Environmental Remediation of Contaminated Sites

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Lecture 02
Introduction Part II

Hello everyone, welcome back to the latest lecture session. Our course is obviously dealing with remediation of contaminated sites, so in this context we were summarizing a case study or 2, so that it would help you come to a decision as to whether to take the course. So in this context, we looked at a brief example of a chromium contaminated site in India where primarily the contamination was ground water contamination and there was limited data in that context.

And then we moved on to a case study where we have a landfill that is leading to contamination of soil, ground water and a few surface water streams and thus there were some affected areas. So again in today's session we are going to finish understanding that particular aspect, as in with respect to remediation of that particular landfill, what are the issues caused due to that particular leachate from that landfill reaching the ground water and surface water.

We are going to look at some of the remedial alternatives and then how did they go about choosing that particular alternative and so on. During our course we are going to look at the technical aspects involved with understanding each of those alternatives.

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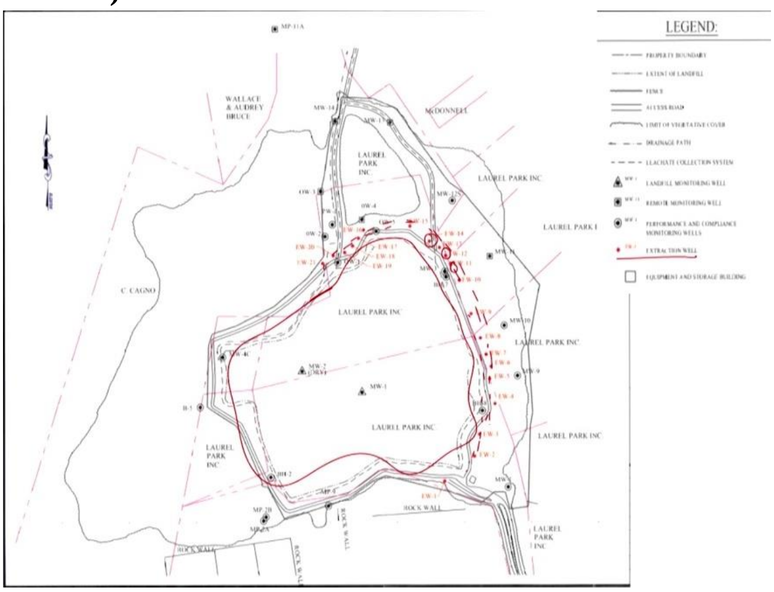

So again let us jump back to where we are; here we looked at this particular figure last time and here we have 2 particular landfills, the major one being here and this was on a hillock.

And as I mentioned, the alternative that was finally chosen was having a ring of extraction wells, pumping out the particular leachate, and then treating that particular leachate offsite, is I believe the option that was chosen, but we are going look at how the decision was made. So that's what we are going to obviously look at. As you can see the extraction wells do not ring the entire perimeter of the leachate; but in a particular site that obviously depends upon site characteristics and transport of the leachate and so on beneath the surface of the soil.

Anyway the different aspects: again a quick recap; and we have been looking at different aspects her. The major aspect being hazard identification, we identified the relevant toxic compounds, we then identified the relevant pathways and we then looked at how toxic is each of this compound that we identified, let us say it is carcinogen, non carcinogen, toxic compound and so on so forth.

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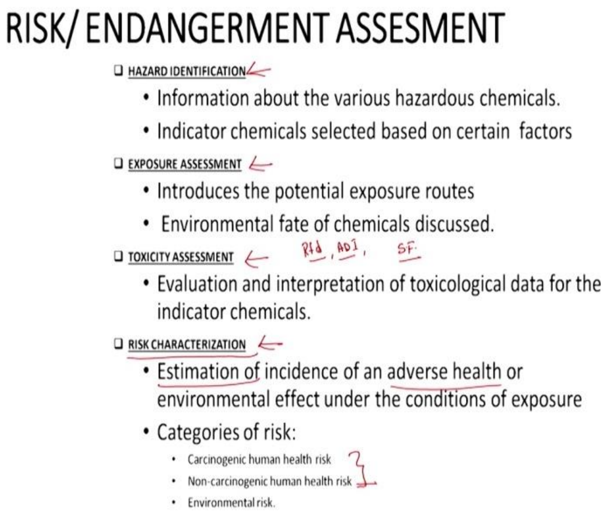

We have relevant data here usually; reference doses or acceptable daily intake levels for non-carcinogens and for carcinogens we have something called slope factor. We are going to look at these aspects in greater detail too.

As in why are we going into look at these in greater detail later on during our course ? That is because we need to understand that it is an exact science yes, I guess, sometimes I wouldn't call it art but it is certainly not an exact science because there are considerable uncertainties involved, especially with trying to come up with risk characterisation. So now we are going to try to put down a number that would estimate or give an idea about let us say the risks that particular contaminated site poses, to either your human population or to the environment or the ecologically sensitive areas out there.

So in that context obviously we look at carcinogenic and non carcinogenic risks. And usually all these we call the toxic compounds and then we obviously look at environmental risks or ecological risk. Ecological risk assessment is much more comprehensive. So during the course of our semester we are going to limit ourselves to only the human health risk assessment which is carcinogenic human health risk and non-carcinogenic human health risk.

So now let us apply this to our particular site so what do I have here, I have a plethora of information out here, but let us not be blown away. So what are we dealing with? We are trying to identify the relevant hazards and in this particular table you know these are the various compounds that were identified from different monitoring wells in the location of or in the vicinity of that particular landfill.

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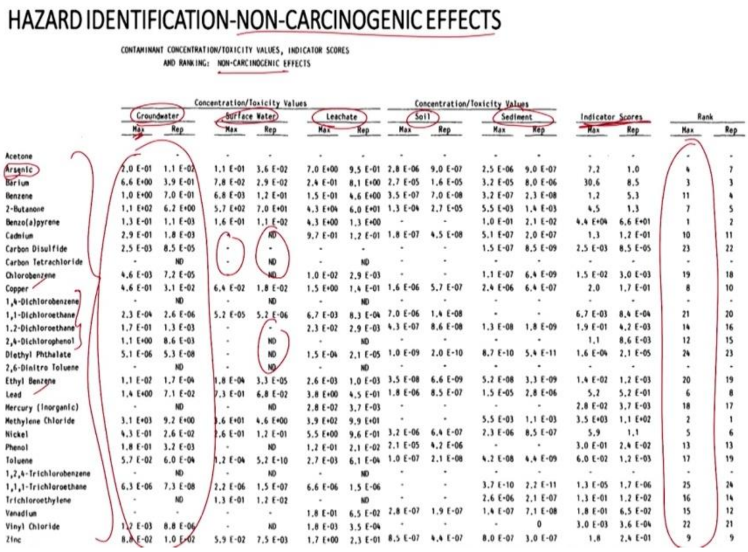
HAZARD IDENTIFICATION-NON-CARCINOGENIC EFFECTS

CONTAMINANT CONCENTRATION/TOXICITY VALUES, INDICATOR SCORES AND RANKING: NON-CARCINOGENIC EFFECTS

	Concentration/Toxicity Values						Concentration/Toxicity Values							
	Groundwater		Surface Water		Leachate		Soil		Sediment		Indicator Scores		Rank	
	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep
Acetone	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic	2.0 E-01	1.1 E-02	1.1 E-01	3.6 E-02	7.0 E+00	9.5 E-01	2.8 E-06	9.0 E-07	2.5 E-06	9.0 E-07	7.2	1.0	4	7
Barium	6.6 E+00	3.9 E-01	7.8 E-02	2.9 E-02	2.4 E-01	8.1 E+00	2.7 E-05	1.6 E-05	3.2 E-05	8.0 E-06	30.6	8.5	3	3
Benzene	1.0 E+00	7.0 E-01	6.8 E-03	1.2 E-01	1.5 E-01	4.6 E+00	3.5 E-07	7.0 E-08	3.2 E-07	2.3 E-08	1.2	5.3	11	4
2-Butanone	1.1 E+02	6.2 E+00	5.7 E+02	7.0 E+01	4.3 E+04	6.0 E+01	1.3 E-04	2.7 E-05	5.5 E-03	1.4 E-03	4.5	1.3	7	5
Benzo(a)pyrene	1.3 E-01	1.1 E-03	1.6 E-01	1.1 E-02	4.3 E+00	1.3 E+00	-	-	1.0 E-01	2.1 E-02	4.4 E+04	6.6 E+01	1	2
Cadmium	2.9 E-01	1.8 E-03	-	ND	9.7 E-01	1.2 E-01	1.8 E-07	4.5 E-08	5.1 E-07	2.0 E-07	1.3	1.2 E-01	10	11
Carbon Disulfide	2.5 E-03	8.5 E-05	-	-	-	-	-	-	1.5 E-07	8.5 E-09	2.5 E-03	8.5 E-05	23	22
Carbon Tetrachloride	-	ND	-	ND	-	ND	-	-	-	-	-	-	-	-
Chlorobenzene	4.6 E-03	7.2 E-05	-	ND	1.0 E-02	2.9 E-03	-	-	1.1 E-07	6.4 E-09	1.5 E-02	3.0 E-03	19	18
Copper	4.6 E-01	3.1 E-02	6.4 E-02	1.8 E-02	1.5 E+00	1.4 E-01	1.6 E-06	5.7 E-07	2.4 E-06	6.4 E-07	2.0	1.7 E-01	8	10
1,4-Dichlorobenzene	-	ND	-	ND	-	ND	-	-	-	-	-	-	-	-
1,1-Dichloroethane	2.3 E-04	2.6 E-06	5.2 E-05	5.2 E-06	6.7 E-03	8.3 E-04	7.0 E-06	1.4 E-08	-	-	6.7 E-03	8.4 E-04	21	20
1.2-Dichloroethane	1.7 E-01	1.3 E-03	-	-	2.3 E-02	2.9 E-03	4.3 E-07	8.6 E-08	1.3 E-08	1.8 E-09	1.9 E-01	4.2 E-03	14	16
2,4-Dichlorophenol	1.1 E+00	8.6 E-03	-	ND	-	ND	-	-	-	-	1.1	8.6 E-03	12	15
Diethyl Phthalate	5.1 E-06	5.3 E-08	-	ND	1.5 E-04	2.1 E-05	1.0 E-09	2.0 E-10	8.7 E-10	5.4 E-11	1.6 E-04	2.1 E-05	24	23
2,6-Dinitro Toluene	-	ND	-	ND	-	ND	-	-	-	-	-	-	-	-
Ethyl Benzene	1.1 E-02	1.7 E-04	1.8 E-04	3.3 E-05	2.6 E-03	1.0 E-03	3.5 E-08	6.6 E-09	5.2 E-08	3.3 E-09	1.4 E-02	1.2 E-03	20	19
Lead	1.4 E+00	7.1 E-02	7.3 E-01	6.8 E-02	3.8 E+00	4.5 E-01	1.8 E-06	8.5 E-07	1.5 E-05	2.8 E-06	5.2	5.2 E-01	6	8
Mercury (Inorganic)	-	ND	-	ND	2.8 E-02	3.7 E-03	-	-	-	-	2.8 E-02	3.7 E-03	18	17
Methylene Chloride	3.1 E+03	9.2 E+00	[illegible].6 E+01	4.6 E+00	3.9 E+02	9.9 E+01	-	-	5.5 E-03	1.1 E-03	3.5 E+03	1.1 E+02	2	1
Nickel	4.3 E-01	2.6 E-02	[illegible].6 E-01	1.2 E-01	5.5 E+00	9.6 E-01	3.2 E-06	6.4 E-07	2.3 E-06	8.5 E-07	5.9	1.1	5	6
Phenol	1.8 E-01	3.2 E-03	-	ND	1.2 E-01	2.1 E-02	2.1 E-05	4.2 E-06	-	-	3.0 E-01	2.4 E-02	13	13
Toluene	5.7 E-02	6.0 E-04	1.2 E-04	5.2 E-10	2.7 E-03	6.1 E-04	1.0 E-07	2.1 E-08	4.2 E-08	4.4 E-09	6.0 E-02	1.2 E-03	17	19
1,2,4-Trichlorobenzene	-	ND	-	ND	-	ND	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane	6.3 E-06	7.3 E-08	2.2 E-06	1.5 E-07	6.6 E-06	1.5 E-06	-	-	3.7 E-10	2.2 E-11	1.3 E-05	1.7 E-06	25	24
Trichloroethylene	-	ND	1.3 E-01	1.2 E-02	-	ND	-	-	2.6 E-06	2.1 E-07	1.3 E-01	1.2 E-02	16	14
Vanadium	-	-	-	-	1.8 E-01	6.5 E-02	2.8 E-07	1.9 E-07	1.4 E-07	7.1 E-08	1.8 E-01	6.5 E-02	15	12
Vinyl Chloride	1.2 E-03	8.8 E-06	-	ND	1.8 E-03	3.5 E-04	-	-	-	0	3.0 E-03	3.6 E-04	22	21
Zinc	8.[illegible] E-02	1.0 E-02	5.9 E-02	7.5 E-03	1.7 E+00	2.3 E-01	8.5 E-07	4.4 E-07	8.0 E-07	3.0 E-07	1.8	2.4 E-01	9	9

And obviously if we look closer or look at this data closely you see that it is limited to the potential carcinogens right. Here we are looking at potential carcinogens and they come up with ranking and indicator scores; and why do we need to come up with ranking and indicator scores? Because we are going to look at which particular compounds are we going to pay more attention to or such right.

So obviously that is going to be dependent upon let us say factors like how toxic or how carcinogenic is the compound; usually if it is a carcinogenic, people do to take that into

consideration for remedial action and what is the frequency of detection and what is the level of detection or what is the concentration at which the compound is detected and so on.
So here I guess they have again different compounds and a few heavy metals and so on here right. Yes and the other compounds too here: 1,2 DCA again right.

Trichlorophenol and such chlorinated organics; so in general we see quite a few heavy metals and then chlorinated organics right. And then what do we see here? We see the different pathways, usually ground water, surface water, and in the leachate. They analysed the concentration, they looked at the maximum and average values for the different pathways right.

And again similarly for soils and sediments, and then based upon a ranking matrix let us say or their own weightage that they gave to different compounds, again we are not going into that in great detail at this stage. They came up with indicators scores for these compounds right. For both the maximum, or the worst case scenario and the average case. And then they ranked the compounds, 1 being of the greatest concern. I guess again that was hazard identification and then potential carcinogens. So obviously if we considered carcinogens right, we are also going to look at non-carcinogens or the toxic compounds.

And obviously again the same case, we are going to look at non-carcinogens right and here we have let us say again different compounds depending upon their mode of ingestion or exposure and level of concentration can have both toxic effects and also carcinogenic effects, right and one example is arsenic; it has both carcinogenic effects and also toxic or non-carcinogenic effects too.

And again you have various other such heavy metals so on and again chlorinated organics too I guess right. So what do we have, same case, we have different pathways right and then they come up with the concentrations, the average and the maximum concentration in each of these pathways so obviously as you see the remediation of any contaminated site is a resource intensive job; as in right now as you see a lot of data is required and for that obviously you need lot of resources right.

So, it is again resource intensive so obviously we would always try to look for or try to promote measures that would stop such spills; or thus obviously if the relevant people who manage the landfill paid greater attention at the time of laying the landfill and maybe if they had impermeable layer or impermeable liner beneath the landfill and a particular leachate collection system, so this level of resources and expenditure probably would not have been required at a later stage. Again this is where we are. So concentrations are looked at and different pathways are looked at and in some of them obviously it is not detected right. And then based on these indicator scores and then again we rank the different compounds right depending upon let us say various factors. And again keep in mind that various countries or various states have their own ways at giving different weightages.

But usually it is again as I mentioned the level of toxicity or, you know if it is a carcinogen, obviously they will consider it in general anyway, level of detection, level of frequency of occurrence right.

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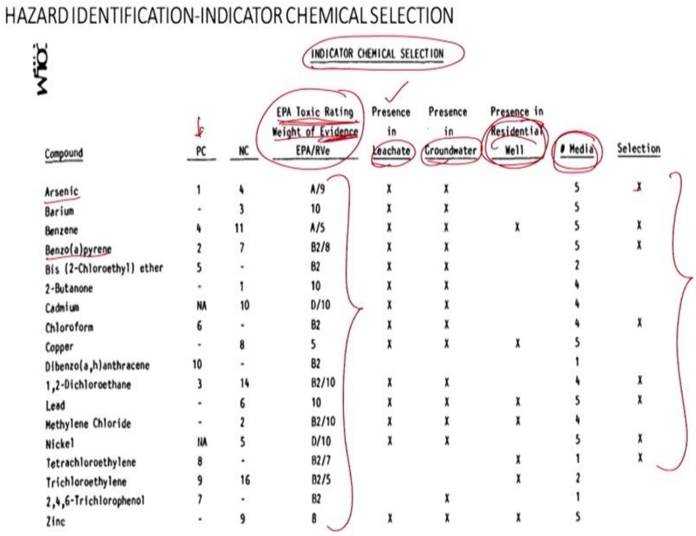
HAZARD IDENTIFICATION-INDICATOR CHEMICAL SELECTION

INDICATOR CHEMICAL SELECTION

Compound	PC	NC	EPA Toxic Rating Weight of Evidence EPA/RVe	Presence in Leachate	Presence in Groundwater	Presence in Residential Well	# Media	Selection
Arsenic	1	4	A/9	X	X		5	X
Barium	-	3	10	X	X		5	
Benzene	4	11	A/5	X	X	X	5	X
Benzo(a)pyrene	2	7	B2/8	X	X		5	X
Bis (2-Chloroethyl) ether	5	-	B2	X	X		2	
2-Butanone	-	1	10	X	X		4	
Cadmium	NA	10	D/10	X	X		4	
Chloroform	6	-	B2	X	X		4	X
Copper	-	8	5	X	X	X	5	
Dibenzo(a,h)anthracene	10	-	B2				1	
1,2-Dichloroethane	3	14	B2/10	X	X		4	X
Lead	-	6	10	X	X	X	5	X
Methylene Chloride	-	2	B2/10	X	X	X	4	
Nickel	NA	5	D/10	X	X		5	X
Tetrachloroethylene	8	-	B2/7			X	1	X
Trichloroethylene	9	16	B2/5			X	2	
2,4,6-Trichlorophenol	7	-	B2		X		1	
Zinc	-	9	8	X	X	X	5	

So, again moving forth, we are looking at hazard identification right. And then what else have they looked at? They have looked at the EPA toxic rating, based on the weight of evidence.

Weight of evidence as in, how do we know whether a compound is toxic or carcinogenic? We conduct tests on this laboratory animals right and then come up with what is the response or the adverse effect that was noticed due to the particular dose, as in hair fall after dosage of 1 milligram per kg of body weight. I guess these are very random values, but I am just giving you the example for the purpose of visualization.

So obviously you know you will have uncertainties out there so there are different levels of evidence out there right. As you see out here and you know some might require further testing and some might have insufficient data and so on. So, again this aspect was considered.

And what else have they considered for screening those relatively long list of chemicals? They looked at what is the presence, if it is present in leachate, its presence in ground water, its presence in, more importantly, the residential wells and then the number of media that it was present.

So considering these factors they came up with a few of these compounds being chosen; let us say arsenic and so on. So they did not obviously choose all the compounds, they looked at the indicator compounds, if I can so call them. So obviously what did they look at? Some of the rankings that they looked at earlier here from the previous case, the EPA weight of evidence and its presence in different media or pathways and also the number of media and they chose that. I think we have a list here:

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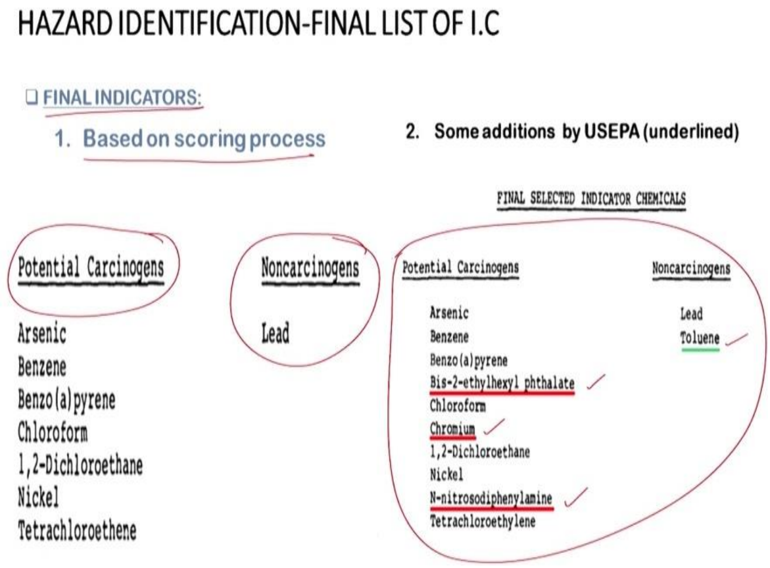

So here we have the final indicators. So based on the scoring process, they chose carcinogens and a few non-carcinogens or 1 non-carcinogen. So this is what they studied throughout. And then what did EPA or US EPA suggest? Again EPA is the environmental protection agency and so they suggested adding a few more compounds, and here they have the final list of compounds that they need to consider for relevant action or for risk assessment.

I am just giving a brief idea about how things work. And then obviously we need to look at exposure routes and characterization of human exposure points. So exposure routes as in, what particular path or what pathways are leading to transport of this particular contaminant. So what do we have here. We have ground water, surface water and sediment, air and soil.

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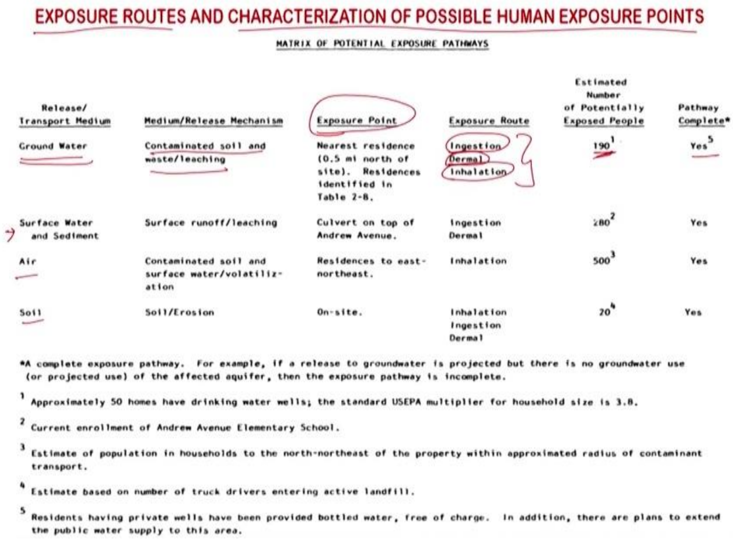

EXPOSURE ROUTES AND CHARACTERIZATION OF POSSIBLE HUMAN EXPOSURE POINTS

MATRIX OF POTENTIAL EXPOSURE PATHWAYS

Release/ Transport Medium	Medium/Release Mechanism	Exposure Point	Exposure Route	Estimated Number of Potentially Exposed People	Pathway Complete*
Ground Water	Contaminated soil and waste/leaching	Nearest residence (0.5 mi north of site). Residences identified in Table 2-8.	Ingestion Dermal Inhalation	190[1]	Yes[5]
Surface Water and Sediment	Surface runoff/leaching	Culvert on top of Andrew Avenue.	Ingestion Dermal	≈80[2]	Yes
Air	Contaminated soil and surface water/volatilization	Residences to east-northeast.	Inhalation	500[3]	Yes
Soil	Soil/Erosion	On-site.	Inhalation Ingestion Dermal	20[4]	Yes

*A complete exposure pathway. For example, if a release to groundwater is projected but there is no groundwater use (or projected use) of the affected aquifer, then the exposure pathway is incomplete.

[1] Approximately 50 homes have drinking water wells; the standard USEPA multiplier for household size is 3.8.

[2] Current enrollment of Andrew Avenue Elementary School.

[3] Estimate of population in households to the north-northeast of the property within approximated radius of contaminant transport.

[4] Estimate based on number of truck drivers entering active landfill.

[5] Residents having private wells have been provided bottled water, free of charge. In addition, there are plans to extend the public water supply to this area.

And how can it go? For example, one example is that contaminated soil and waste leaching, so here the contaminated soil or the waste leachates through to the ground water, we have contamination of the groundwater and so on. Then what next, we have the exposure point here; how are the humans being exposed or where though, what is the exposure route, for example, ground water ingestion as in they drink the water.

Dermal, as in they are going to bathe with this particular ground water that is pumped out, so dermal contact or contact through the skin and then absorption through the skin, that is one point of way and then inhalation, let us say cooking with this particular ground water or coming in contact with the relevant compound depending upon how volatile it is, you know chang in phase from water to the gaseous phase, and then I can breathe the relevant compound and thus be affected by it.

So in this context, let us say, ground water, we looked at few aspects I guess exposure points and ingestion route as in I drink the water, if I bathe with it, let us say my skin comes in contact and my skin can absorb the relevant compound and through inhalation. Again, for different compounds, let us say, for if I take the case of skin contact or dermal contact, so not all compounds will be taken in (absorbed) at the same rate, so obviously I am going to look at those relevant standard values too, they are relatively available.

So estimated number of people that are exposed and is the pathway complete or are there any missing links in the transport chain. So based on this I am trying to characterize the exposure routes.

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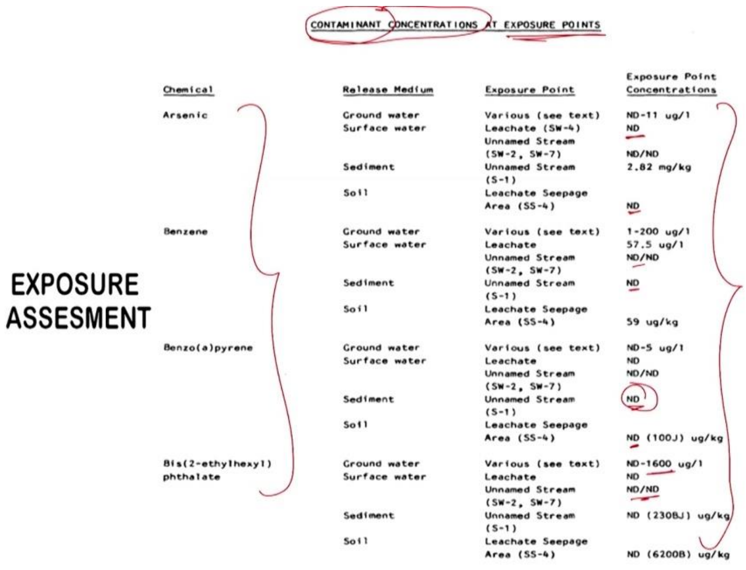

EXPOSURE ASSESMENT

CONTAMINANT CONCENTRATIONS AT EXPOSURE POINTS

Chemical	Release Medium	Exposure Point	Exposure Point Concentrations
Arsenic	Ground water	Various (see text)	ND-11 ug/l
	Surface water	Leachate (SW-4)	ND
		Unnamed Stream (SW-2, SW-7)	ND/ND
	Sediment	Unnamed Stream (S-1)	2.82 mg/kg
	Soil	Leachate Seepage Area (SS-4)	ND
Benzene	Ground water	Various (see text)	1-200 ug/l
	Surface water	Leachate	57.5 ug/l
		Unnamed Stream (SW-2, SW-7)	ND/ND
	Sediment	Unnamed Stream (S-1)	ND
	Soil	Leachate Seepage Area (SS-4)	59 ug/kg
Benzo(a)pyrene	Ground water	Various (see text)	ND-5 ug/l
	Surface water	Leachate	ND
		Unnamed Stream (SW-2, SW-7)	ND/ND
	Sediment	Unnamed Stream (S-1)	ND
	Soil	Leachate Seepage Area (SS-4)	ND (100J) ug/kg
Bis(2-ethylhexyl) phthalate	Ground water	Various (see text)	ND-1600 ug/l
	Surface water	Leachate	ND
		Unnamed Stream (SW-2, SW-7)	ND/ND
	Sediment	Unnamed Stream (S-1)	ND (230BJ) ug/kg
	Soil	Leachate Seepage Area (SS-4)	ND (6200B) ug/kg

So once I move on to that, I need to look at what is the concentration at the receptor. So earlier we looked at the concentration in the vicinity of the landfill, now I am going to look at the concentration at the receptor.

Let us say I am the human living in the vicinity, I am the receptor, I am concerned about what the concentration is at my particular point of view is, not what the concentration is at the landfill. So obviously again for the chosen compound, arsenic, benzene and so on, we looked at the exposure point concentration. So obviously if you try to look at or go back to the relevant slides earlier, you see that the concentrations are either low or not detected.

So what does the mean, there has been some attenuation during the pathway as in by the leachate reaching the groundwater and then reaching the receptor which is the human here. So obviously these concentrations at the receptor are lower compared to the concentrations at the landfill I guess right. Again, different cases, exposure points, great level of detail, we are not going to go into that at that level of detail right now. So then obviously I need to characterize the human health risk.

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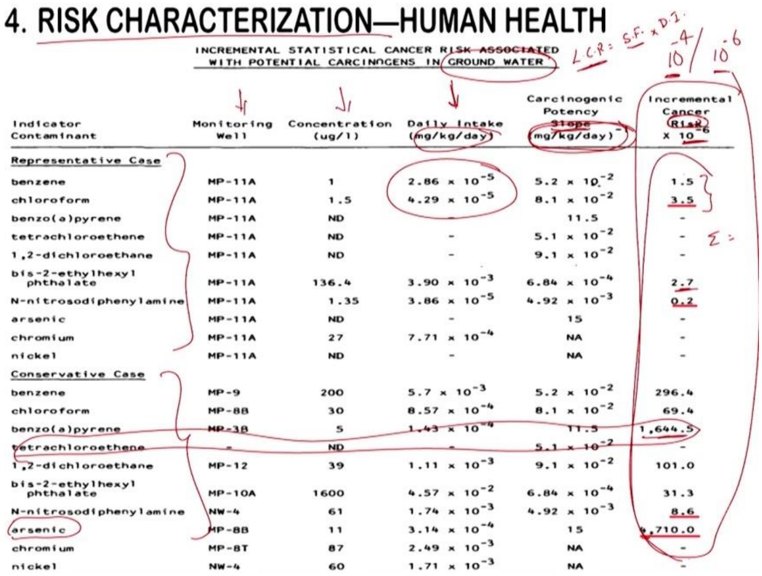

4. RISK CHARACTERIZATION—HUMAN HEALTH

INCREMENTAL STATISTICAL CANCER RISK ASSOCIATED WITH POTENTIAL CARCINOGENS IN GROUND WATER

Indicator Contaminant	Monitoring Well	Concentration (ug/l)	Daily Intake (mg/kg/day)	Carcinogenic Potency Slope (mg/kg/day)$^{-1}$	Incremental Cancer Risk x 10^{-6}
Representative Case					
benzene	MP-11A	1	2.86×10^{-5}	5.2×10^{-2}	1.5
chloroform	MP-11A	1.5	4.29×10^{-5}	8.1×10^{-2}	3.5
benzo(a)pyrene	MP-11A	ND	-	11.5	-
tetrachloroethene	MP-11A	ND	-	5.1×10^{-2}	-
1,2-dichloroethane	MP-11A	ND	-	9.1×10^{-2}	-
bis-2-ethylhexyl phthalate	MP-11A	136.4	3.90×10^{-3}	6.84×10^{-4}	2.7
N-nitrosodiphenylamine	MP-11A	1.35	3.86×10^{-5}	4.92×10^{-3}	0.2
arsenic	MP-11A	ND	-	15	-
chromium	MP-11A	27	7.71×10^{-4}	NA	-
nickel	MP-11A	ND	-	NA	-
Conservative Case					
benzene	MP-9	200	5.7×10^{-3}	5.2×10^{-2}	296.4
chloroform	MP-8B	30	8.57×10^{-4}	8.1×10^{-2}	69.4
benzo(a)pyrene	MP-3B	5	1.43×10^{-4}	11.5	1,644.5
tetrachloroethene	-	ND	-	5.1×10^{-2}	-
1,2-dichloroethane	MP-12	39	1.11×10^{-3}	9.1×10^{-2}	101.0
bis-2-ethylhexyl phthalate	MP-10A	1600	4.57×10^{-2}	6.84×10^{-4}	31.3
N-nitrosodiphenylamine	NW-4	61	1.74×10^{-3}	4.92×10^{-3}	8.6
arsenic	MP-8B	11	3.14×10^{-4}	15	4,710.0
chromium	MP-8T	87	2.49×10^{-3}	NA	-
nickel	NW-4	60	1.71×10^{-3}	NA	-

So obviously from different monitoring wells, what is the concentration for different compounds: representative case and conservative case, again, obviously I need to able to estimate the daily intake; that I can get based on let us say, if it is with respect to ingestion,n let us say, I know the average amount of water that a human consumes. So from that I can come up with daily intake and based on the concentration I can come up with the actual mass of the compound that is being taken in or can be taken in by that particular human exposed to that particular compound I guess.

So obviously you know I have the slope factor here, this is from the standard data and so here I calculate risk * 10^{-6}, usually the thresholds are either 10^{-4} or 10^{-6}. So depending on the agency, if the risk is greater than either 10^{-4} or 10^{-6}, it is deemed to be high enough such that you need to take remedial action. So obviously here they are choosing the threshold I believe to be 10^{-6} and the compounds that have relatively high risk are highlighted out here: tetracholoroethene obviously has very high risk and again I believe it is arsenic.

So here after calculating the risk; risk will give me an idea or what will it take into account, it will take into account the concentration that I am exposed to, the pathway and here, I believe what am I looking at, in ground water; associated with potential carcinogens in ground water. So the pathway, the type of compound and the amount that I am taking in and then it will give me a particular risk.

So as you see now, I can try to have a relative comparison. I can understand let us say which particular compound, that is present in ground water at those relevant levels right, obviously not all compounds are present at the same concentration. So here we have different compounds at different concentrations, different compounds have different levels of carcinogenicity.

So the risk characterization takes that into account and obviously comes up with the incremental cancer risk. As in what is the additional cancer risk that ingestion of this particular ground water would pose to that particular human. So that is what we have here and I guess this is something we are going to look at in detail during our particular course. So again how do I calculate the lifetime cancer risk, obviously we have the slope factor for that particular compound into this daily intake.

As you see, the units they cancel each other out and that is how I come up with lifetime cancer risk and obviously I need to sum up all these risks to understand the cumulative risk posed.

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RISK CHARACTERIZATION HUMAN HEALTH

NON-DRINKING WATER USE

SHOWER WATER

Adult—70kg

200L water---30m³ room vol.

ED---20 mins daily for 70years

POTENTIAL HEALTH RISKS ASSOCIATED WITH VOLATILE ORGANICS IN SHOWER WATER

Indicator Contaminant	Monitoring Well	Concentration (ug/l)	Daily Intake (mg/kg/day)	Carcinogenic Potency Slope* $(mg/kg/day)^{-1}$	Incrementa Cancer Risk $(\times 10^{-6})$
Representative Case					
benzene	MP-11A	1.0	0.00003	2.6×10^{-2}	0.8
chloroform	MP-11A	1.5	0.00004	8.1×10^{-2}	3
1,2-dichloroethane	MP-11A	ND	-	9.1×10^{-2}	-
tetrachloroethene	MP-11A	ND	-	1.7×10^{-3}	-
Conservative Case					
benzene	MP-9	200	0.005	2.6×10^{-2}	130
chloroform	MP-8B	30	0.0008	8.1×10^{-2}	65
1,2-dichloroethane	MP-12	39	0.001	9.1×10^{-2}	91
tetrachloroethene	-	ND	-	1.7×10^{-3}	-
Max. Residential Data					
benzene	W-129	32	0.0008	2.6×10^{-2}	21
chloroform	-	ND	-	8.1×10^{-2}	-
1,2-dichloroethane	-	ND	-	9.1×10^{-2}	-
tetrachloroethene	W-131	187	0.005	1.7×10^{-3}	9

*Carcinogenic potency slopes for inhalation route were adopted for this exposure pathway.

So again here, now I am going to look at non-carcinogens, earlier we looked at carcinogens. We are now considering the case where ground water is again contaminated and I am ingesting that ground water and I am looking at non-carcinogens.

Again concentration, daily intake, and acceptable daily intake or referenced dose and then I am going to calculate the hazard index, sum is , I think Hazard quotient, how do I calculate that, it is daily intake by the referenced dose or the acceptable daily intake. Usually the threshold is 1. If it is greater than 1, if the sum of all the hazard index is greater than 1, that means that I am taking way too much of the toxic compound and I need to look at the relevant remedial measures.

So in general, as you see know though most of the individual risks are relatively low, but there are still risk posed from some particular compounds that can potentially lead to considerable toxic effects. So I guess I did highlight a few of those particular compounds. Obviously the sum will be greater than 1, so obviously I need to, at this stage I can scientifically come to a conclusion that individual compounds too pose unacceptable levels of risk as we can see in this case of ethylhexyl phthalate, which I believe is a plasticizer.

And certainly the sum of all these risks will be greater than 1; that tells me that, alteast for non-carcinogens or from point of view of toxic effects of non-carcinogens, I do need to remediate the site. Again going forth, what do we have, potential risks associated with volatile organics in shower water, a different kind of pathway. I am not going to go to that in detail. So in different pathways, now we see that for now I guess benzene and chloroform and 1,2 DCA, which are relatively volatile, the risks in this particular case, as in shower water with relatively higher temperatures and such are remarkably high, which probably was not the case here as you see in ground water.

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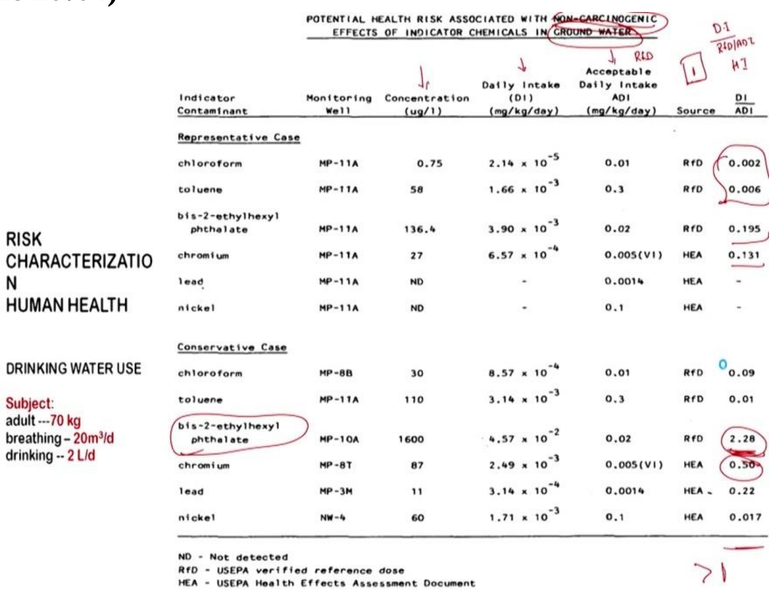

POTENTIAL HEALTH RISK ASSOCIATED WITH NON-CARCINOGENIC EFFECTS OF INDICATOR CHEMICALS IN GROUND WATER

Indicator Contaminant	Monitoring Well	Concentration (ug/l)	Daily Intake (DI) (mg/kg/day)	Acceptable Daily Intake ADI (mg/kg/day)	Source	DI/ADI
Representative Case						
chloroform	MP-11A	0.75	2.14×10^{-5}	0.01	RfD	0.002
toluene	MP-11A	58	1.66×10^{-3}	0.3	RfD	0.006
bis-2-ethylhexyl phthalate	MP-11A	136.4	3.90×10^{-3}	0.02	RfD	0.195
chromium	MP-11A	27	6.57×10^{-4}	0.005(VI)	HEA	0.131
lead	MP-11A	ND	-	0.0014	HEA	-
nickel	MP-11A	ND	-	0.1	HEA	-
Conservative Case						
chloroform	MP-8B	30	8.57×10^{-4}	0.01	RfD	0.09
toluene	MP-11A	110	3.14×10^{-3}	0.3	RfD	0.01
bis-2-ethylhexyl phthalate	MP-10A	1600	4.57×10^{-2}	0.02	RfD	2.28
chromium	MP-8T	87	2.49×10^{-3}	0.005(VI)	HEA	0.50
lead	MP-3M	11	3.14×10^{-4}	0.0014	HEA	0.22
nickel	NW-4	60	1.71×10^{-3}	0.1	HEA	0.017

ND - Not detected
RfD - USEPA verified reference dose
HEA - USEPA Health Effects Assessment Document

As in for chloroform in the conservative case, we see that the risk is around 0.09, but for chloroform in the case of shower water we see that the risk posed is remarkably high. It is incremental cancer risk, I should not compare it with here. So I look at the cancer risk here, chloroform that is standing out to be 69.4 okay, they are comparatively high and are pretty high. This is from the cancer risk and again bath water and so on.

Again what do we have here, we are trying to analyse different pathways, so when I sum up all the risks associated with that pathway, then I will be able to understand or come up with an idea about which pathway, is it through bathing or through shower water contact with my skin that I am exposed to the greatest adverse effects or potential adverse effects or is it through the drinking water.

So again this level of risk characterization and risk assessment will help me understand those aspects now. So moving on, let us say, depending upon the relevant analysis we are going to do during our course, we are then going to come up with different alternatives.

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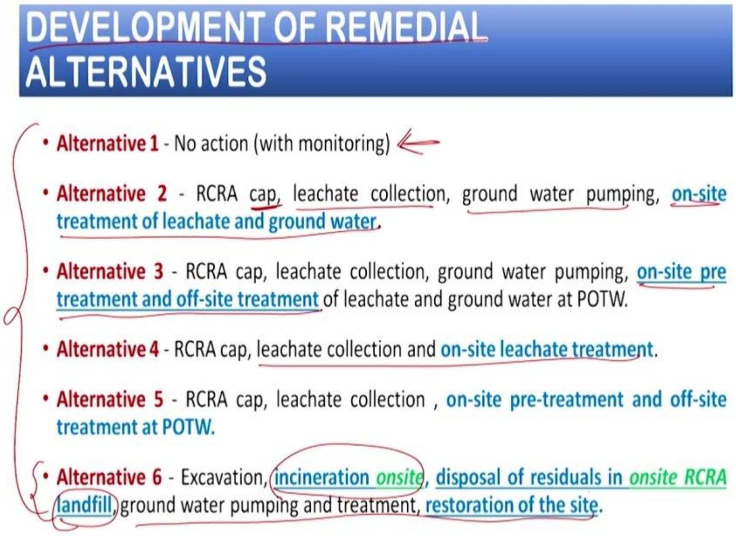

So here obviously we are not going to go into that at that level of detail. So here, one aspect is doing nothing. Let us say if it is a remote location and the risks associated are less, that is one aspect that you can certainly choose, but usually obviously for looking at the no action alternative will let you come up with the relevant costs and risks for relative comparison, right. So that is one aspect. The other one is cap.

A cap on the particular landfill so it will limit formation of the leachate, leachate collection, ground water pumping and onsite treatment of leachate and ground water. Another one is onsite pretreatment and offsite treatment more or less 2 and 3 are in conjunction, again onsite treatment, leachate collection. As you see here, we are coming up with different alternatives more or less they are geared towards pumping the leachate out and then treating it.

Again we are going to look at that in greater detail later on, but the other aspect that is relatively unique is it says that incineration onsite, and disposal of residue onsite in a landfill or hazardous waste landfill and then ground water pumping, treatment and restoration of the site. So here on one hand you have more of the same kind of alternatives which look at more or less pumping out the ground water, having a cap so that the landfill will not be exposed to any rainfall or snow in that particular area and again treating the ground water.

The other one is again incineration of the relevant contaminated soil and then disposal of residual on a landfill, again more costs, and again ground water pumping and so on.
So how do we go about choosing between different alternatives, let us see. Again more alternatives here, we are not going to go through that, major aspects being incineration offsite.

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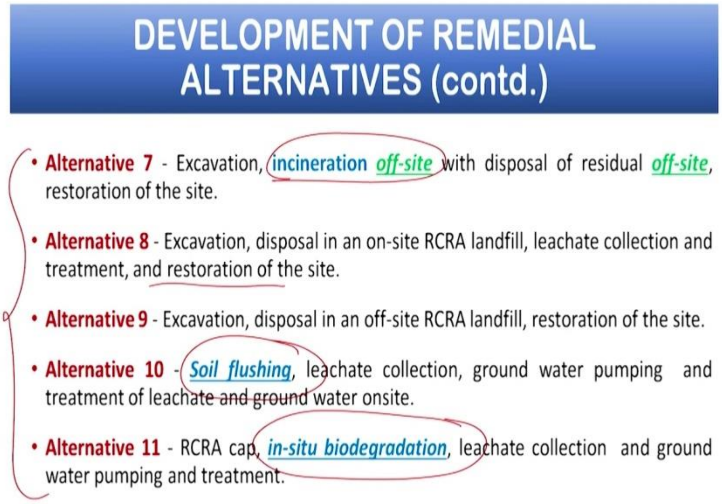

I carry the contaminated soil offsite and then incinerate it. The other one is soil flushing or soil washing if I can call that and the other one is insitu biodegradation similar to what we talked about with respect to the ground water contaminated by chromium in the Ghaziabad case. So major aspects, combination of such aspects are different alternatives.

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REMEDIAL ALTERNATIVES AND APPLICABLE REMEDIAL TECHNOIOGIES

Applicable Remedial Technologies	Remedial Alternatives										
	1	2	3	4	5	6	7	8	9	10	11
Multimedia Capping		X	X	X	X						X
Soil Cover										X	
Onsite and/or offsite ground water pumping		X	X			y				X	X
Leachate Collection		X	X	X	X			X		X	X
Drainage ditches		X	X	X	X			X		X	X
Gas collection systems		X	X	X	X			X			X
Gas ventilation systems		X	X	X	X			X			X
Grading		X	X	X	X	X		X		X	X
Revegetation		X	X	X	X	X		X		X	X
Diversion channels		X	X	X	X			y		X	X

So how do I go about that, obviously I need to look at various factors. So here obviously I am going to look at different cases here, as in all the alternatives are listed here 1 to 11, that is the number of alternatives that we just considered and we are going to look at let us say what are the aspects involved here.

So that we know the amount of resources that we are going to look at or possibly involved and also going to look at the practicality of this particular remedial options in addressing those particular risks. So that is what we see here.

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Applicable Remedial Technologies	Remedial Alternatives										
	1	2	3	4	5	6	7	8	9	10	11
Excavation						X	X	X	X		
Incineration						X	X				
Leachate and water treatment		X		X		X		X		X	X
Odor and Dust Control		X	X	X	X	X	X	X	X	X	X
Insitu Treatment										X	X
Off-site treatment of leachate and ground water			X		X			X			
RCRA landfill						X		X	X		
Additional hydrogeologic investigations			X								
Monitoring	X	X	X	X	X	X	X	X	X	X	X
No action	X										
Public Water Supply	X	X	X	X	X	X	X	X	X	X	X

And then again available remedial technologies, can this particular aspect meet your particular alternative and so on, so we are going to look at that. As you see, odor and dust control will be met by most of the alternatives, insitu treatment will only be met by a few alternatives and so on. Why would you consider insitu or ex-situ or offsite because transportation cost and also potential contamination of the air during excavation and transportation. So again we are not going to go into great detail here, but we are just trying to compare different aspects here with respect to the alternatives.

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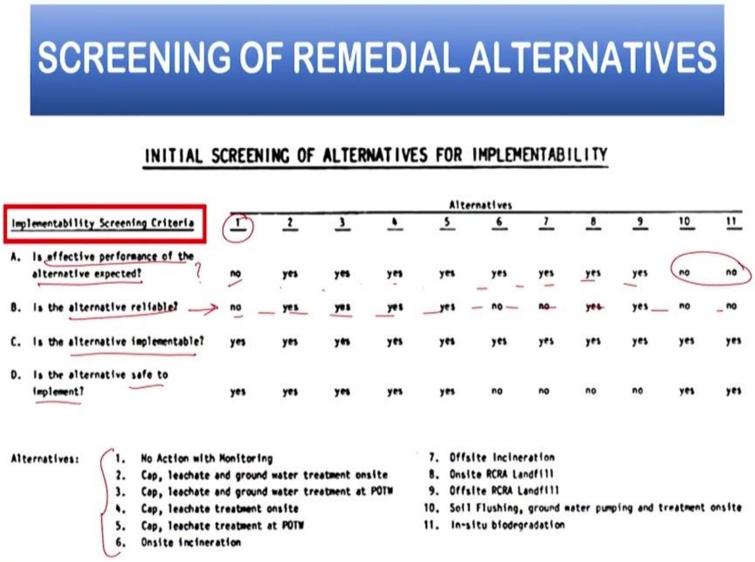

SCREENING OF REMEDIAL ALTERNATIVES

INITIAL SCREENING OF ALTERNATIVES FOR IMPLEMENTABILITY

Implementability Screening Criteria	Alternatives 1	2	3	4	5	6	7	8	9	10	11
A. Is effective performance of the alternative expected?	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no
B. Is the alternative reliable?	no	yes	yes	yes	yes	no	no	yes	yes	no	no
C. Is the alternative implementable?	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
D. Is the alternative safe to implement?	yes	yes	yes	yes	yes	no	no	no	no	yes	yes

Alternatives:
1. No Action with Monitoring
2. Cap, leachate and ground water treatment onsite
3. Cap, leachate and ground water treatment at POTW
4. Cap, leachate treatment onsite
5. Cap, leachate treatment at POTW
6. Onsite incineration
7. Offsite Incineration
8. Onsite RCRA Landfill
9. Offsite RCRA Landfill
10. Soil Flushing, ground water pumping and treatment onsite
11. In-situ biodegradation

So again moving on to implementability of screening criteria, what are they looked at, effective performance of the alternative expected, how effective it is, looks like 1 is no and most of the others are yes and 10 and 11 no.

Is the alternative reliable? Obviously something that you put in should be reliable in long term. So in that context again they looked at different alternatives, the 1 to 11 that we looked at, is it practically implementable depending upon the site conditions out there, is it safe to implement. During the course of remediation I should not lead to further contamination of the site.

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SCREENING OF REMEDIAL ALTERNATIVES

INITIAL SCREENING OF ALTERNATIVES FOR IMPLEMENTABILITY

Implementability Screening Criteria	Alternatives										
	1	2	3	4	5	6	7	8	9	10	11
A. Is effective performance of the alternative expected?	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no
B. Is the alternative reliable?	no	yes	yes	yes	yes	no	no	yes	yes	no	no
C. Is the alternative implementable?	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
D. Is the alternative safe to implement?	yes	yes	yes	yes	yes	no	no	no	no	yes	yes

Alternatives:
1. No Action with Monitoring
2. Cap, leachate and ground water treatment onsite
3. Cap, leachate and ground water treatment at POTW
4. Cap, leachate treatment onsite
5. Cap, leachate treatment at POTW
6. Onsite Incineration
7. Offsite Incineration
8. Onsite RCRA Landfill
9. Offsite RCRA Landfill
10. Soil Flushing, ground water pumping and treatment onsite
11. In-situ biodegradation

So based on these aspects obviously, all the 11 alternatives are again considered.

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INITIAL SCREENING OF ALTERNATIVES FOR EFFECTIVENESS IN ENVIRONMENTAL PROTECTION

Environmental Screening Criteria	Alternatives										
	1	2	3	4	5	6	7	8	9	10	11
A. Will the alternative improve the environmental quality of the following media:											
1. ground water?	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
2. surface water/sediment?	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
3. air?	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
B. Will the alternative cause new airborne emissions (vehicle emissions, particulates, uncontrolled emissions, treatment emissions)?	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
C. Will the alternative cause a new discharge which is detrimental to:											
1. ground water?	no	no	no	no	no	no	no	no	no	no	no
2. surface water?	no	no	no	no	no	no	no	no	no	no	no
D. Will the alternative result in a known or expected significant adverse effect on the environment or human use of environmental resources?	yes	no	no	no	no	no	no	no	no	no	no

Alternatives:
1. No Action with Monitoring
2. Cap, leachate and ground water treatment onsite
3. Cap, leachate and ground water treatment at POTW
4. Cap, leachate treatment onsite
5. Cap, leachate treatment at POTW
6. Onsite Incineration
7. Offsite Incineration
8. Onsite RCRA Landfill
9. Offsite RCRA Landfill
10. Soil Flushing, ground water pumping and treatment onsite
11. In-situ biodegradation

And then obviously the major aspect is the public health screening criteria, alternative minimize or prevent exposure to contaminated ground water, surface water and so on, so they look at or analyze different particular alternatives and again different public health screening criteria.

So obviously what do we need to balance, we need to balance the effectiveness of remediation which is what we see here in the public health screening criteria and also the practical aspects right, so those are the aspects that are looked at but during our course though we are going to look at the technical aspects as in trying to understand can a particular alternative meet the requirements or how effective is it in reaching your remediation goal.

So that is something that we are going to look at. So moving on, now we have with respect to the environment, earlier we had it with respect to the human health and now here we have the screening criteria with respect to the environment, again more such criteria and so on, for example improve the environmental quality of ground water, surface and so on. I am going to skip this.

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SUMMARY OF RESULTS OF INITIAL SCREENING

Remedial Alternative	Passes Public Health Screening	Passes Environmental Screening	Passes Implementability Screening	Included for further Evaluation
1. No Action (with monitoring)	no	no	yes	yes
2. Cap, leachate and ground water treatment onsite	yes	yes	yes	yes
3. Cap, leachate and ground water treatment at POTW	yes	yes	yes	yes
4. Cap, leachate treatment onsite	yes	yes	yes	yes
5. Cap, leachate treatment at POTW	yes	yes	yes	yes
6. Onsite incineration, disposal in an onsite RCRA landfill	yes	yes	yes	yes
7. Incineration and disposal offsite	no	no	no	no
8. Onsite RCRA landfill	no	no	no	no
9. Offsite RCRA landfill	no	no	no	no
10. Soil Flushing, leachate and ground water treatment	no	no	no	no
11. In-situ biodegradation, caps, leachate and ground water treatment	yes	yes	yes	yes

And then what do we come up with, so passes health screening, passes environmental screening and passes implementability screening. Again, practical aspects and human health risk assessment aspects or adverse human health aspects and then environmental screening aspects; so based on that they come up with let us say a few particular alternatives as being considered and a few alternatives are screened out right at this preliminary stage.

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Lifetime = 30 years SUMMARY OF INITIAL COST DATA

Handbook of Remedial Action at Waste Disposal Site. USEPA. 1985

Remedial Alternative	Capital Costs	Annual O&M	Present Worth Discount Rate = 15 %
1. No Action	$ 0	$ 216,000	$ 2,030,000
2. Cap, leachate collection, ground water recovery, onsite treatment	$12,600,000	$ 536,000	$17,600,000
3. Cap leachate collection, ground water recovery, offsite treatment	$13,400,000	$1,210,000	$21,400,000
4. Cap, leachate collection, onsite treatment	$12,000,000	$ 320,000	$15,000,000
5. Cap, leachate collection, offsite treatment	$12,200,000	$ 294,000	$15,000,000
6. Onsite incineration	$60,500,000	$4,040,000	$85,300,000
7. In-situ bio-degradation	$17,300,000	$3,440,000	$49,700,000

Treating

M.W.T.P

So what next? So obviously the resources, that is something that you need to look at and here let us say they have, based upon the 7 alternatives that I have further chosen, they look at capital cost, annual operation and maintenance cost and present worth, that is something we are not going to look at, so obviously you know capital cost are relatively comparable right.

For most of these particular alternatives as you see, but if you are coming to operation and maintenance cost as you see having the cap and collecting the leachate and then onsite treatment of the leachate or the ground water, the costs are relatively low compared to onsite incineration or biodegradation. So annual costs here are almost let us say 10 times higher with respect to 6 and 7 alternatives compared to the alternatives 4 and 5. So here is where let us say the management needs to take a decision.

Here you have costs that are exponentially high, 10 times high is almost infeasibly high, so obviously here we have relatively less invasive techniques in insitu biodegradation I guess. So here they are now going to take a decision based on the relevant effectiveness in addressing the human health risk concerns and then the costs and go forth with choosing an alternative.

To my knowledge they chose number 5; they chose number 5 as in they are going to put a cap over the landfill and then they are going to extract the leachate based upon strategic placement of these extraction wells. As you remember we had the landfill in this shape, I believe and we had extraction wells out here and we also had monitoring wells out here and I am pretty sure near the human receptors too, and so on; extraction wells and then pumping it out and then treating it, and then sending this particular treated effluent to the municipal waste treatment plant again; so they are treating it twice more or less but pretreatment of the particular heavy metals and the chlorinated solvents; and during this course they are going to spend money obviously on providing safe or portable drinking water to the relevant population out there.

So this is how we go about looking at different aspects when it comes to contaminated sites or remediation of contaminated sites. So in this course as I mentioned we are going to look at some aspects in greater detail. So let us look at what they are.

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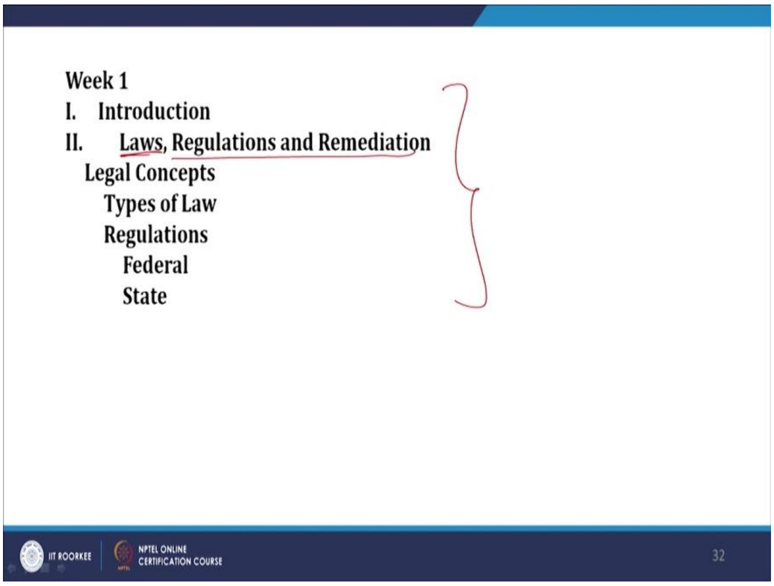

So week 1 or maybe during the final week let us say we are going to look at what are the different laws and regulations in this context. Let's say in our context or the Indian context, maybe we will spend some time on comparing how we fare with respect to the level of regulation that the western countries have, so we are going to look at our particular case mostly. I mean obviously we need to know what are the legal safeguards that are in place.

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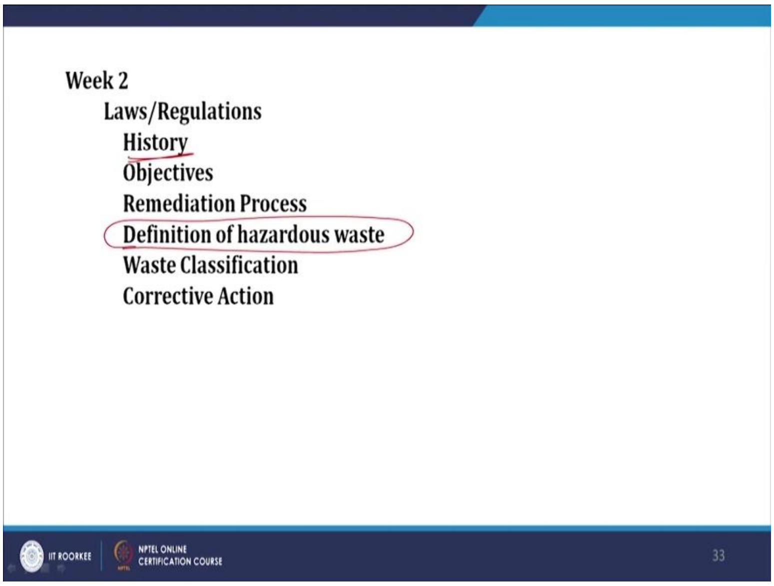

So that is something we are going to spend some time with and then again the relevant aspects with respect to history primarily. And then in this context obviously this is a major aspect we are going to discuss as in, definition of hazardous waste. I mean what is hazardous, how do you classify a compound as hazardous; so that is something that you need to look at; obviously you know you have municipal wastes and you have the hazardous wastes. This is a category by itself that is something we are going to discuss.

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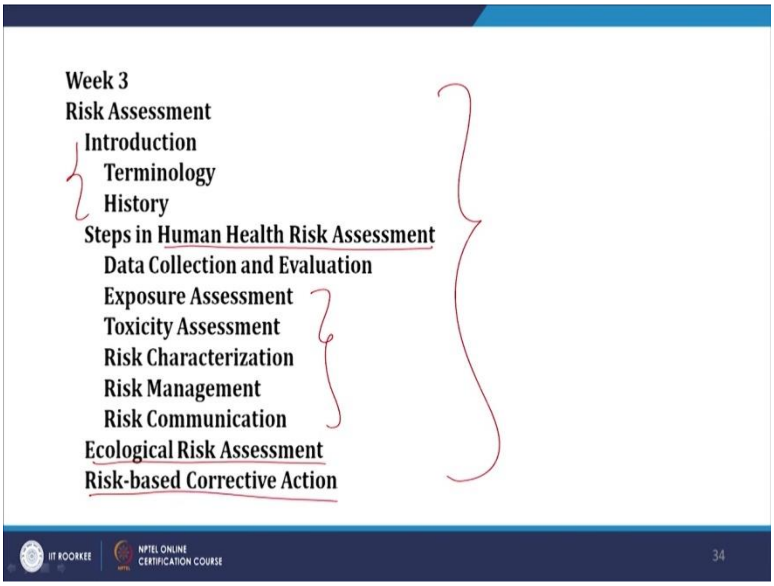

Then we are going to move on to risk assessment right as in introductory aspects and then human health risk assessment, we looked at these aspects in great detail and ecological risk assessment and based on the risk that you calculate you need to take the corrective action. So that is something that again we are going to look at I guess. So I guess due to lack of time I am going to wrap up here and I guess I will start looking at the relevant aspects from the next session while also finishing up the relevant outline, right, so I guess with that I bid adieu and thank you.