Environmental Quality: Monitoring and Analysis
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Lecture – 51
Air-Water Exchange

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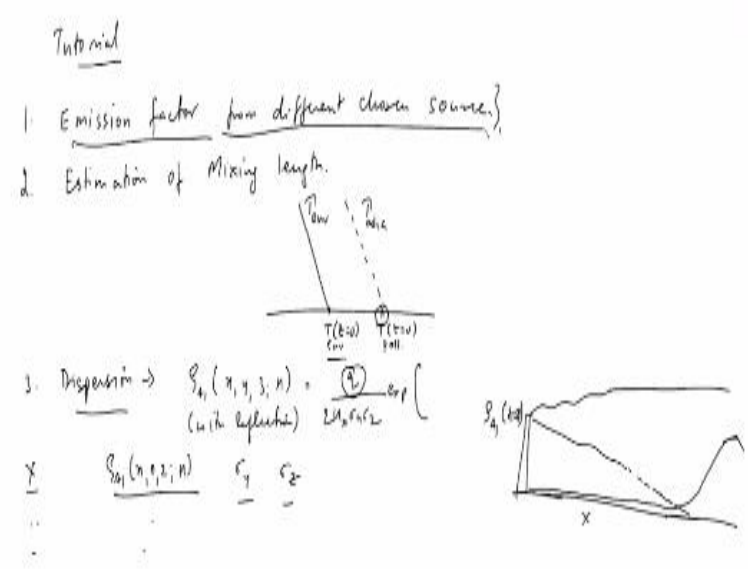

Tutorial

1. Emission factor from different chosen source.}
2. Estimation of Mixing length.
3. Dispersion → $\rho_A(x,y,z;H) = \frac{q}{2\pi u \sigma_y \sigma_z} \exp\Big($ (with reflection)

X $\rho_A(x,y,z;H)$ σ_y σ_z

Tutorial is to get emission factor. So, there are different categories I have already given that. So, you can pick any 3 and go to the website that we talked about, pick the emission factor for any 3 different pollutants and then for those sources we do dispersion problem exercise. So, in the dispersion problem, I think before the dispersion problem, I have one exercise on estimation of mixing length. So, here I think mixing length you have to determine graphically, for example you have to determine what is the temperature at the ground Tz at z = 0 for the environment and Tz = 0 for the pollutant.

So, the environment temperature and there is a corresponding environmental lapse rate and for the pollutant whatever temperature is there that is adiabatic lapse rate. So, depending on **so** the problem itself, I think you have to decide which is the environment starting point, lapse rate starting point, which is the adiabatic lapse rate starting point, so that I think we discussed in class. So, based on whatever the discussion we had, you can recall that, if you do not recall this, just go back to the notes and read it, otherwise sent e way sent me an email and I will help you at that time, yeah.

So, this is a calculation of the mixing length estimate. So, sometimes the mixing length is infinite, does not say it is infinity, but in this case it will be a finite intersection somewhere. So these will intersect somewhere and that will be mixing height. So you can do it either graphically or arithmetically either way by equations and this is a dry adiabatic lapse rate and this is the environmental lapse rate, the mixing height based on that. The next is a dispersion exercise. So, you start with the full form of the Gaussian dispersion equation.

So, the full form that we have is x y, z, and H we have this full equation with reflection. This example we did in class, you start with that and then reduce it. So, one of the things that I have asked in the problem is for a given set of conditions and for a certain stability class, so you have to estimate the stability class for this particular problem, you have to calculate what we are asking is rho A1 at some height, I think height I m asking is z equals to 1 or 2 or 2 meters or some such thing as a function of x, which means that you have to calculate.

You have to calculate rho A1 x, y, z, H, so along the center line which means you have to calculate at 0, 2 meters and whatever is the height for different x values, which means you have to run this model for different x, running for x, so the dispersion coefficient will change with x okay. So, you can do it graphically and then you will get some relationship like this. Typically, you will see something like this yeah. The reason you do this, you see this is, what happens is if there is a stack is very high, the plume is going like this, you will not see anything at ground level for some distance.

Once the plume reaches the ground is when you start seeing some concentration. So, at this site nothing seen here, then it starts increasing. So, I want you to plot that. So, that is one exercise. This is a manual exercise. When you are doing AERMOD, this is done automatically by the software. Software will do 4000 points at one shot within 1 second. You can set it up like that to do in Excel also provided you know equations for sigma y and sigma z. There are equations, mathematical equations.

It is a little painful but if you know for that stability class, you can take the points from the graph and fix a curve and then use that curve. So automatically you do for one, do for all of them okay. I think you can figure it out how to do it automatically, so okay. So that I would like you to try this on your own and then after that if you have doubts, questions, how to do it, you are unable to get any of these things. So the emission factor that you get here you, I do not remember if the discussions problem has a link to this first problem.

The first problem, the emission factor is meant to be used in AERMOD. So, whatever you do here, you will do it and use that source in AERMOD, one of the sources in AERMOD, but you are free to choose this, but I think I have given you some number here for the q. This is q by some equation right ux sigma y sigma z exponential whatever. So, this q is I think given, I have given this to you in the problem, I do not remember, you check that okay. So, I would like you to try this on your own, sometime next week we can discuss this.

So, before the quiz, you have enough time to revise. The quiz will be in class next to next Wednesday, again this 30th, either in 355 or 356, one of those rooms okay, most likely in 355. We will assemble there and we will this discuss that, decide that day and previous day I will tell you.

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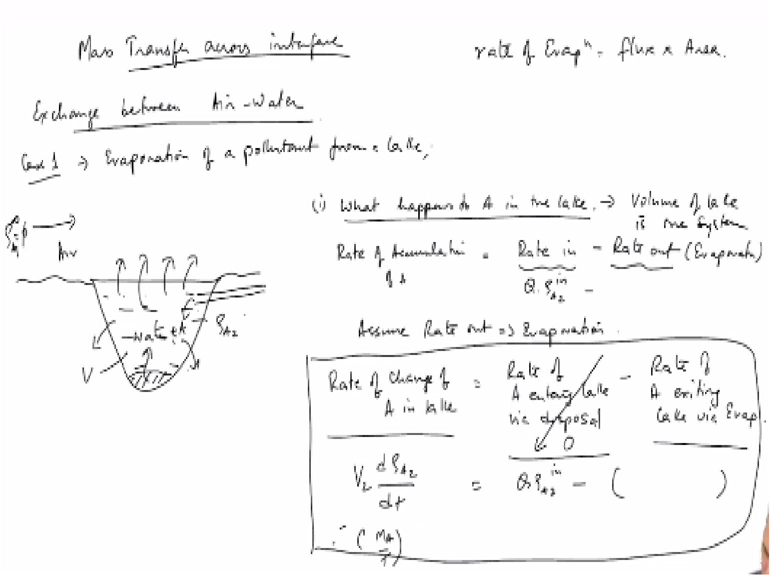

Mass Transfer across interface

rate of Evapn = flux × Area.

Exchange between Air-Water

Case 1 → Evaporation of a pollutant from a lake,

(i) What happens to A in the lake, → Volume of lake is the system

Rate of Accumulation of A = Rate in − Rate out (Evaporation)

$Q \cdot \rho_{A2}^{in}$ −

Assume Rate out ⇒ Evaporation

Rate of change of A in lake = Rate of A entering lake via disposal − Rate of A exiting lake via Evap.

$$V_L \frac{d\rho_{A2}}{dt} = Q\rho_{A2}^{in} - (\qquad)$$

So I want to continue our discussion. This is an application of what we were doing. So, so far the recap, what we did mass transfer at the interface. We first take the exchange between air and water. So, this is a simplest case for which we even derived the interfacial expression air and water. So, the conditions for air and water for example this is a box model example we started with originally when we started doing the modeling, the description of the model. So, we are looking at exchange between for a simple case, so case 1.

We look at evaporation of a pollutant from a lake okay. So, there is a lake and there is air. There are some volume and we are talking about this thing okay. So, this problem can be posed differently. The one way in which it can be posed is let us say that this background concentration of A is in the air rho A1 infinite is 0, which means there is no chemical A in the background air and so there is a chemical. This scenario can be that somebody has spilled a lot of chemical here A.

This A is entering the water from the sediment or somebody has dumped a lot of chemical into the lake and this lake is contaminated and so on, different scenarios. So, the simplest scenario areas there is a concentration of A in the water and so what are the implications of this? The questions that you can ask are the following. The first one, first possibility is what happens to A in the lake? First question. This is the concentration of A in the lake, how is it changing? So, this problem if you want to solve, we can write the mass balance, rate of accumulation.

So, automatically when we ask this question in the lake our system becomes a lake, the lake becomes a system. So, this volume of the lake is a system. So, for this system, rate of accumulation of A in the system equals rate in minus rate out. So, how can A come in, rate of a coming in is let us say somebody is constantly dumping stuff every day continuously, there is a pipeline coming in and disposing material here okay. So let us say there is a pipeline coming in and disposing stuff here.

So you have Q into some concentration of rho A2in, let us call it as in minus rate out, what is this rate out? So in this case, several processes, possibilities we can discuss. One rate out could be it is going into the sediment, we have not yet considered that, let us for the time being ignore that part status 1. So, we assume rate out is evaporation only, which means this is evaporation, rate out by evaporation only. So, you have to write this statement in English first.

This is very important because then from each term here, so this conversion of the statement will be rate of change of A in the lake is a result of rate of A entering lake via disposal minus rate of A exiting the lake via evaporation. **"Professor – student conversation starts."** Sir what if already some person has dumped it just for once, yeah, like one time. After that he did not, nothing had happened. Then, how do we consider rate in that situation. Yeah, so that there will be no rate in, it will already be there, your initial condition already will exist. **"Professor – student conversation ends."**

The initial condition exist, even here that initial condition exist. So, I am going to remove one of these terms now. So, we are going to be assuming this first. There is no rate of entering, which means somebody has already dumped it okay. So which means that there is an initial mass that is sitting there already and that we have estimated it somehow, either by measurement or by estimation that you know that 4400 kilograms of some chemical has been dumped in.

So we have linked back to our first problem that we did in this course, that is mass balance, a 400 kilograms of dumped in what is the concentration at equilibrium in the water, the worst case scenario. That is the highest concentration of A in the water. That is your starting point. From there now, that problem was an equilibrium problem. So now if that is happening, then after that, you take that as starting point and emission starts from there, the release start from there. So, we will take one by one.

This problem can be as complicated as you want and then corresponding to that the equation will change and mathematics form will change. So now we are saying that rate of change is equal to rate of evaporation okay. So you see a negative sign there, this is zero, nothing is entering. So, because somebody has dumped already everything and it is a finite volume of dumping and nothing is entering, exiting. So, this becomes the rate of A exiting the lake. So, rate of change of this thing is dou rho A2 by dou t into V of the lake of the water.

So, every term in the mass balance has units of mass of A by T. So, therefore, V2 into d rho A by dt. It is the rate of change of liquids that is in unsteady state system, nothing is coming in okay. So, if somebody is putting material into it. This is second term, this term is not 0 there will be a term here, so we will have it as rho A in constantly minus rate of evaporation, rate of evaporation will be what here, this is the term now we have been discussing in the last few classes, to fill up this term okay, the rate of evaporation term.

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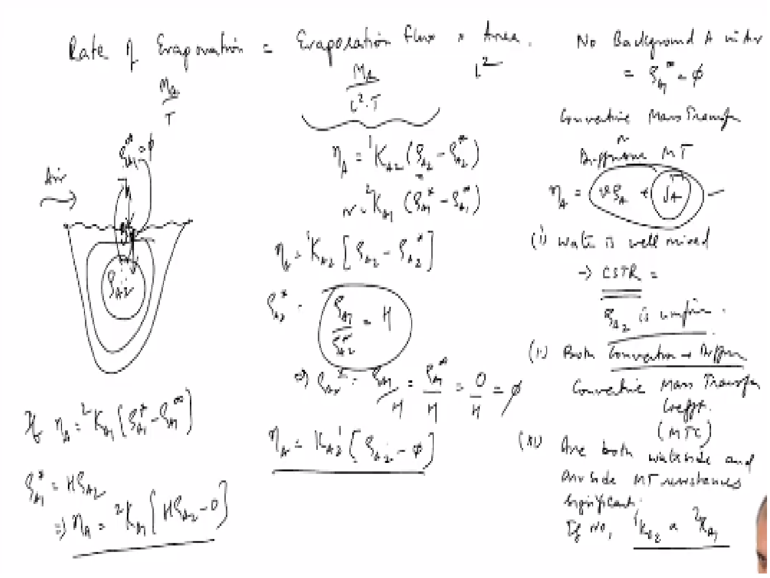

So, that evaporation is flux into area. So evaporation flux has units of MA by L square into T, area is L square, MA by T. Now, so this is evaporation flux. The evaporation flux is nA okay. This nA has to be now computed. So, now we look at the system. There is water, there is air and there is a concentration here. Now it is going out from here to here. Concentration here is rho A2 infinity which we will assume to be 0 for the time being, no background concentration. When you say no background A in air, we are essentially saying this rho A1, this is rho A1 infinity is 0.

This is the assumption we are making Now what do we write this term here? Now, first of all, you have to make this judgment whether it is a convective mass transfer or diffusive mass transfer. We have nA equals entire term, we have this term was v rho A + jA, we make a decision right here, which one do you consider? If you are considering only jA, how will you write the equation? If you are considering both, how will you write? So what is the likelihood of this in this system, the information given to you it is not sometimes enough for you to, so you have to make some assumptions here.

If no information is given, you can do problems in multiple ways. So let us make it easy on you for the time being. Let us say that the lake is very shallow and it is well mixed, one assumptions. The water is well mixed. What will this immediately do, what is well mix means? The concentration wherever in this region, everywhere the concentration is the same. So, well mixed essentially will make this into what is called as a CSTR, completely stirred tank reactor, which means that rho A2 is uniform throughout the volume.

Which also allows you to do this on the left hand side accumulation term, you can write it like that because it is uniform, otherwise you cannot write it like that. You have to integrate that thing over the entire volume, otherwise you cannot write v into d rho A2 dt cannot be written okay. The water is well mixed. Air is anyway moving. So, what is well mix, there is convection in the water and there is convection in the air. So, now we are assuming both and we will say both convection plus diffusion.

When we have conduction and diffusion as a condition, then we use a convective mass transfer coefficient, we use a convective, we give term by MTC, mass transfer coefficient write as MTC, I will write MTC henceforth okay. Now, we have decided that which means there is a k mass transfer coefficient term multiplied by a driving force that needs to come here. So we will start with the driving force. So, yesterday's last class, we had discussed how we can write this flux term, you have various options to doing it.

So, in this particular scenario, we are taking rho A2 which is a solution in the aqueous phase going into the vapor phase in the air. So many resistances are there. This resistance are both water side and air side mass transfer resistances significant, which means can you in neglect any of them? By this point of time, you have no reason to neglect either of them? You do not have any information that can tell you that neglecting of it because it is not pure chemical, you cannot neglect one of the phases.

You have to consider the solution here and it is going across. So, there is an interface resistance here and so both. The answer is no, both kA21 and kA12 are to be considered, okay, both are to be considered. Then, this term here will become, you can have two choices, you either have rho A2 - rho A2 or rho A1 star - rho A1 infinity, either way. So if you do this, we will do kA21, when you do this, we do kA12 okay. Is it clear? Anybody has a question on this how we do this? So we further write this.

Let us take the first one, kA2 because we already know rho A2. We need to do this in rho A2, why? The other term that is there sitting in the accumulation, we can do either way. So, let us take this first how we can do this, rho A2 star. What is rho A2 star? Rho A2 is connected to rho A1. This is the equilibrium concentration, an equivalent concentration of rho A2 that is in equilibrium with whatever is there in the air. What is there an air? Zero. So it is rho A1 by rho A2 star equals Henry's constant, which means rho A2 star equals rho A1 by Henry’s constant.

In this case, this rho A1 is rho A1 infinity by Henry's constant. Rho A1 infinity is 0, 0 by H is 0. Therefore, this equation becomes nA2 equals kA2 star into rho A2 – 0. This is capital KA. Alternatively, you write the other term. If you write KA, if you nA = KA12 into rho A1 star - rho A1 infinity. Rho A1 star = H into rho A2 based on this. In this case it is rho A1 star divided by rho A2 = H, we are not taking the equivalent concentration of A in the air which is in equilibrium with whatever of A is there in the water and using the water concentration to find an equivalent equilibrium concentration in air.

So what we are doing is we are taking this entire thing and finding an imaginary concentration here that is in equilibrium with this mass, this concentration and so we are calculating this one. In the other case, we did we take this concentration and find out an equivalent concentration here and we are taking this section okay. So which means that nA will become KA1 into H rho A2 – 0. When you calculate, these 2 expressions are different, so eventually become they should give you the same value if you compute either way okay.