Engineering Hydrology

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Module 2 Lecture 23

Evaporation

Hello all, welcome back. In the previous lectures we were discussing about rainfall and its measurement, representation, analysis and detailed discussion related to rainfall we have covered. Now, we will move on to the next hydrologic process, evaporation. As you all know evaporation is the process by which the liquid is converted to vapor form. So, here in our study we will be dealing with water, the liquid whenever I am emphasizing it is regarding water.

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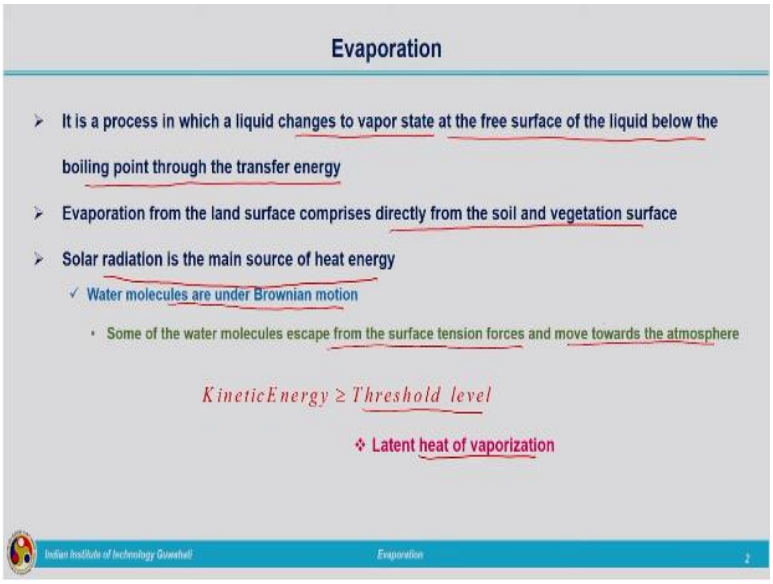

Coming to the definition of evaporation, it is the process in which liquid changes to vapor state at the free surface of liquid below the boiling point through the transfer of energy. So, here it is not reaching at the boiling point, below that it is taking place, the conversion of water to vapor is taking place below the boiling point. This conversion of liquid to vapor form is taking place within the water body and also near the land surfaces. When we talk about the land surfaces, the top layer of the soil may be sometimes in saturated

region in the monsoon season, other times it will be in the unsaturated zone. So, some amount of water which is present on the soil layer or the land surface also will be getting converted to the vapor form. The evaporation from the land surface is mainly from the soil layer and also from the vegetative cover. It comprises directly from the soil and vegetation surface.

What is the main reason behind evaporation? It is nothing but main reason commonly we tell is the heat energy. Heat energy from the sun will be absorbed by the water molecules and these water molecules will be attaining certain energy. So, beyond that, beyond a threshold level this energy goes, these water molecules will be escaping from the surface tension forces. So, at that time these molecules, water molecules will be converted to water vapor, so then it will be moving towards the air or above the free surface.

So, the main reason is the solar radiation from the sun. What will happen? The water molecules are under Brownian motion. In any direction these molecules will be moving, colliding each other and there is a continuous energy dissipation taking place. Extra amount of energy is coming from the heat energy or the solar energy. This will be absorbed by the water molecules which are under Brownian motion. So, this absorbed energy will be increasing the energy level of each molecule on the surface.

When it reaches above a certain threshold level, what will happen? This will be free from the surface tension forces which is there on the surface and then these molecules are in a position to escape from the water surface in the form of vapor and it will be moving towards the atmosphere. So, these water molecules escape from the surface tension forces and move towards the atmosphere.

Now, coming to the kinetic energy, I was talking about some threshold level, the kinetic energy of these molecules should be greater than or equal to a certain threshold level, then only it will be escaping from the surface tension forces. So, what is this threshold level? You are familiar with this particular term. That is nothing but the latent heat of vaporization. So, latent heat of vaporization is representing the threshold level, if the kinetic energy is beyond this particular energy level, these water molecules will be converted to the vapor form and it will be escaping.

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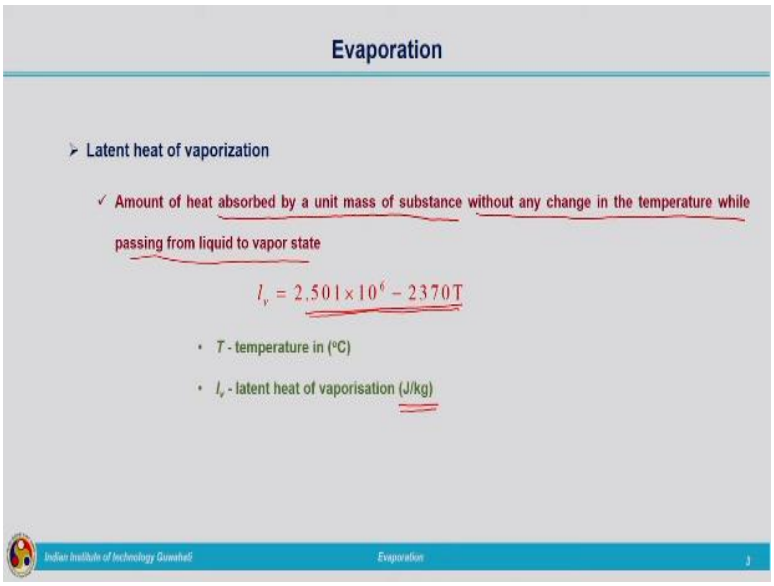

Now, let us see what is meant by this latent heat of vaporization. Latent heat of vaporization is the amount of heat absorbed by unit mass of substance without any change in the temperature while passing from liquid to vapor state. After absorbing this heat energy what is happening, the energy level is increasing. Because of that it is converting from the liquid state to vapor form. During that stage (that is when it is changing from liquid to vapor form), what is the process which is taking place? Some amount of energy is absorbed by the particles or the substance. So, the amount of heat energy absorbed by the unit mass of substance when it changes from liquid form to vapor state, without any change in the temperature, that is the latent heat of vaporization.

We are having an equation to calculate latent heat of vaporization, that is given by an empirical equation.

$$l_v = 2.501 \times 10^6 - 2370T$$

This is an empirical equation that is why you have to be very careful about the units. Temperature (T) is in °C, and l_v is the latent heat of vaporization (in J/kg). So, if we are making use of this particular equation, we can calculate the latent heat of vaporization. So, if the water molecules attain an energy beyond these, it will be converted from liquid phase to vapor form.

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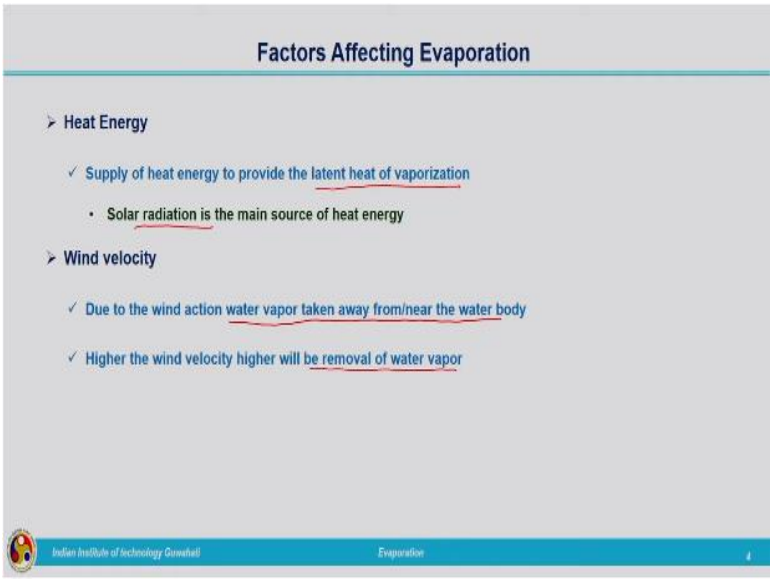

Now, let us move on to the factors which are influencing evaporation. Main factor is the heat energy, the heat energy or the solar energy which is from the sun that is the main reason behind evaporation. So, heat energy is supplied by the sun. This is providing the latent heat of vaporization, that is some amount of energy which is required by the molecule to change its state from liquid to vapor that is the latent heat of vaporization, that energy is attained from the heat energy, the main source is the solar radiation.

Second factor which is affecting evaporation is the wind velocity. You imagine there is no wind and the water is getting converted to vapor form and it will be free from the water surface, it will be moving upward. So, these water vapor needs to be removed from that particular position. Then only more and more vapor will be moving towards the air. Otherwise what will happen this will be preventing the incoming of the water vapor to the atmosphere. So, there comes the role of wind, this wind action will be taking away this water vapor which are present just above the water body, so it will be providing the space for extra water vapor to be accommodated by the air. So, the wind velocity is the second factor which is influencing evaporation. Due to wind action, water vapor is taken away from the water body.

When the wind velocity is high, higher will be the removal of water vapor, so the rate at which the evaporation is taking place will be more. Because more and more space is available for the water vapor to be accommodated and that much of sufficient solar energy or heat energy is available to the water, then evaporation rate will be high. Simply, by means of wind action, wind velocity, evaporation rate would not be high, sufficient energy should be provided by the sun or heat energy should be there to attain that level, threshold level to escape out of the water surface.

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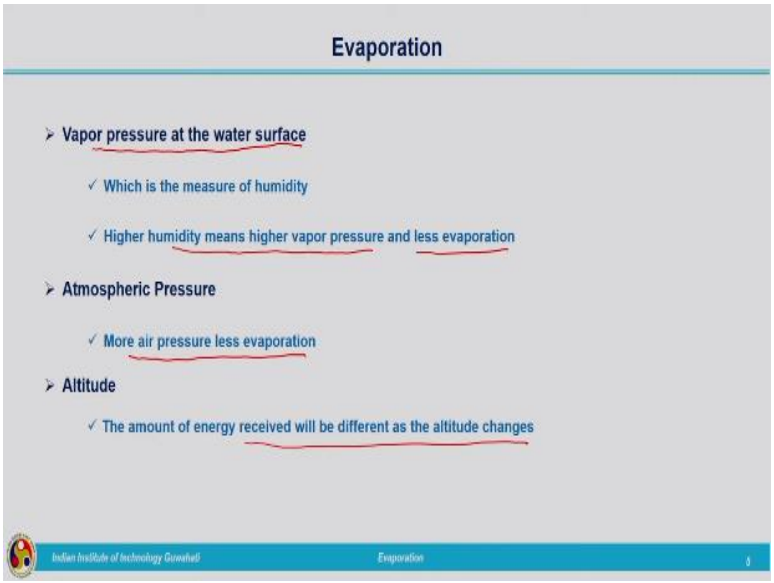

Next is vapor pressure, vapor pressure at the water surface. Actually, vapor pressure is a measure of humidity. So, when we will be telling that it is very humid that is more and more water vapor is present in the air then we will be telling the weather is very humid. So, water vapor is getting added to the atmosphere. The pressure exerted by the water vapor is the vapor pressure, pressure exerted by the vapor present in the moisture is the vapor pressure. So, if more and more vapor is present, vapor pressure will be more.

So, if vapor pressure is more and again and again water vapor is added into the atmosphere, that means finally it will be reaching the saturation vapor pressure. The difference between the saturation vapor pressure and the vapor pressure will be less in case if the water vapor is added again and again. So, if the humidity is very high, the

evaporation will be less, the capacity of the air to accommodate more and more water vapor will be less because already majority of the air is having so much of water vapor, humidity is very high. Now, the space available for the vapor to be added to the air is very less, it is almost reaching the saturation vapor pressure, at that time the evaporation rate will be less. Higher the humidity means higher vapor pressure and less evaporation.

Next is the atmospheric pressure, pressure exerted by the air. More air pressure means less evaporation. Next is altitude. We have found out a relationship with the altitude and temperature, altitude and pressure. We have found that as the altitude is increasing, the temperature is decreasing, pressure also decreasing. So, temperature is the main reason behind the process of evaporation.

So, at hilly region and all, as the altitude increases temperature decreases. So, depending on the prevailing condition, what is the temperature, what is the pressure, depending on that the rate of evaporation also will be different. Amount of energy received will be different as the altitude changes, based on that there will be variation in the rate of evaporation also.

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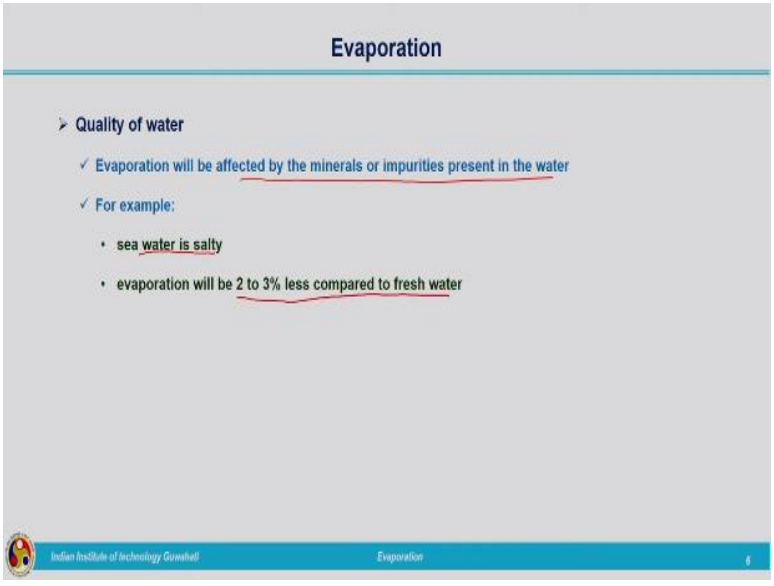

Next factor is quality of water. Consider you are having pure water, fresh water and also saline water. So, because of the impurities present in the water, the rate at which the water vapor, water is converted into vapor form will be reduced. So, evaporation is affected by the minerals or impurities present in the water. In the case of sea water, sea water is salty water, saline water and the evaporation in the case of sea water is 2 to 3 percentage less compared to fresh water. That is in the freshwater case, impurities are not there. Because of that the rate at which the evaporation taking place will be higher but in the case of impure water or in the saline water the rate at which evaporation is taking place is at a lower rate.

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Next is seasons and time of the day. You consider a particular day. In a particular day you can understand when it will be very hot? It is during the afternoon time. So, during that time, compared to morning and evening time, high intensity of heat will be during the afternoon time, noon time. So, during that time maximum evaporation rate will be occurring. Other times, mornings and evenings it will be less.

So, there will be hourly variation in evaporation, it will be maximum in the afternoon and mornings and in the night, it will be less. And in winter it will be less and in summer it

will be more because the heat energy or sun rays which are reaching the water body or the land surface will be less compared to summers, the effect of that will be less.

Now, coming to sky conditions, you can clearly tell that if it is a cloudy day, the sun rays which are reaching the water body will be less compared to sunny days. So, cloudy days, the cloud cover will be preventing the amount of heat reaching the water body, so less amount of heat causes less evaporation.

So, sky conditions plays a major role, seasons, time of the day plays important role because evaporation in summers will be more than that of winters. Then we have seen the wind velocity, solar radiation, impurities present in the water, all these matter. But out of these, we need to find out all the factors, when we calculate the evaporation or compute evaporation we will not be able to make use of all these factors, so we will be prioritizing each and every one and will be considering only the important factors which are influencing the evaporation.

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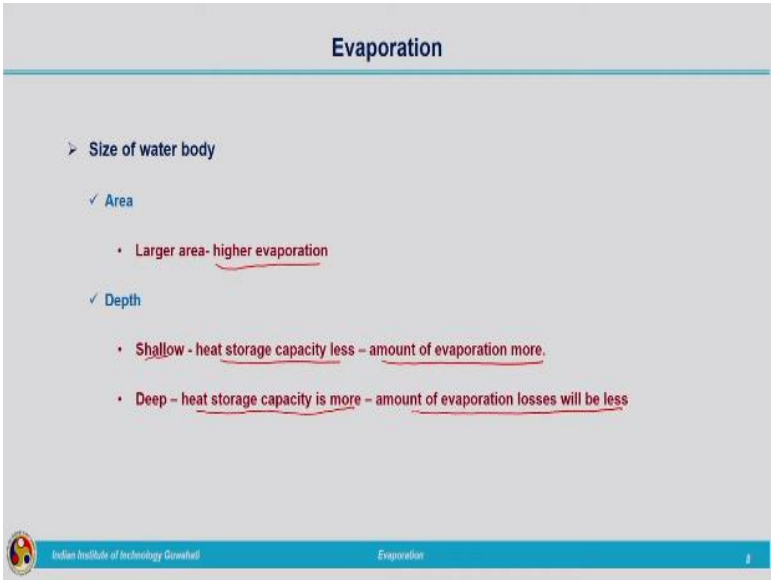

Next is the size of water body. Size of water body matters because you consider a large lake which is having a large surface area, so more area is exposed to sunlight, so the area

matters a lot. As the area is more, the evaporation also will be high. And in the case of depth, shallow depth, pond or water body, the depth is shallow, heat storage capacity of that particular water body will be less, so the amount of evaporation will be more and in the case of deep-water bodies, deep lake or whatever reservoir or any storage component, heat storage capacity is more, so, the amount of evaporation losses will be less.

So, the size and shape of the water body matters. How much is the area, large area evaporation rate will be more and in the same way as the depth is shallower, heat carrying capacity, storage capacity is less, so more evaporation will be taking place. If the depth is more, it can hold, get hold of more heat and it can store more heat and based on that the evaporation rate will be less.

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Now, we need to see different methods of estimating evaporation. So, method of estimating evaporation, these are three kinds,

1) Experimental methods,
2) Empirical equations, and
3) Analytical methods.

So, three different methods are there. We can go for experimental methods, if we are having the equipment for measuring the evaporation, we can make use of experimental

methods. Sometimes we would not be having all those facilities then we will be making use of empirical methods or analytical methods. So, we will see these methods one by one.

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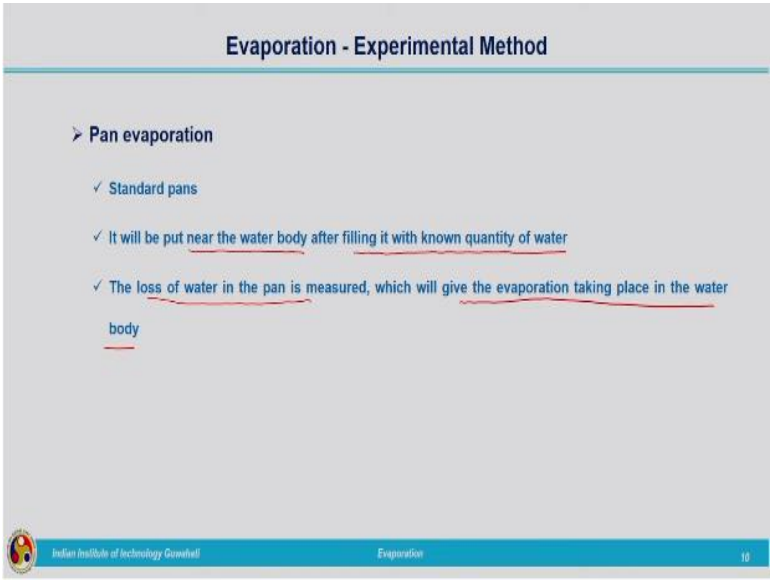

First let us start with experimental methods. First one is pan evaporation. Usually, for estimating evaporation we will be making use of standard pans, standard pans are available for the measurement of evaporation. So, what is meant by this, what is the working of this, it is a very simple measurement, simple way of experimentation. So, we are having standard pans and what we will be doing, we will be keeping or putting that near the water body where we need to measure the evaporation rate. For example, a particular lake is there, we need to evaluate the evaporation rate from that particular lake.

So, then what we will be doing, we will be installing these pan, standard pan near to the water body, after filling it with known quantity of water. Now, what we will be doing, we will be measuring the loss of water in the pan, how much amount of water is lost to the atmosphere, that we can find out by measuring the initial level and the final level in the pan. So, that will be indicating the evaporation taking place in the water body. So, this is the mechanism behind this particular experimental method. We are keeping a pan filled with known quantity of water and due to evaporation, some water will be lost to the

atmosphere, that amount will be measured, there will be measuring mechanisms within the pan itself.

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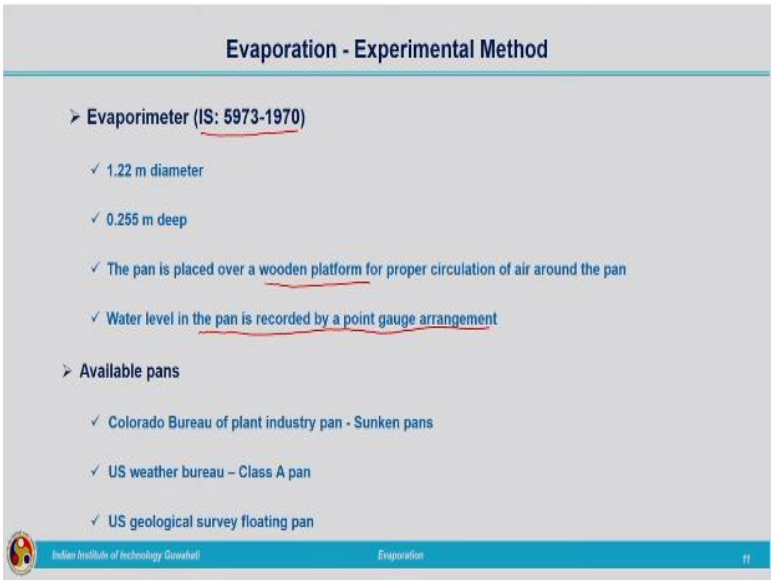

The pan which are commonly used in India is Evaporimeter, that is the IS code related to that is IS: 5973-1970. So, Evaporimeter is the standard pan according to IS code and it is having a diameter of 1.22 m and depth of 0.255 m. So, it is just like a circular tank, this pan is having a particular diameter, different types of pans will be having different dimensions. So, here this Evaporimeter is having 1.22 m diameter and 0.255 m depth.

What we will be doing, we will be placing this pan over a wooden platform. Why do we want to keep it on the wooden platform instead of ground surface? In order to have the proper circulation of air, otherwise it will be affecting the water which is getting evaporated because the heat circulation of energy would not be uniform. So, for that we would not be keeping on the ground, so we will be keeping on a wooden platform for proper circulation of air around the pan.

Water level in the pan is recorded by a point gauge arrangement, within the pan itself there is an arrangement with the point gauge that will be measuring the reduction in the

water level, that will be indicating the evaporation rate. Different pans are available, another one is Colorado Bureau of plant industry pan, this is commonly known as Sunken pans. Other one is U.S weather bureau - Class A pan and U.S geological survey floating pan.

Different types of pans are available, sometimes we will be keeping the pan near to the water body, sometimes this floating pan from the name itself it is very clear that it will be floating on the water body, so the same condition which are prevailing there on the water body can be attained for this particular pan also.

How can we calculate the lake evaporation? That is we have got the value from the Evaporimeter or evaporation pan, how much is the reduction taken place for the water level. So, once we get that, we can calculate the corresponding evaporation from the water body.

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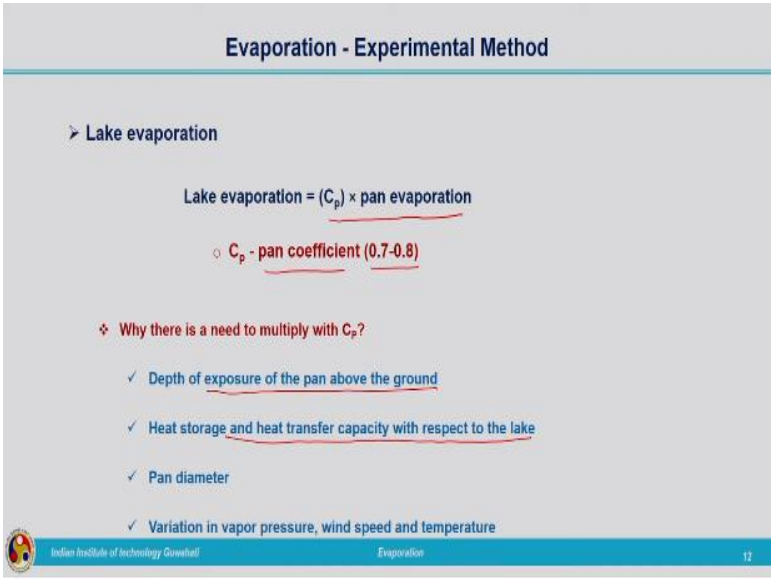

So, lake evaporation can be calculated by using the formula

Lake evaporation = C_p × pan evaporation

C_p – the pan coefficient, the value is varying between 0.7 to 0.8.

So, the pan evaporation is the value which is obtained, measured within the pan, how much is the reduction taken place in the water level within the pan.

Now, why do we want to multiply this pan evaporation with C_p for getting the lake evaporation? That is the next question, because we are multiplying with a factor less than 1, 0.7 to 0.8. I will tell you why there is a need to multiply with C_p because the depth of exposure of the pan above the ground, that is you can see we are keeping the pan on the ground or above the wooden platform so that depth of exposure matters, that is different from the water depth which is present in the water body and second reason is that heat storage and heat transfer capacity of this pan is different than that of the lake.

Definitely, water body will be having larger size and depth than that of this particular pan. So, the storage capacity and the heat transfer capacity of the pan will be different than that of the water body. Then the diameter of the pan, it is a certain standard dimension. Then variation in vapor pressure, wind speed and temperature. In the case of pans which are installed near to the water body the vapor pressure, wind speed, temperature which is experienced by the water within the pan may be different from the water body. We can attain the same parameters for the lake and in the case of pan when we are making use of the floating pans but other type of pans it will be different.

So, because of all these factors, material property of the pan, depth of exposure, heat storage and heat transfer capacity of the pan, all these makes the pan evaporation rate to be higher than that of the evaporation rate which is there available within the water body. So, that is why we would not be experiencing the same amount of evaporation as that of the pan that in the case of water body. So, we need to reduce that amount. That is why for a particular pan, considering all these factors a pan coefficient is defined. Evaporation rate which we are getting from the pan we will be multiplying it with the pan coefficient, that will be giving you approximate value of the evaporation taking place from the water body.

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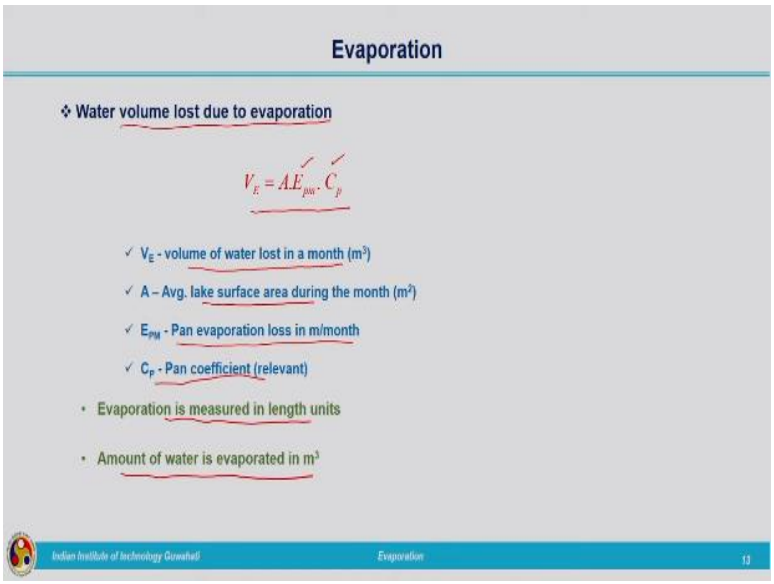

Then we need to calculate the volume of water lost due to evaporation. That is in the case of standard pans we are calculating the depth or rate. So, now what we are going to do, we are going to calculate the water volume lost due to evaporation, volume of water lost because that is very important, this much of volume is lost due to evaporation. So, whenever we are quantifying the water which is required for water supply and these losses will be represented in terms of volume.

So, water volume loss due to evaporation (V_E) can be calculated by using this formula,

$$V_E = A.E_{pm}.C_p$$

A is the average lake surface area (m^2) and V_E is the volume of water lost in a month (m^3). That time period may be depending on the problem, it may be month, it may be a day but the time period should be properly used, it should be same in the case of all the variables. E_{PM} is the pan evaporation loss in m/month and C_p is the pan coefficient. For that particular pan, what is the pan coefficient that value we will be taking and E_{PM} is the pan evaporation loss that can be in m or cm for that time period.

If you are considering for a month, within that entire month how much is the water loss, how much is the depth of water lost or how much is the depth of evaporation taken place. And A is average lake area, that will be changing, during summer months the area

exposed to heat energy, water level will be reducing, if it is not a uniform area and the uniform cross section the water is lost to the atmosphere will be causing the area to be reduced. So, average area surface area will be considered and V_E is the volume of water lost in a month. So, by making use of this simple formula, we can calculate how much is the volume of water which is lost due to evaporation.

So, first what will we need to calculate, we need to make use of the standard pans and we need to calculate the pan evaporation, how much is the value corresponding to pan evaporation. So, once pan evaporation loss is obtained, we can calculate the volume by considering the area of the lake or the water body.

This thing needs to be noted that is evaporation is measured in length units, evaporation rate we will be telling in length per time, that is when we were talking about the rainfall intensity it was in length per time, when we were talking about rainfall depth it was in the length unit. In the similar way evaporation will be represented in depth units, that is in the length units or evaporation rate when we talk about we will be expressing in terms of depth per time, that is the length per time unit. So, these units thing should be taken into account carefully.

So, now coming to the amount of evaporation water, that is amount when we talk about water is evaporated that will be in m^3, volume will be represented in terms of m^3, evaporation loss in depth will be represented in terms of m or cm, length units.

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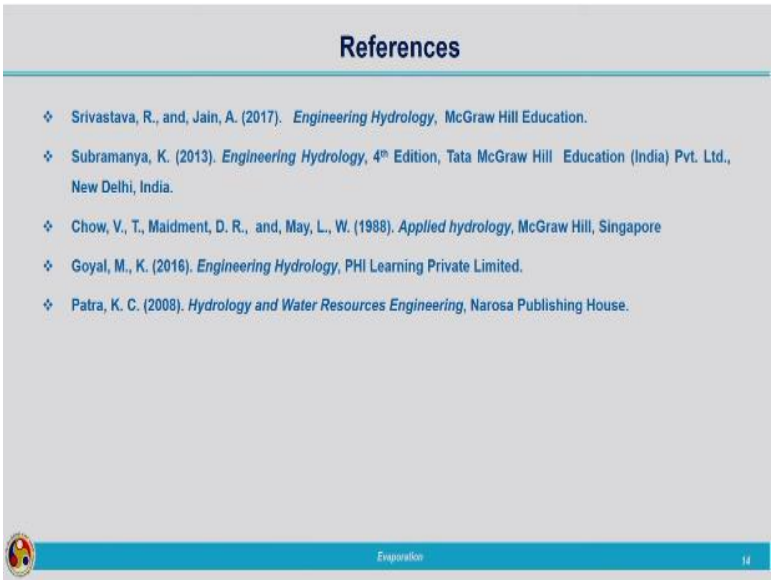

Now, regarding this topic these are the reference text books and here I am winding up this particular topic related to evaporation, factors influencing evaporation and we have seen the experimental method of measurement of evaporation. In the next lecture we will see other techniques how we can calculate the evaporation by using empirical equations and also analytical approaches, and some of the numerical examples also we will be solving in the coming lectures. So, here I am winding up today's lecture, thank you.