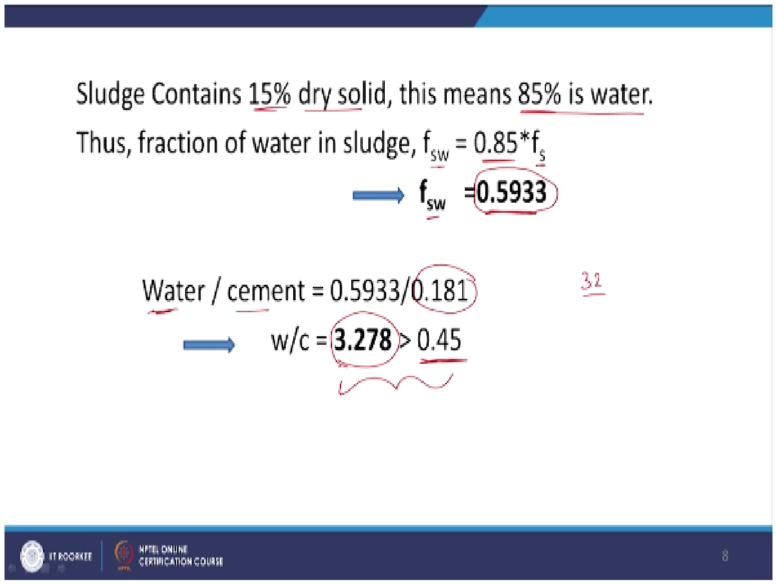

So sludge contains 15% dry solid, obviously what is that mean 85% is water. So this water itself we are presuming that is going to contribute to the hydration of the cement. Let us see if that is going to be good enough or not. So fraction of water n sludge right it is 85% of that fraction of sludge so that is what I have here as a total here, right. And looking at it the fraction of water/cement it comes out to be seems 3.278, right and we only need 0.45 right, fraction of water is something we calculate out here.

And fraction of cement is something we calculate in the earlier slides. And water/cement ratio now comes out to be 3.278 right. So as you can see there is enough water present for your hydration of your relevant cement now. So all these obviously, access water let us say which is not going to be part of consumed by cement for its hydration, what is going to happen to that, it obviously is going to fill up the pour space in your cement or the solidified matrix now, right. And that can contribute to obviously diffusion at so on and so forth, right.

So that is something to keep in mind here. As in if there was just enough water content for hydration right that might be the perfect way to go about it let us say or the ideal scenario. But as you obviously as you see sludge has considerably high quantity of water right, now that is going to fill up the pour space that is something need to keep in mind or that is one particular take home message here now.

So now let us move onto the relevant aspects as in we are going to look at minor case study with respect to two sides. And again there is data is from open source, I am going to present the sources here obviously. But typically, you know from the relevant EPA documents and so on and so forth, right, or the U.S EPA documents. Again, I mean these examples were chosen based on the kind of data were available. Obviously, not all the data is available on online right but I chose those examples were you know relatively more data is available. So let us look at what we have out here.

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So again Creosote Works Superfund Site. Again Superfund side, right now it is one way that you know, the classification of what do we say the priority of such that need to be remitted in the U.S. right. They depending upon the priority they can classify it has Superfund Site. Yes, again Ex-Situ Treatment, right obviously solidification is tabulation is something that they consider but let us look at what are the relevant aspect here, right. So let us move on. What was it mean use for?

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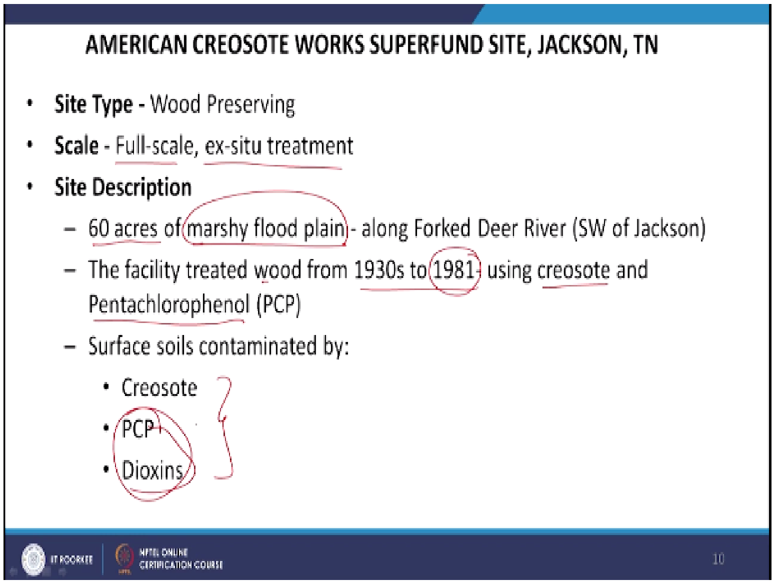

It is use for Wood Preserving let us say. Scale, Full-scale implementation and ex-situ treatment, solidification/stabilization obviously, site description. Description is obviously the key aspect. So 60 acres of marshy flood plain, right you know obviously this is critically important in the flood playing zone, right that is something to keep in mind, right. The facility treated wood from 1930s to 1981 and 1981 that is the one I believe the; you know relevant site was discussed to be contaminated and so on and so forth. We will look at that.

And it was, contaminated was with both Creosote and Pentachlorophenol, right and also Dixons again these are remarkably toxin compounds, right. Certainly Dioxins, right I believe there are also carcinogens. So surface soils are contaminated by these particular relevant aspects or contaminant pardon me.

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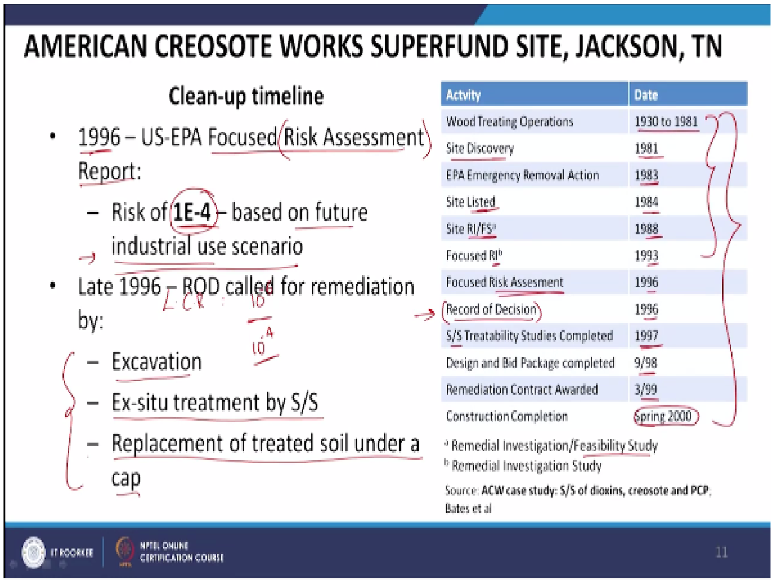

So let us move on. So Clean-up timeline just to understand or get you an idea about you know things were done let us say. So let us look at that. So obviously it ran from 1930 to 80 and then it was discover this particular site was contaminated, right. And then Emergency Removal Action, some relief around 1983; Site was listed I guess or you know maybe as a Superfund Site in 1984. Site Risk, initial risk assessment or so on remedial in the investigation pardon me and feasibility study. Correct myself there.

Site Remedial Investigation or preliminary more or less feasibility study was done. And this is something that we discussed earlier as we obviously need to understand you know what are the relevant aspects involved here and here obviously a focus remedial investigation right. Once you have some data from here, but again as you can see by now itself I guess almost 12 years more than a decade. And then Risk Assessment consider the risk assessment that is something we looked at the initial stages of our course, again 96. Record of Decision obviously this is the term typically use in the context of what do we say remediation in the U.S. right.

So again 96. So Solidification/Stabilization Treatability studies, let us say what conducted again more or less batch studies and so on and so forth, so before you design or you know implement your solidification/stabilization fulltime obviously batch or pilot steady state need to be conducted, so they were conducted. So you know then it was took a year let us say to be awarded to the relevant authority, right for two years.

And; but as you can see you know the construction relatively here is faster process because you just need to be able to mix the relevant system, right and get the things done. Typically, solidification/stabilization you know that is the relevant aspect out here. But as you can see it took almost two decades for the various aspects to be done even in the U.S, right that is something to keep in mind. And let us look at what I have here.

So two aspects to highlight US-EPA Focused Risk Assessment, so they chose 10 power -4 based on future industrial use scenario, right. So as we might have remember let us say or to refresh your memory let me go back to this particular aspect. As and when we look at risk assessment for Lifetime Cancer Risk, we typically look that 10 power -6 risk, right to be able to see to it that the risk pose to relevant people where you know is not going to be greater than 1 in the million or 10 power -6. For various reasons they consider 10 power -4.

And this is something looked at to right. In some cases, they also look at 10 power -4 threshold let us see. And also the scenario is that it is not used for let us say residential purpose or such with the (()) (16:15) that, it is going to be used for industrial purposes let us say, that is something, right. So that is something to keep in mind. And also the record of decision called for; what is this record of decision called for, Excavation, Ex-situ treatment by solidification and stabilization and replacement of treated soil under a cap.

So it is not just that you know you are excavating it, treating in outside and letting at be out there. Let us say you are also putting a cap over this solidified and stabilized the; what do we say, let say mixture here, that is something that you know people have done at least in this particular site, right. Let us look at what else we have here.

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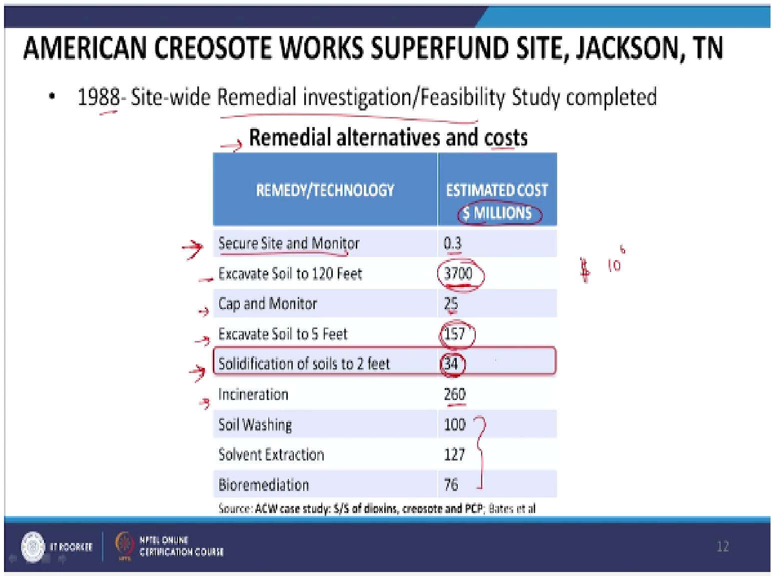

So 1988 obviously Remedial investigation feasible study. We are looking at the relevant aspects in slightly greater deep here to understand how you know, the decision-making when was, you know done. So they looked at remedial alternatives and cost right. So to secure the site and monitor 0.3; excavate soil to 120 feet, it is 3700 let us say, right.

Again this is million let us say, cost is in million, right. And million is I guess 10 power 6, and keep in mind these are in dollars obviously, 3700 millions if you excavate soil to 120 feet to. To cap and monitor it, let us say 25, to excavate the soil to 5 feet, 157 compare that with 120 feet and solidification of soils to 2 feet, it is 34; incineration was considered that is again 260; soil washing, solvent extraction and bioremediation you know different aspects of here, right.

But obviously, the key aspect is solidification of soils to 2 feet, again maybe (()) (17:56) I guess, right. But what was not clear from that data that we have, it is was 34 let us say, right. Again that is something to consider here among all the other alternatives here, right. So if it is just securing this site and monitor yes 0.3 but obviously if it is within as we remember or we looked at it pardon me it is within a flood plain, right.

So this probably is going to be relatively difficult to get done, right. So this is what we have here. These are based on the preliminary studies.

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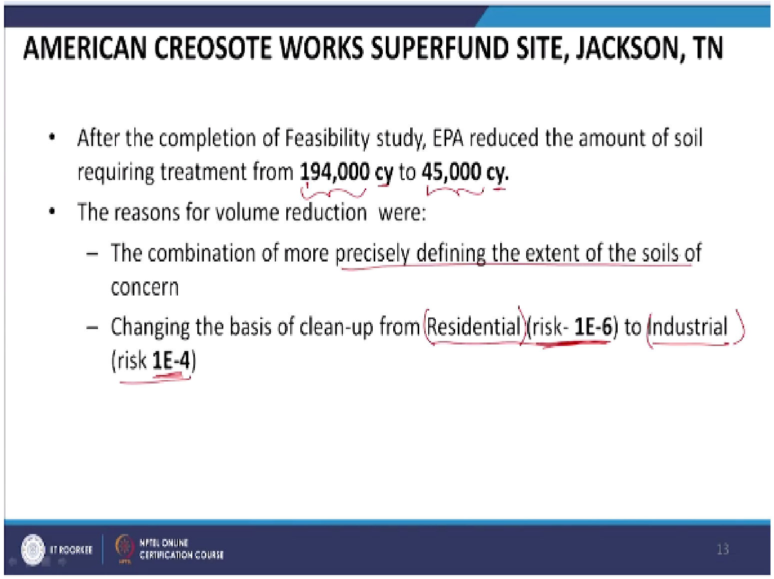

So after completing this study the EPA reduced the amount of soil requiring treatment from you know these many what do we say cubic yards to 45,000 cubic yards, right 1,94,000 to 45,000 almost let us say what is it now, 1/4th of it, right. So decrease the volume of soil that had to be what do we say treated from what do we say 2 lakh cubic yards let us say to 50,000 cubic yards. Again there are two aspects, one obviously was that more detailed site investigation was conducted to see which particular area was more contaminate.

So obviously you need to put in money in the initial stages to you know for site characterization and this is something we have seen either during natural attenuation or permeable reactive barrier and so on and so forth, right and the other key aspect was that you know they also decrease the risk from let us say residential risk to industrial risk, right. So again what are the aspects here? So risk let us say was 10 power -6 typical value that you look at especially if it classified as residential usage. Industrial usage let us say 10 power -4, right.

So one of the aspect is that, they are reducing the what do we say threshold let us say, to treat to this threshold more soil was have to be treated. And as we saw the cost are relatively high and thus obviously the decrease the threshold obviously you know affecting the relevant cost. And also let us say precisely defining the extent of soils of concern or you know better site characterization. So these two aspects, a management decision was taken, right.

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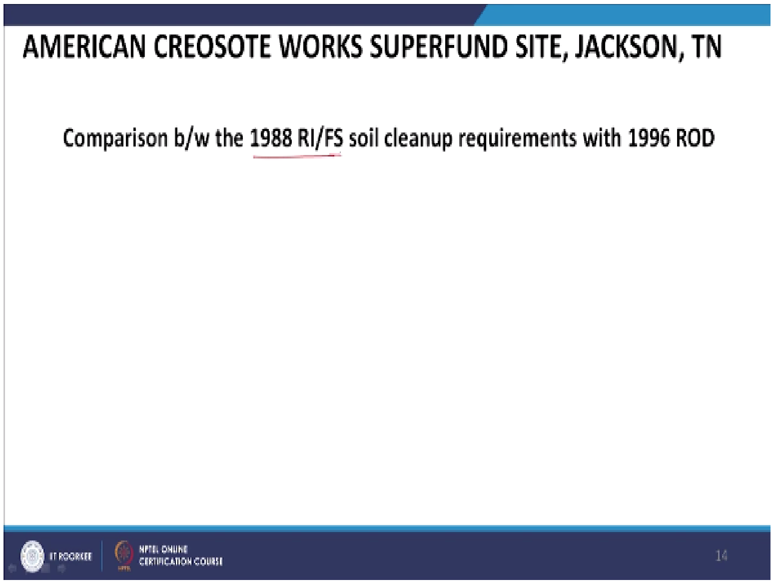

And let us look at what else we have. So comparison between the 1988 Remedial Investigation and Feasibility Study with 1996 Record of Decision let us say, right.

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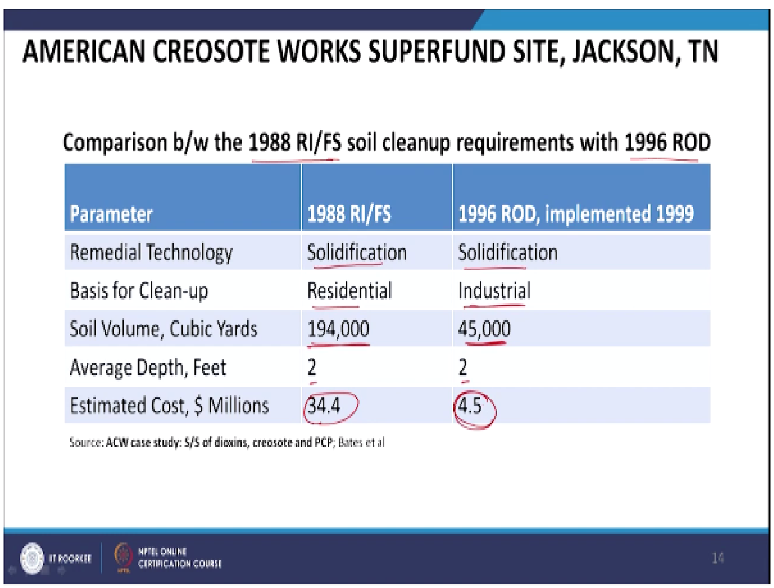

Parameter	1988 RI/FS	1996 ROD, implemented 1999
Remedial Technology	Solidification	Solidification
Basis for Clean-up	Residential	Industrial
Soil Volume, Cubic Yards	194,000	45,000
Average Depth, Feet	2	2
Estimated Cost, $ Millions	34.4	4.5

So here Remedial Technology Solidification and again solidification was considered. Initially they thought residential but finally it was decided to be industrial. And initially it was thought to be this volume of 2 lakh what do we say Cubic Yards but finally they decided on 45,000. Average Depth, yes they let it be at 2 feet, right and Estimated cost from 34.4 now they end up with 4.5 obviously, right this is something that to keep in mind.

And again if you remember this particular was the lowest among all the other alternatives considering let us say other than the one except for monitoring I guess, right, for closing the site and monitoring. So this was one that was lowest and now they obviously bird down feather by decreasing the quantum of the soil that needs to be treated, right. So that is something to keep in mind.

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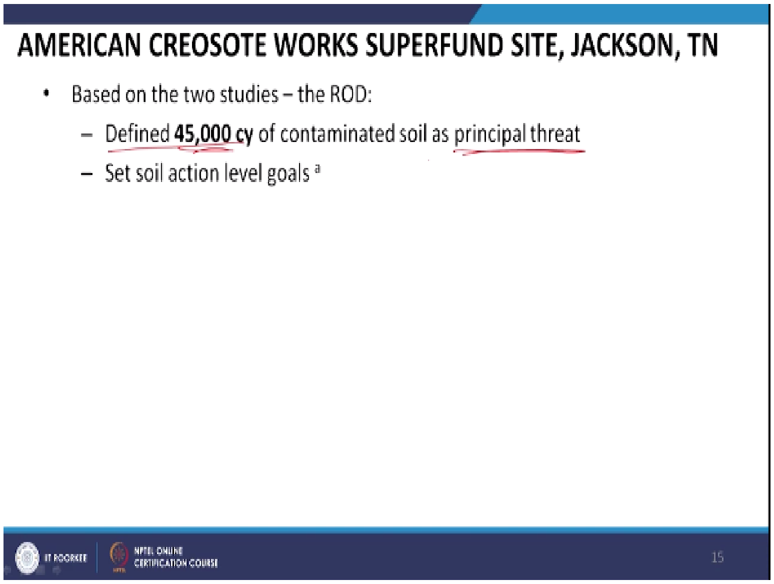

And what else do we have here? So based on the two studies the ROD let us say, defined this particular what do we say contaminated soil to be the principal threat as in you know you still have some contaminated soil other than this 45,000 cubic yards but that was again due to different factors probably the cost let us say and relatively less risk pose to the relevant populations or estimated population let us say due to that particular level of concentration, right. And also action level goals.

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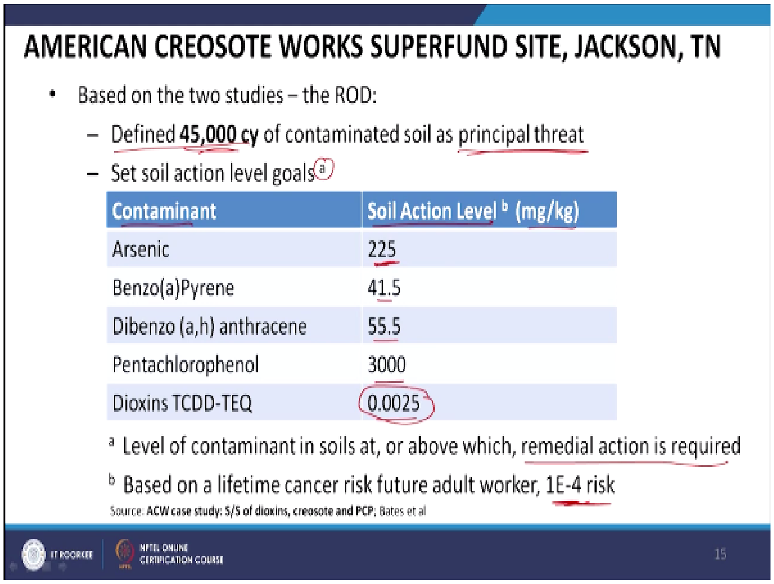

So here the Contaminant action level as in this is the level of contaminated soil set for which remedial action is required right. This is a out here and b is based on the Lifetime Cancer Risk future adult worker, and the risk is 10 power -4, right. So set action level goals, right and action level b based on this particular case. They want to bring it down to 225 milligram per kg of soil, milligram of Arsenic to per kg or soil and Benzo Pyrene, Dibenzo anthracen, Pentachlorophenol and different Dioxins.

Obviously, as I mentioned earlier Dioxins are remarkably carcinogenic or pretty important. And obviously, you see that there is the reason one of the reason why they want to bring down the concentrations here. Again, these are the action levels for these goals that they want to that they set based upon risk of 10 power -4, right. Carcinogenic risk obviously, right. So let us move on.

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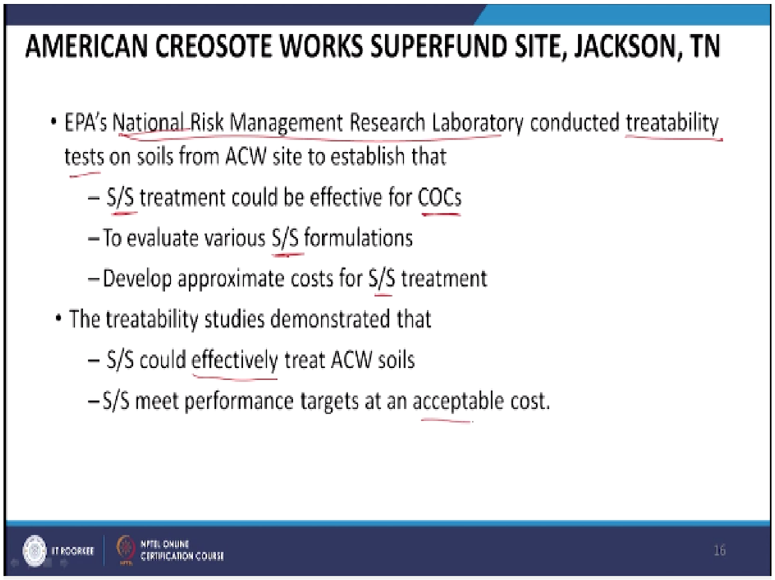

So EPA's National Risk Management Research Laboratory conducted the laboratory test or the bench scale test or the treatability test as they are calling it. To establish that solidification and stabilization treatment can be effective for these contaminated concerns, right. And also evaluate the different formulation as in different binders were looked at let us say, right, different add mixtures and so on.

And then they evaluate the approximate cost again for the solidification/stabilization, right. And the treatability studies demonstrated that, obviously it is effective and that the cost were within remedial, right. So obviously initial estimates and then you based on these initial estimates and different factors minor modifications and they brought it down as in the volume of soil to be treated and so on and so forth and then bench scales studies were done.

And then again is that feasible again or to what extent our prior assumption relevant or so on and that is worked out. And we see that now it is within reasonable cost let us say, right.

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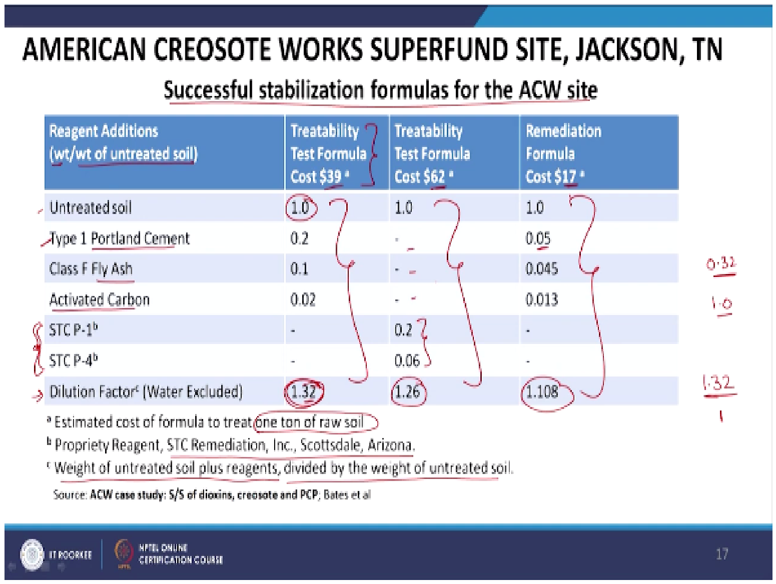

AMERICAN CREOSOTE WORKS SUPERFUND SITE, JACKSON, TN

Successful stabilization formulas for the ACW site

Reagent Additions (wt/wt of untreated soil)	Treatability Test Formula Cost $39 [a]	Treatability Test Formula Cost $62 [a]	Remediation Formula Cost $17 [a]
Untreated soil	1.0	1.0	1.0
Type 1 Portland Cement	0.2	-	0.05
Class F Fly Ash	0.1	-	0.045
Activated Carbon	0.02	-	0.013
STC P-1[b]	-	0.2	-
STC P-4[b]	-	0.06	-
Dilution Factor[c] (Water Excluded)	1.32	1.26	1.108

[a] Estimated cost of formula to treat one ton of raw soil
[b] Propriety Reagent, STC Remediation, Inc., Scottsdale, Arizona.
[c] Weight of untreated soil plus reagents, divided by the weight of untreated soil.

Source: ACW case study: S/S of dioxins, creosote and PCP; Bates et al

And here we have successful stabilization formulas for the different you know, for this particular site, right. So these are the different Reagent Additions; Weight of the Reagent added after addition of reagent to weight of untreated soil let us say, right. So Treatability Test Formula, you know different cost 39 to treat one ton of soil, to treat one ton of soil, this is the what do we say cost that is required let us say for this treatability test formula different types of formulas that we have here.

As in with just untreated soil. Portland Cement, the ratio to the untreated soil is 2 to obviously 0.2/1 so they; what are the different binders that they consider now, and what are the different ratios that they consider, different binders were Portland Cement, Fly Ash they also consider Activated Carbon.

So it is seems they also use some proprietary reagents, right from this particular relevant company right they use proprietary reagents probably to enhance either maybe the degradation of these toxins or you know the binding properties of these particular binders let us say. And then Dilution Factor, right excluding water let us say which is weight of untreated soil plus reagents divided by the weight of the untreated soil.

So this, do you see an idea above, total amount of binder that obviously need to be put in let us see. So here it is 0.32 is the amount of your binders and the other 8 you are putting in and one is obviously the weight of your solid right. So that is what we this means now 1.32 is a total weight of your particular binders, add mixtures and soil and one is the weight of your particular untreated soil, right these are the different fashions. And they looked at different cost obviously, right.

So let us just try to analyze this particular aspect then this case obviously you see the cement is relatively what we say lesser fraction compare to this particular case, right, and that is how they look at it. Obviously you know when they consider the case when they use the proprietary reagents, right you have cost to be considerable even though the cement and fly ash is negligible right that is something else. So let us look at what they ended up with though, right.

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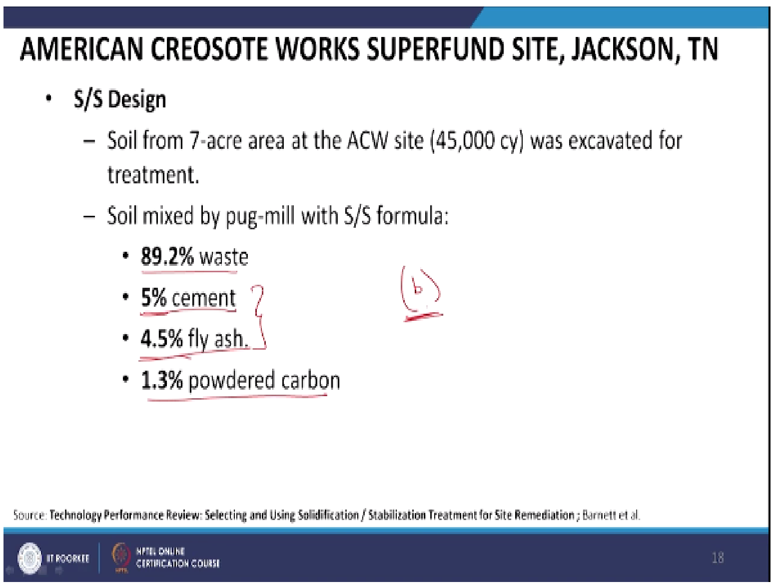

So Soil from 7-acre was excavated for treatment, right we are aware of, and now they ended up with this particular case where they use waste, cement, fly ash and powdered carbon. So let us look at what that is probably waste, cement and powdered carbon probably in this ratio but we need to check those out. So they did not choose this. They choose either particular this option or this option, right.

So we can check the relevant cases based on the fraction of this particular Portland Cement to Fly Ash. Here it is doubled and it is more or less the same. So let us see which option they chose. So it is 5% same, so obviously they chose the (b) one I guess, right. The one with the least cost, right that is something to keep in mind. Obviously, we had you know the relevant laboratory looked at three aspects one with different fractions of fly ash, cement and so on but the differential fact was that the cost was higher for one and lesser for the other.

And there was another aspect where they looked at what do we say binders from let us say or proprietary binders let us say from a particular company. And again the cost was high though, right. So they chose that particular one which was relatively cheaper now. And again we are going to continue this but, you know looks like I am out of time so we will continue this in the next session.

But what we have looked at so far is you know, where we have less a logical what do we say process of decision-making. Initial Site Investigation, right and then based on that what needs to be done was decide on the Record of Decisions and then the bench scale studies, right where they again evaluated different metrics, right which is what we just looked at. And then choosing one particular matrix and then implementing that, right. But again, we are going to continue this in the next session, and thank you for now.