Environmental Remediation of Contaminated Sites

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Lecture – 52
Soil Vapor Extraction: Part-II

Hello every one. So welcome back to the latest lecture session. Again, a quick recap of what we have been out to. So in the context of a silent sedimentary me remediation, we looked at different phases, and in those particular case of solve extraction, you are looking at, you know the various zone or let us say the unsaturated zone out there, where we have eight and trapped, and let us see if you have a wall tile compound or hydrophobic compounds.

That is also Walter, let us says you will have contamination of that particular gas rate or the aid and trapped. There are no contamination of the air and trapped and that particular zone. So in that context we looked at soil vapor extraction.

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Soil Vapor Ext.

Yes. So we looked at soil vapor extraction. So in that context we discuss the various aspects as in what are the relevant data, what did we say, aspects that you need to look into that see when you are trying to set up soil vapor extraction, as in we need obviously a source of vacuum. We need a extraction wells to remove or you know, to extract the relevant gas and also you need to have, either an active or passive injection well, you will also need to have monitoring wells.

And you will also need to have a permeable a cap or impermeable cap out there, so we look at those aspects and then moved on to looking at let us see, I believe calculate the total mass, or M total that context we looked at the, what do we say the contaminant present in the water out in the acquiesce phase in the soil, in the gas and then in the NAPL and we looked at relevant aspects but one aspect obviously that we need to consider in those case is the partitioning between the gaseous and acquiesce phase, as in the compound let us say, which is really truly Walter.

Let us say his wall tile. That is, he is in the acquiesce space and you expose that to a lecture, what is going to happen? It is going to change phase and there is going to be an equilibrium between the compound that has changed your face from the water into the gaseous phase, or the compound in the gaseous phase to the, in the acquiesce space and in that context, we looked at something called Henry's constant that has an idea about the concentration in the gaseous phase.

Typically, expressed in terms of the partial pressure times the concentration in the acquiesce phase, this is what we have and depending on the units of h, you can also how concentration in the gaseous phase to the concentration in the acquiesce phase such that hatches dimensionless. And as we mentioned, that is it. Depending on the units of h, you will choose the relevant variables depending upon the relevant variables that you have. You will choose the relevant Henry Scholarship, Lexi. So that is something to look into or consider when we go about it.

So in that context, we were looking at design, so in the context of design. Let us see, what are some of the aspects to consider? So this particular, what is the soil vapor extraction is similar to if I may say so, pump and treat in pump and treat. We tried to estimate the plume size or the contaminant plume size and distribution and then you know, based on the Hallandale at all design more or less an analytical model, let us hear it.

We put up or we decided where to place the relevant wells, as in say this is our particular bloom and this is the source of contamination. Ground water is flowing in this direction and this is the top view, so let us say we decided on, you know, based on having a lot all design, we can choose different, what did we say perturbations, let us say with respect to the number of wells, the spacing between the wells, and so on and so forth.

And we could come up with it. So similarly here we can look at analytical models, but typically it has been a, what do we say? Because of what is it conceivable variation from site to site, let us see, you know, the ability of these models to predict the relevant behavior is a relatively less, let us see, so our has been relatively unsatisfactory. So people typically look at let us say more or less a, what do we see cases based on the site, I guess, so in this context, what do we need to typically look at the site? Let us see.

So based on you putting in your vacuum source of vacuum, you will be able to come up with a radius of influence, the radius of influence, and this radius of influence is defined in different ways, what did this radius of influence? Now, let us say I have my particular extraction well or the vacuum source at this location, as I move further away from it, obviously the effect of this particular vacuum source is going to decrease rate.

So let us tell the side view here, side view, and let us look at that. Let us say this is my soil surface. Let us see. And this is my extraction. Well, let us say, or let us say my vacuum source. So let us see as a move maybe from the pressure let us say is going to be decreasing, so I am going to have to look at a particular threshold. Let us say of the pressure for example, is it 0.1 or so on inches of water? Typically, we measure it in terms of inches of water.

So one set off, what do we see? People define it in terms of either 0.1 or one inch of H2O or inch of water. Let us that is the pressure that the, minimum pressure that you know should exist. Let us head that location for that particular point to be considered within this particular radius of influence as in from this side who have, this is the extraction. Well, what can we see? And this is the radius of influence.

Let us say all this is the radius of influence. We can say that all the points within the zone, let us say experience of pressure or vacuum pressure greater than 0.1 or one inch of H2O. So outside those particular zone, let us say that level of pressure is maintain it here. So that is something to keep in mind and others how mentioned something like you know, either 10% or 1% of pressure at the well for example, you have maintained some pressure out here, x, let us say some people let us say based on their particular definitions of you know, many quite a few people rather than how looked at 10% of x, for the threshold to define the radius of influence.

So different ways to define radius of influence. Yes, so once you define the radius of influence, what do you need to look at? Obviously the placement of the rate. Stacy, typically you look at the, overlapping patterns here, let us say and global did keep in mind that unlike groundwater, let us see here, we do not have this particular trap there, let us say moving him, so it makes the job relatively easier. Let us say to relatively if I miss you.

So at least with respect to the placement of the dots, why is that? Because for the particular case of pump and treat, when you are trying to pump out the ground water, we had to look at the placement of wealth because the radius of influence was something that needed to be taken into mind. Keeping in mind that the groundwater flows because there is a gradient and tells the ground water will flow because you had to take those into account.

So again, then we are going to look at the placement of the relevant routes, so we will look at one example now within a couple of minutes, but we, before we go for them, we will talk about let us say one particular aspect or a couple of aspects as in water. Some of the other enhancements that we can look at. Let us see, I was in, the DNA sparging let us see, what else can you use this in conjunction with. So one aspect I think we talked about briefly was a bio venting.

Let us here, so I thought if you want to increase the, what did we say? Context, let us say, or biodegradation let us say, or biodegradable capacity. Let us see, are the natural attenuation capacity of a particular system. You obviously need to introduce the relevant, what is a nutrient electrons accepted electrons. So sometimes it is say, or quite often rather this particular, soil vapor extraction is used to, let us say, introduced one of these relevant aspects.

Typically, the electron acceptor, which is oxygen, so it is used in conjunction with a, what did we say, relevant aspects to promote biological degradation and tells, you know, we ended up with bio venting in that particular case capture, so the next aspect again that we are going to consider his bio slurping, not something again, used in conjunction with what did we say once a object to let us say, to also remove new NAPL at the same time, what do we have here?

We have bio slurping, and for example, when do we use those? Let us say this is a game, let us say the side view out here, the side view. And this is the groundwater level, let us say. And let us say you have some NAPL out here, and you also have contaminated air out here, and so let us say typically bioslurpee, you also extract the LNAPL let us here late or the less dense or light a non-aqueous liquid along with, you know, pumping out the relevant gas out there, so it can be good done in conjunct and, and That is something That is called a bio slurping itself.

And there are other aspects to, you know, write to typically that can be used to either enhance the effectiveness of this particular, soil vapor extraction. So what is one way to go about it? Let us say you, how this particular soil or sediment that has, you know, this contaminant adsorb do not yet, and if It is very well, tile are highly tell compound. Obviously once you remove the gas that is in contact with this particular soil, what is going to happen?

Again, there is going to be changing phase of the relevant contaminant from being absorbed onto the soil to being, you know, transferred into the gaseous phase. But let us say if it is not greatly while tight and you want to cut down on the time required to remediate Lacey, what is going to be the case here? So again, as we, I am saying, let us say maybe kind take sometimes can play role context of what now kind of takes off changing phase from either the acquiesce to the gas shoes, all from the solid to the gas shows and so on kind takes two plus rolls as in until now.

We have looked at only the equilibrium case, as in the system had, has enough time or is fast enough to reach equilibrium within the relevant timeframes. But let us say time is an issue as in changing the fears is you know also at a rate limiting step. Let us see, what do you need to do to enhance that? Let us say you can, how you can heat it on. The one system lets you write hitting by different means.

Let us say you know; electrodes are such or dermal enhancements. That is what we are talking about. So we apply heat as in you are supplying energy obviously and that helps him, let us say, you know, changing the, you know, changing the guilt phase of the contaminant from solid to the gas. She slips here, again, you can look at potentials and so on. And that is where the relevant concept comes in.

Let us see, you want to be able to supply enough energy for the, what was he born of attraction to be broken if I may say so in Layman's terms between the containment and the soil it, so that is something to keep in mind. These are the different aspects or enhancements that can be looked at, so now we will move on and look at relevant example here, so let us look at what we have here.

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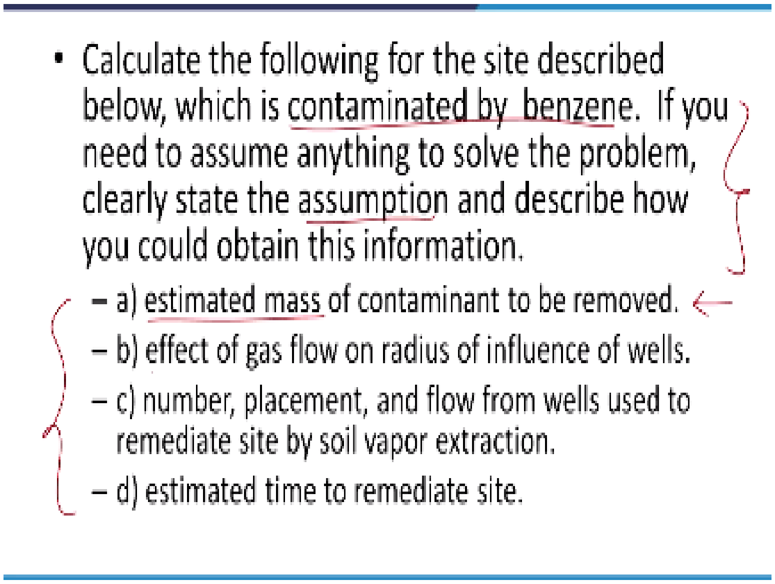

- Calculate the following for the site described below, which is contaminated by benzene. If you need to assume anything to solve the problem, clearly state the assumption and describe how you could obtain this information.
  - a) estimated mass of contaminant to be removed.
  - b) effect of gas flow on radius of influence of wells.
  - c) number, placement, and flow from wells used to remediate site by soil vapor extraction.
  - d) estimated time to remediate site.

We are going to calculate obviously let us say for this site that is contaminated by benzene, what are we going to calculate it? We are going to look at that and this is something we typically need to use him as an if you do not know what you know, some of the variables are not giving. You obviously need to look at the relevant literature and get those relevant aspects. Or do you need to make, what did we say working? what did we say?

Assumptions here, and typically they are based on let us say conservative estimates or such, but we will look at what they are, that is what we have out here as in you need to make typical assumptions here late. So what is the first aspect here? What is the estimated mass of the contaminant to be removed? For example, let us say now we are going to use this particular set of information as we are going to see to be able to try to design a portal system.

Again, a simplistic design more or less, obviously to design the system you need to know, you know, what the mass of the contaminant and in what phases is it present. So obviously we need to be able to look at that particular aspect. And then let us see, what is the effect of gas flow on the radius of inference of wells started gas flow? I guess here they are combining both the vacuum source and the extraction wells. Let us see.

So what is that effect on the various of influence of the well start something we are going to look at and also what is the number placement and flow from the wells? Obviously, let us say depending upon the number of, what do we say? A wells that you place and the amount of flow from those wells, you are going to have to look at the relevant placement. So that is something you need to look at.

And thus, we are going to look at the time required to remediate the contaminated site, obviously that is something that is going to be used to let us say as we have seen in quite a few case studies, we have seen let us say a preliminary studies let us say to be able to look at, let us see, is it feasible or not Lexi or remedial investigation, let us see our feasibility studies, that is something, you know, as we have seen people do typically or needs to be done.

So in that context, you know, you are going to have to calculate some of these aspects to see Lexi, the system is feasible or you know, the two, if the system of you know, applying soil, soil vapor extraction, to this particular immediate or any particular contaminant side is a feasible option or not. You need to get those relevant aspects looked into.

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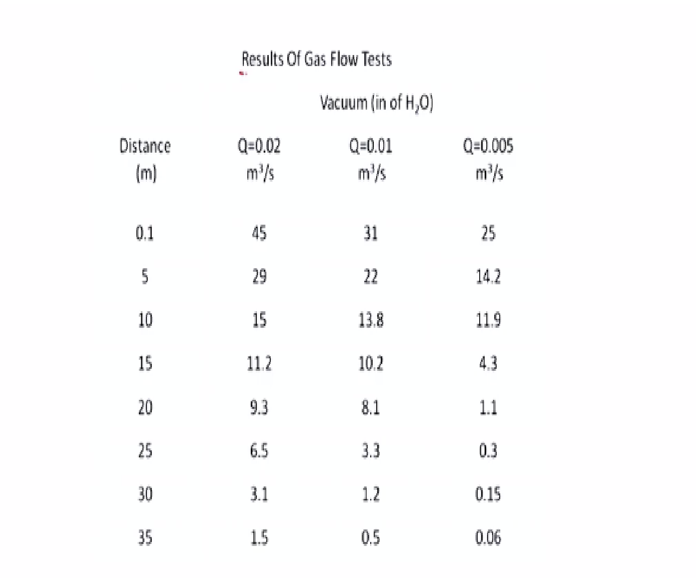

Results Of Gas Flow Tests

Distance (m)	Vacuum (in of H_2O) Q=0.02 m^3/s	Q=0.01 m^3/s	Q=0.005 m^3/s
0.1	45	31	25
5	29	22	14.2
10	15	13.8	11.9
15	11.2	10.2	4.3
20	9.3	8.1	1.1
25	6.5	3.3	0.3
30	3.1	1.2	0.15
35	1.5	0.5	0.06

So let us move on. So what do we have here? So here we have results of the gas flow tests, and how are we measuring this vacuum in inches of H2O too in is obviously inches of H2O, and what do we have? We have obviously metric of distance. This is the distance from the well, distance from the well from 0.1 meter, 5 so on and so forth and we have three kinds of measurements.

One for 0.02 meter cubed per second, one for 0.01 meter cube per second, the other for 0.005 meter cubed per second. These are the fluids of the gas That is being pumped out, let us say from that particular well and we are trying to measure let us say, how was the present changing as we move away from the relevant value rate. So obviously let us look at this particular set of data as an obviously nearest to this particular value are going to how we are experienced relatively high pressures.

So obviously poor, 45 here 31 inches of water, 25 and why is the decreasing obviously, because the flow rates are decreasing. There is the flow rate of aliens here, or The gas flow here, so get the gas of That is being pumped out or gas That is being pumped out. The greater the pressure. Let us say a, you know, a vacuums pressure. Let us say a 0.1 meter from the relevant. Well here, let us see, so now let us look at this particular set of data.

So here as we go down, the distance from the well is increasing, 0.1 to 35 and Taz, what do you see? Now obviously I do see the influence and tells the pleasure is decreasing now, so same case out here from 31 to 0.5 25 to 0.06 pardon me. So these are some data that we have from the relevant field. We are going to use this.

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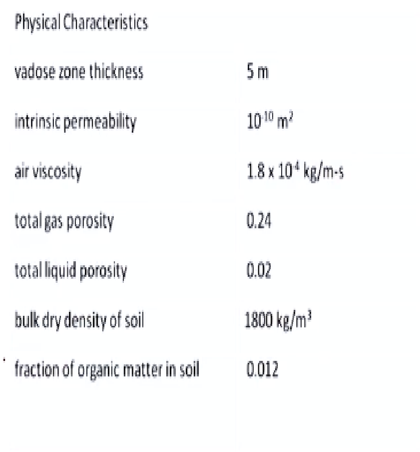

Physical Characteristics	
vadose zone thickness	5 m
intrinsic permeability	10^{-10} m^2
air viscosity	1.8 x 10^{-4} kg/m-s
total gas porosity	0.24
total liquid porosity	0.02
bulk dry density of soil	1800 kg/m^3
fraction of organic matter in soil	0.012

Obviously they are drawn, some of the physical characteristics are given as in the vadose zone or the unsaturated zone thickness is five meters. intrinsic permeability air viscosity, total gas porosity, liquid porosity, bulk dry density, fraction of organic matter and so on. Again, keep in mind that let us say there is because you know you have a lot of data out there, it does not mean all the data is going to be useful to you. Only a few of these particular aspects are going to be a relevant to you. Let us see.

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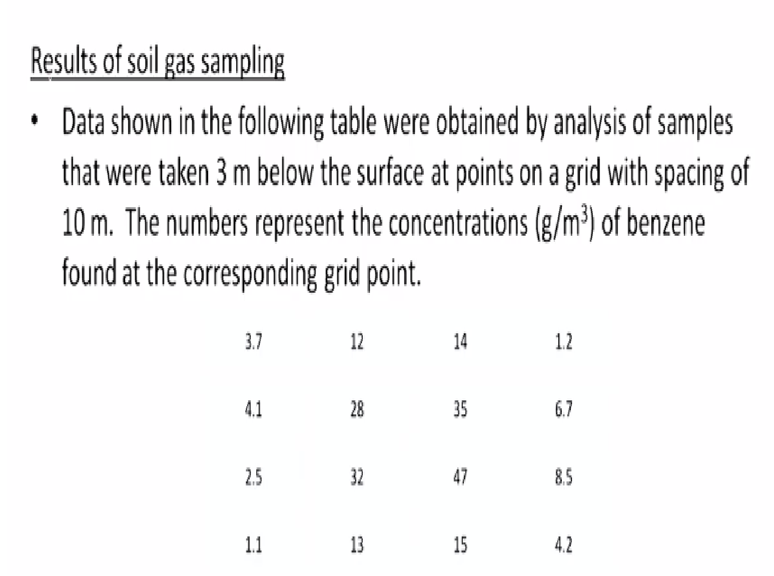

Results of soil gas sampling

- Data shown in the following table were obtained by analysis of samples that were taken 3 m below the surface at points on a grid with spacing of 10 m. The numbers represent the concentrations (g/m^3) of benzene found at the corresponding grid point.

3.7	12	14	1.2
4.1	28	35	6.7
2.5	32	47	8.5
1.1	13	15	4.2

So again, that is something that we have out here cause itself, gas floaters, physical characteristics and last year let us say, and constantly important glitzy we how the results of this soil gas sampling. Let us see, and what is the gas that we are going trained to look at itself? Benzene, so let us look at what we have out here. Data shown in the following table, what obtained by analysis of samples that were taken 3 meters, let us see, three meters below the surface at points on a good. So there is a great legacy with spacing off 10 meters.

Let us see, the good spacing is 10 meters. The numbers represent the concentration in grams per meter cube off benzene found at the corresponding grid point. So one aspect as in you, how grids, let us see, one, two, three, four, spacing between the center to center of the goodies. Yeah. What is it now? 10 meters. And keep in mind that though they have taken a sample 3 meters from the surface or below the surface, keep in mind that we have the data that says that vadose zoners 5 meters thick.

So obviously for in order for the continuity, you estimate we had to go into cancer, that whatever concentration that we have at that particular 3 meters depth, they have the same throughout that 5 meter depth, so That is something to keep in mind. And here, let us say, obviously a how the table here and they are in that in such a way that day can seem like a grid but obviously does not turn out to be as clear as it should be, but rather the rectangle.

But for visualization purposes, what does this mean? So as in we have a grid here, this is one grid, second grid, one, two, three, four let see and distance between these good central lines is 10 meters. And let us say the average concentration within this particular grid is given here, 3.7 12 grams per meter cube and I think 14 and 1.2 or 1.4 and 1.2 I am not sure. 4.1 28 and so on. Let us see.

So as you can see here, let us see, if depending upon the concentrations that we have experienced or looked at, another source seems to be somewhere out here Lexi maybe out here. But maybe it can change too, depending upon these concentrations of the relevant, gases. Let us see, the source. Some seems to be somewhere out here. Again, you can look at it in greater detail though, so again, the distance between let us say the good is, what do we say? You are 10 meters.

So what is the victim? The land, obviously It is going to be centered two centers, center to center, I guess 40 meter says it. So 10 20 30 and including these two, what do we say? Pieces we have more or less 40 meters. So 40 by 40 I guess. Hopefully. Let us see what we have out here. So that is what we have here.

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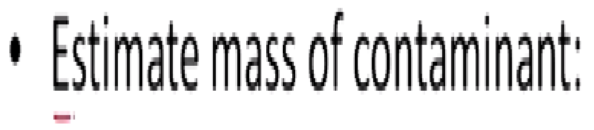

- Estimate mass of contaminant:

So the first aspect is we need to obviously estimate the mass of the contaminant, and That is for that particular aspect. We have a particular formula we came up with. So here we are assuming that there is no NAPL, so will assume that there is no NAPL. And with no NAPL being present, how did we calculate the total mass? M time equals zero and total zero. We calculate that. So we have the concentration of the relevant contaminant or contaminant present in the water, the soil and the gaseous phase.

So let us write them in that particular order. So porosity of water times volume, total volume, we will give you the volume occupied by that particular water. It is not porosity of water, but I guess you know the fraction of the total porosity that is occupied by water. It is not obviously porosity of water times the concentration of the water plus total volume bulk density into Q. Q is the; what do we see?

Concentration of the contaminant adsorbed onto the soil, plus again, the porosity occupied by this particular word. This now here we are talking about the gas while total volume into concentration in the gas phase, so what are some of the phases are relationships that we have here that will make are was to make this. But could we question simple. Let us obviously we have three phases, a gas, a water, and a compound absorbed onto the side. Let us see.

And obviously there are going to be equilibrium, equilibrium relationships here, so let us look at some of them. So we have looked at this particular case quite often, Q, which is the concentration of the contaminant adsorbed onto the soil is going to be in equilibrium with the concentration in the water, so that is something that we looked at and also we know that similarly, let us say we are going to have an equilibrium for the compound.

Let us say between it being in the gaseous phase and acquiesce phase, so that is given by Henry slow, let us say, which going to be CG/C in the water lets you rate our concentration in the water. Again, as I mentioned, we need to look at the different units of Henry's constantly out there, so let us go ahead and plug them in here. So we are going to have we total concentration. So again, here as you saw, we always had what we say in our particular question.

All the data that we had were in the units of concentration for gas. Let us, and we did not have the concentration in the acquiesce phase. So we are going to how to transform this equation into the, in terms of the concentration, the gaseous phase. So let us do that. So those concentration of relevant component water is going to be equal to Cg/h, so Cg/h plus total volume, bulk density Q is KP time see Cg/h KP Cg/h plus porosity occupied by gaseous phase volume in concentration of gas.

So I think I can take out a V and Cg, V and Cg and that is going to be equaled to for us to hear. And we as out there /h + Robie KP by Henry's constant plus porosity to here. So the using this particular equation, I can, you know, estimate the mass of the contaminant in that. In this particular scenario, obviously I need to calculate the volume out here? So again, Henry's constant from the relevant literature is out here, but as you see, what are the units here?

This is the case when Henry's constant is equal two partial pressure of the relevant component. The gas just fears by the relevant concentration in the acquiesce phase, ways that, because the units are atmosphere spur, moles per meter cube let us see, that is what we have out here, obviously we need to transform that into diamond shine less because we are looking at H= Cg/C. So obviously if you look at PV= NRT and so on, let us say, you will obviously need to divide by r t typically that is what we are have out here.

So I am trying to make a diamond from last year and the diamonds and less constant is more or less 0.196 so what does that mean? We have 0.196 to be the concentration in the gaseous phase to the concentration, the relevant a water. See? so That is what we have out here for benzene.
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C_g

- K_{oc}=83 ml/g

- Calculate average gas concentration as average of measured concentrations.

Then so let us move on. So it is I guess is, what do we say given, so the average of the measured concentrations is required, so obviously here, there are some issues as in let us say, you know, for one grid itself, you are trying to obviously approximate the relevant concentration by one particular sampling point. So here also we need to be able to calculate the, let us say the average over the entire area.

But why is that required though? That is required because typically later on, let us see, you are going to how to use, let us say the terms for calculating the time required for remediation or even in this particular case now that say when we are trying to, how to contact the concentration, not contact, pardon me, calculate the concentration in the gaseous phase, as in, in this equation we have concentration in the gaseous phase.

But as you rumor, let us see you, we have seen that we have different girls and we have different concentrations in the relevant gaseous Phase. Different concentrations in the gaseous phase for different grid so obviously there are two ways to go about it. One way, maybe not a great way is something that I have here as an, you know, I am going to take the average gas concentration as the average of the measured concentrations. That is obviously not a great way or let us see, maybe I can look at calculating the masters individually and so on.

Let us hear it. So let us just try to look at that particular aspect. So here, let us see, I have the all the different grid numbers rate and a how all these particular aspects out here and I can calculate development, mass, not mass. Pardon me, the outage concentration in this particular balance, so that is something that can be done. Yes. And let me move back to that. So why, how 14.25 or older? So that is what we have here.

And volume I guess rate as we mentioned, grid size is 40 by 40. We had I think four goods square, one, two, three and four and same case like that out here. Center line to center line or centerpoint to centerpoint. It is 10 meters. Search and landed 40 meters. Same case the word test, 40 meters in depth as we, saw or was given the cushion or the as in the depth of the saturated zone or unsaturated zone or the vadose zone was five meters.

So from that we get the volume of 8,000 meter cube. And that is something that we have out here. So Kp, obviously this is the partitioning caution which we use in q=Kp times C, so that depends upon the fraction of organic carbon. Again, why do we need to look at fraction of organic carbon here, which is this particular variable here It is because let us say you are going to how, what do we say the organic compounds present or organic fraction in the soil.

And this organic fraction is water actually absorbs to, pardon me at jobs it relevant contaminant here. Let us see. So that is why you need to look at that. I guess it was given at 1.2% and that is why we have air force here. Kyc for benzene. Again, this is from literature and changing the units. We have this and so the partitioning coefficient is out here. 0.996 liters per kg now, so let us go ahead again, porosity gushes of porosity editorial policy.

Let us see, 0.2 is occupied by gas 0.0 to buy what Roger's rate and bulk densities out here. Again, these were given in your particular relevant a question I guess, so the total mass is nothing, but this is total volume and this is concentration average in the gaseous phase, and let us look at the variables that we have out here. This is probably going to be equal. Let me write it down, I guess, this is certainly going to be Henry's constant by h.

So It is going to be watered by Henry's constant plus Roby Kp by Henry's constant plus in the gaseous phase, porosity the gaseous phase, and that is what we see out here. 0.2, 0.196 and so on and so forth. And now let us see what it is that we end up with. We have 1.1 * 10 power 6 grams, or let us just calculate that. Let us see. So 1.1 * 10 power 3 kg. Let us see, almost a one ton of the relevant, component here.

Again, this is both in the, what is he not both, it is a between Lexi, our exam on the soil gas and the acquiesce phases, so we end up with the, what do we see? Almost two tons of that particular component here.

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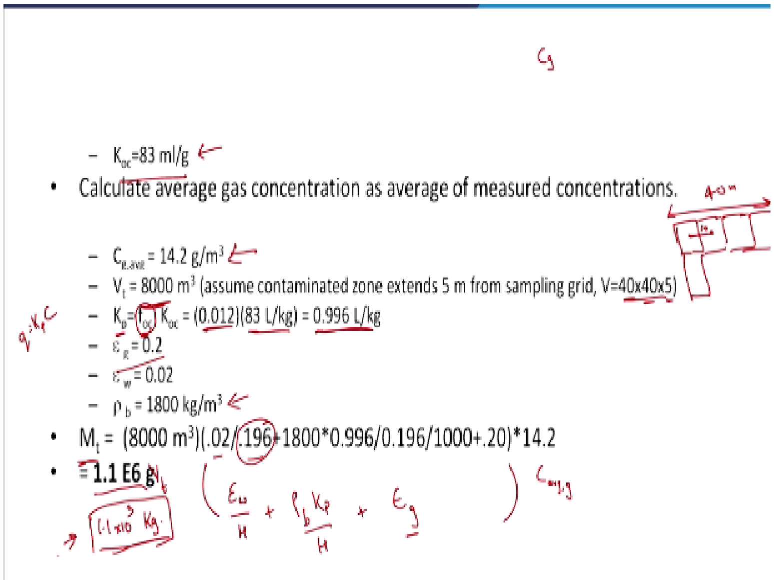

C_g

- K_{oc}=83 ml/g
- Calculate average gas concentration as average of measured concentrations.
  - $C_{g,avg}$ = 14.2 g/m^3
  - V_t = 8000 m^3 (assume contaminated zone extends 5 m from sampling grid, V=40x40x5)
  - K_p=f_{oc} K_{oc} = (0.012)(83 L/kg) = 0.996 L/kg
  - ε_g = 0.2
  - ε_w = 0.02
  - ρ_b = 1800 kg/m^3
- M_t = (8000 m^3)(.02/.196+1800*0.996/0.196/1000+.20)*14.2
- = 1.1 E6 g

M_t

1.1×10^3 Kg

$$\left(\frac{\varepsilon_w}{H} + \frac{\rho_b K_p}{H} + \varepsilon_g \right) C_{avg,g}$$

$q : K_p C$

So let us move on. Let us see. So the second aspect, part B was to look at the effect of gas flow on the radius of influence here, it is again, how do we go about this? The, we are just trying to understand the system in terms of the data that we have here, so if I look at the top view let us see, you could have been done, but again, top view let us see. This is my particular gas flow or your extraction. Well, let us see.

And out here we had a mirror. If you look at it that 0.1 distance, we had around 45 inches of water, so on and so forth. We ended up with something like 0.05 or something like that, inches of water inches of H2O. And this was the case for a, what was it now for I believe when the flow rate of the gas was 0.002 meter cube per second and obviously we had the relevant data for different cases and so on and different cases as in for different distances and also for different cases of flow rates. Let us here.

So obviously we need different flow rates because later on you will need to have to choose between different flow rates are interpolate between them. So that is something to keep in mind, but I am almost out of time. So let me just, you know, quickly look at what we are going to do and wrap this up for to this session I guess. So we will go into how to look at effect of gas flow on radius of influence.

So obviously we need to come up with one particular definition of radius of influence as, and if you remember, two people typically look at either 0.1 inch or one inch of water. Let us see here. The pressure, to be able to define the radius of influence are also looked at 10% of the initial pressure to define the radius of influence? So, but 10% or 1% of the initial pressure That is subject to as an initially.

Let us say for have they know 50 inches, then the threshold is going to be, you know, a 5 I guess, but initially if I had only 10 inches, then it is going to be 1 inch. So it is conceivable variation between the threshold of 5 and 1. So to have a uniform a, what did we say? A reference, let us say we are going to choose this part of case, 1 inch of water for our particular of influence.

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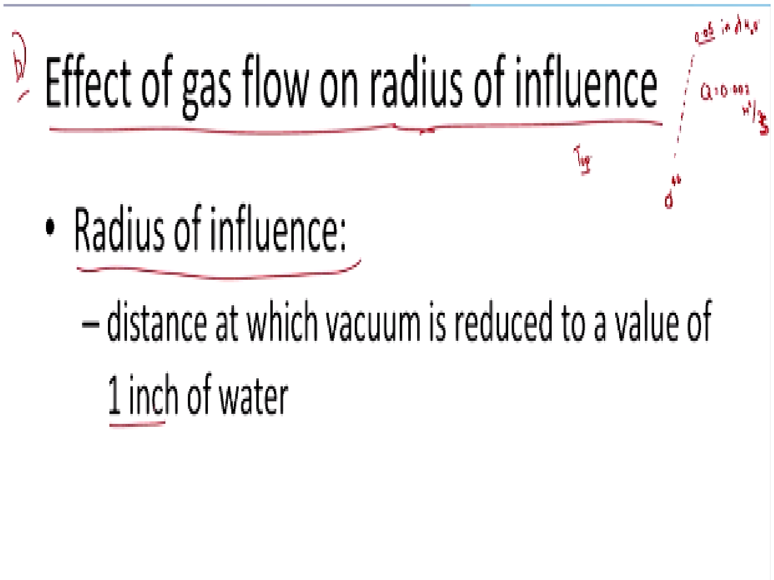

Effect of gas flow on radius of influence

- Radius of influence:
  - distance at which vacuum is reduced to a value of 1 inch of water

So let us look at how we are going to, you know, take these aspects into account and you know our design for the system for them. But I guess since I am almost out of time, I will continue this in the next session and thank you.