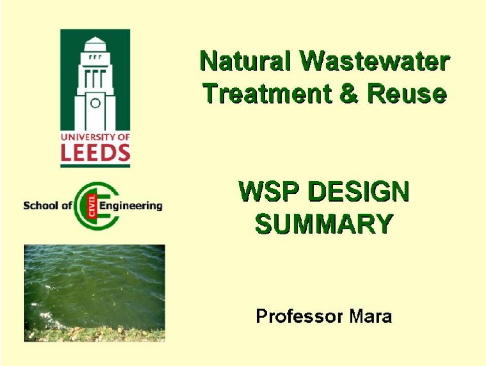
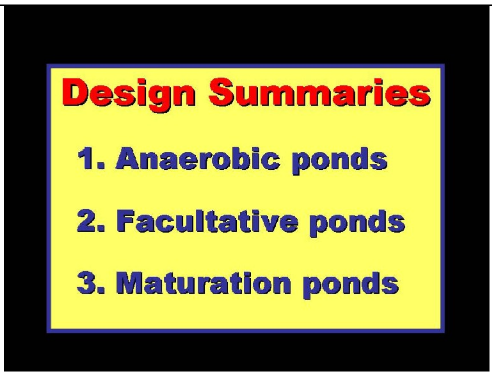
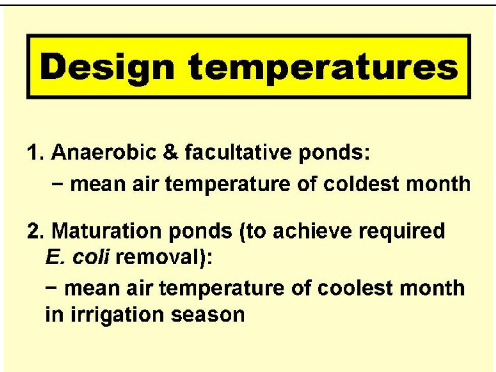
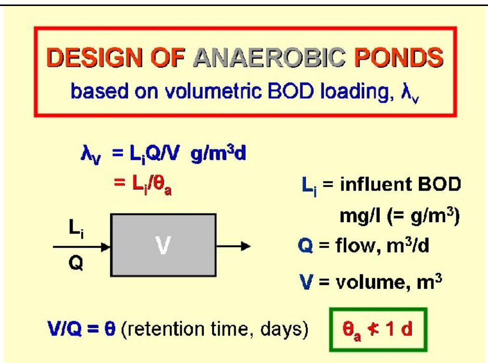
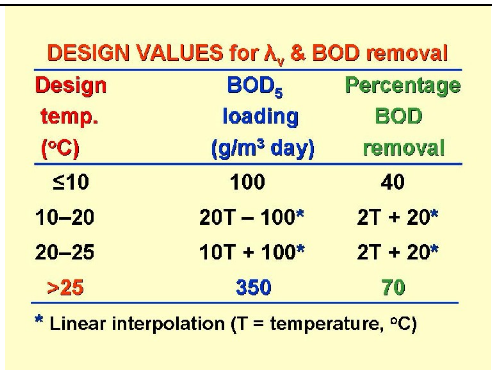
WASTE STABILIZATION PONDS 7
WSP design summary

1.		This presentation is a summary of the design procedures for …
2.		anaerobic, facultative and maturation ponds.
3.		But first, a reminder about design temperatures: For anaerobic and facultative ponds we use the mean temperature of the coldest month, and for maturation ponds we use the mean temperature of the coolest month in the irrigation season.
4.		Now anaerobic ponds, and we design these on the basis of volumetric BOD loading, λ_v which is expressed in units of g/m^3 day. So, if L_i is the influent BOD in mg/l (which is the same as g/m^3), Q is the flow in m^3/day and V is the volume in m^3, then: $\lambda_v = L_iQ/V$ or, since V/Q is the mean hydraulic retention time θ_a, $\lambda_v = L_i/\theta_a$ The value of θ_a should not be less than 1 day.

5.



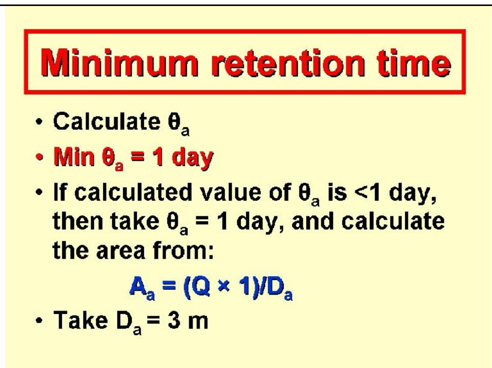
DESIGN VALUES for λ_v & BOD removal

Design temp. (°C)	BOD_5 loading (g/m³ day)	Percentage BOD removal
≤10	100	40
10–20	20T – 100*	2T + 20*
20–25	10T + 100*	2T + 20*
>25	350	70

* Linear interpolation (T = temperature, °C)

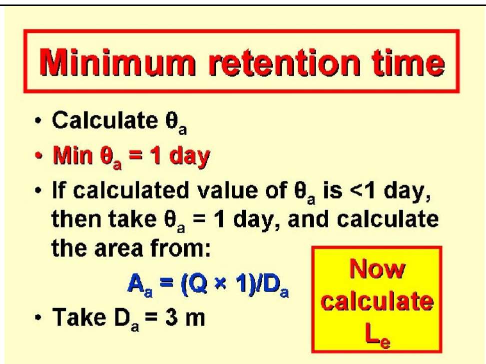
This table gives the design values of λ_v. They are: 100 g/m^3 day at 10°C and below; 200 at 15°C; 300 at 20°C; and 350 at 25°C, with linear interpolation in between. The BOD removals that we assume in our design are 40% at 10°C and below; 50% at 15°C; 60% at 20°C; and 70% at 25°C, again with linear interpolation in between.

6.



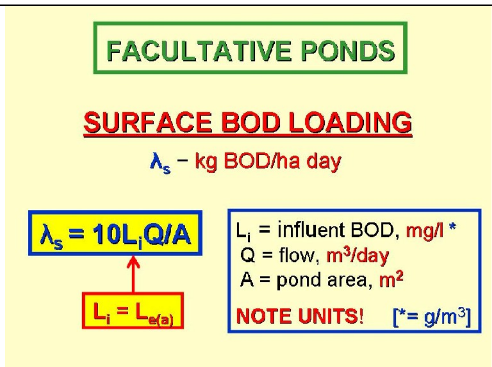
We must remember that the minimum retention time in an anaerobic pond is 1 day. So if our calculated value of θ_a is <1 day, we have to use a value of 1 day and recalculate the area, as shown on the slide, assuming a depth of 3 m.

7.



Now we calculate the value of L_e, the BOD of the effluent from the anaerobic pond. We know the raw wastewater BOD and the percentage BOD removal, so it's a simple matter to calculate L_e.

8.

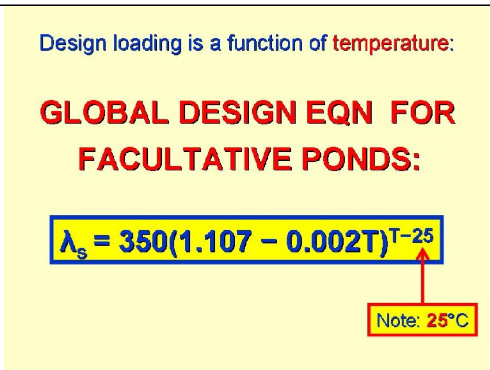
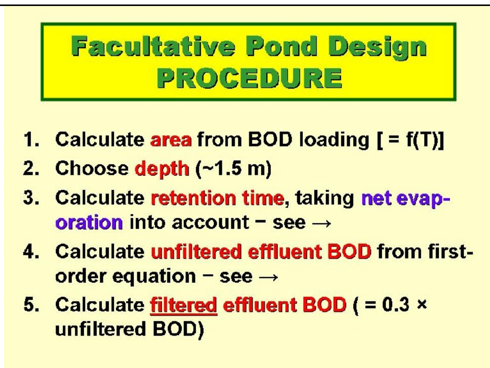
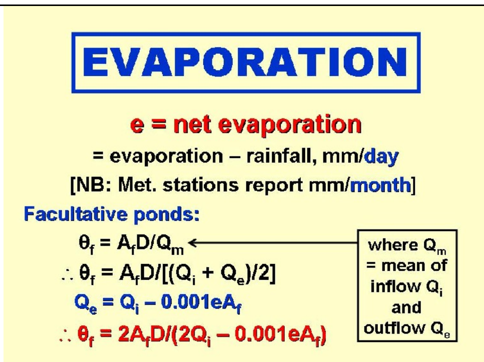
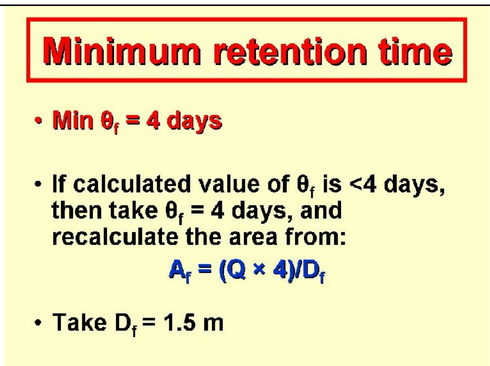


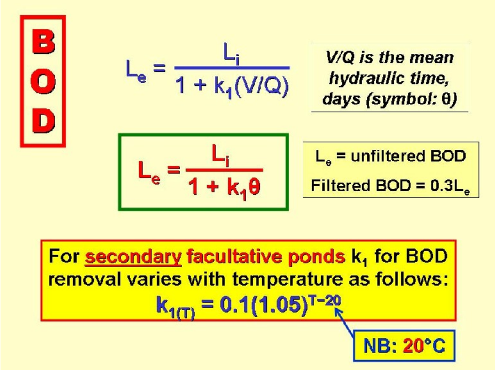
With facultative ponds, it's the **surface** area that's important as the light from the sun (which the algae need to power their photosynthetic activities) arrives at the pond's surface. So we design facultative ponds on the basis of a surface BOD loading, λ_s expressed in kg of BOD per ha per day.

If L_i's in mg/l, i.e. g/m^3, Q's in m^3/day and A, the area, is in m^2, then:

$$\lambda_s = 10 L_i Q / A$$

We end up with a '10' in this equation as there are 10^3 g in a kg and 10^4 m^2 in a ha.

9.		The value of λ_s that we use depends on the design temperature, as given by this global design equation. This is based on a value of 350 kg/ha day at 25°C (from our experience in northeast Brazil), 80 kg/ha day at 8°C and below (from experience in winter in the UK, France and New Zealand), and on an arbitrary value of 500 kg/ha day at 35°C.
10.		This is the procedure we follow when designing a facultative pond: First, we calculate the area from the equation for λ_s (which is, as we have just seen, a function of the design temperature). Second, we choose a depth, and this is usually 1.5 m. Next, we calculate the retention time, taking net evaporation into account, and I'll come to this in a moment. Then we calculate the unfiltered effluent BOD from a first-order equation, and again I'll describe this in a moment. Finally we calculate the filtered, that is to say the non-algal, BOD of the effluent as 30% of the unfiltered value.
11.		Net evaporation is evaporation minus rainfall, both expressed in mm/day. The equations on the slide basically say that the retention time, θ_f, is the volume divided by the flow, with the volume written as area × depth. But the flow is the mean flow, the mean of the inflow and the outflow; and the outflow is the inflow minus the losses due to evaporation, and these are 0.001 × *e*, the net evaporation in mm/day × the facultative pond area in m^2.
12.		The minimum retention time in a facultative pond is about 4 days. So if our calculated value of θ_f is <4 days, we have to use a value of 4 days and recalculate the area, as shown on the slide, assuming a depth of 1.5 m.

<table>
<tr>
<td>13.</td>
<td>
</td>
<td>This is how we calculate the unfiltered BOD of the facultative pond effluent. We use the first-order equation shown in the red box, with k_1 varying with temperature, as follows:

$$k_{1(T)} = k_{1(20)}(1.05)^{T-20}$$

The value of k_1 at 20°C is 0.1 day^{-1} in secondary facultative ponds, and 0.3 day^{-1} in primary facultative ponds.</td>
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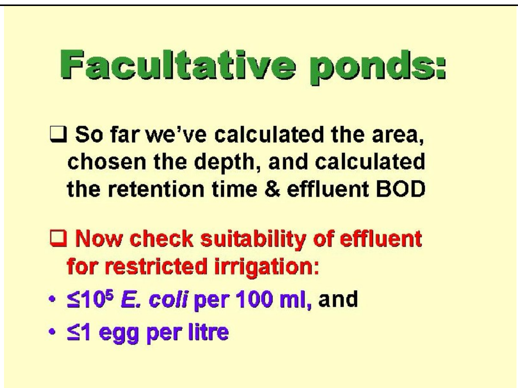
<td>14.</td>
<td>
</td>
<td>So far we've calculated the area, chosen the depth, and calculated the retention time and effluent BOD.

What we should do next is to check if the facultative pond effluent can be used for restricted irrigation. For this we generally need an effluent quality of:[*]

≤10^4 *E. coli* per 100 ml, and

≤1 human intestinal nematode egg per litre.

[*See the presentations on Wastewater Reuse for details.]</td>
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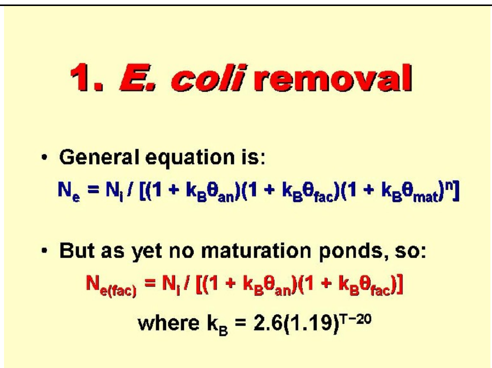
<td>15.</td>
<td>
</td>
<td>This is the general equation for *E. coli* removal in a series of anaerobic, facultative and maturation ponds. But, at this stage in our design, we don't have any maturation ponds, so we use this simpler version which covers just the anaerobic and facultative ponds.</td>
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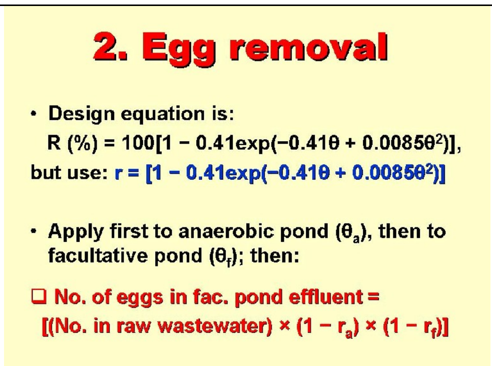
<td>16.</td>
<td>
</td>
<td>The removal of helminth eggs is by sedimentation and the percentage removal R is a function of the retention time in each pond, as shown in the equation in black. But it's simpler to use r as given by the equation in blue, so that the numbers of eggs per litre of facultative pond effluent is given by their number in the raw wastewater × $(1 - r_a)$ × $(1 - r_f)$, where r_a and r_f are the r values for the anaerobic and facultative ponds, respectively.</td>
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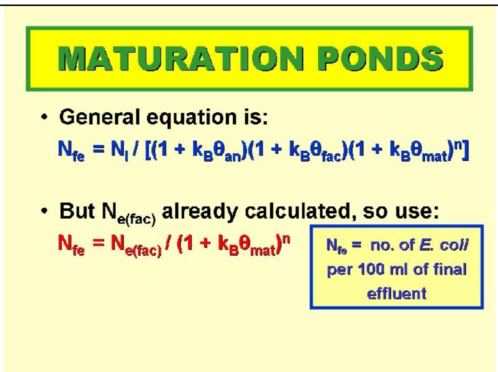
17.



Now maturation ponds. We've already worked out the number of *E. coli* in the facultative pond effluent, so we can use a simpler form of the general equation:

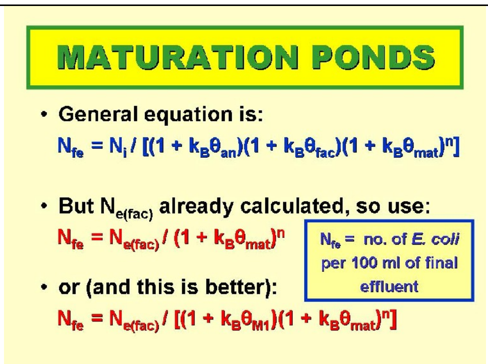
$$N_{fe} = N_{e(fac)}/(1 + \theta_{mat})^n$$

where N_{fe} is the number of *E. coli* per 100 ml of final effluent, $N_{e(fac)}$ their number per 100 ml of the fac. pond effluent, k_B is the first-order rate constant for *E. coli* removal in day^{-1} given by:

$$k_B = 2.6(1.19)^{T-20}$$

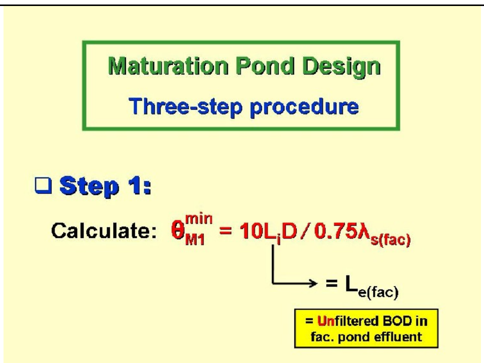
and θ_{mat} is the retention time in each of the n maturation ponds.

18.



A better version of this equation is now shown at the bottom of the slide; it includes a term for the first maturation pond and, as we will see in just a moment, this is very important.

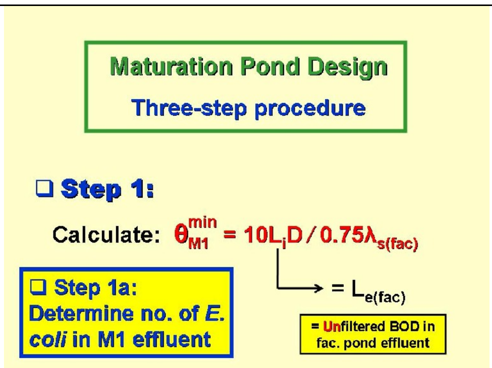
19.



We use a three-step procedure for the design of maturation ponds.

Step 1 addresses the constraint that the BOD loading on the first maturation pond should be no more than 70% of that on the facultative pond. This version of the λ_s equation gives us the minimum retention time in M1, the first maturation pond, which ensures that the BOD loading constraint on M1 is satisfied.

20.



Actually we would now normally check to see if the effluent from M1 has a low enough *E. coli* count for restricted or even unrestricted irrigation.

21.	**❑ Step 2:** Calculate retention time in second & subsequent maturation ponds: $\theta_m = \{[N_{e(fac)}/N_{fe}(1 + k_B\theta_{M1})]^{1/n} - 1\}/k_B$ now the retention time in M2, M3 etc. Solve for n = 1, 2, 3 etc. and **STOP** when $\theta_m < \theta_m^{min}$ (= 3 days) – assume this happens when n = ñ	**Step 2** is to calculate the retention time in the second and subsequent maturation ponds, and we solve the equation on the slide first of all for $n = 1$, then for $n = 2$, and so on until our calculated value of θ_m is less than θ_m^{min} (i.e., <3 days) and we'll assume this happens when $n = \tilde{n}$.
22.	**❑ Step 3:** Choose most appropriate combination* of θ_{mat} and n, including θ_{mat}^{min} and ñ * ie, the one for which their product is a MINIMUM, as this gives the least land area requirement	In **Step 3** we choose the most appropriate combination of n and θ_m, including $\tilde{n}$ and θ_m^{min}. This is the combination for which their product (that is to say, $n \times \theta_m$) is a minimum as this gives us the smallest land area requirement.
23.	**❑ Step 3:** Choose most appropriate combination* of θ_{mat} and n, including θ_{mat}^{min} and ñ * ie, the one for which their product is a MINIMUM, as this gives the least land area requirement Now calculate the maturation pond areas taking evaporation into account	We now calculate the areas of the maturation ponds, taking net evaporation into account.
24.	For facultative ponds we had: ▪ $\theta_f = A_fD/[(Q_i + Q_e)/2]$ ▪ $Q_e = Q_i - 0.001eA_f$ ① ∴ $\theta_f = 2A_fD/(2Q_i - 0.001eA_f)$ ② For maturation ponds, rearrange ②: $A_m = 2Q_i\theta_m/(2D_m + 0.001e\theta_m)$ ❖ Q_i = effluent flow from preceding pond (use ① above) ❖ Take D_m = 1 m	And we do this by rearranging the equation we had before for facultative ponds. Basically we rearrange equation ② to express it in terms of A, which is now A_m, as shown in the yellow box on the slide. The value of Q_i that we use in this equation is the outflow from the preceding pond (i.e., from the fac. pond in the case of M1, or from M1 in the case of M2, and so on), and this is given by equation ① on the slide. Normally we take the depth of the maturation ponds as 1 m.