











Aquacultural Use of Wastewater

1.	 <p>Natural Wastewater Treatment & Reuse</p> <p>WASTEWATER USE IN AQUACULTURE</p>   <p>Professor Mara</p>	<p>This presentation is on wastewater use in aquaculture, specifically growing fish in wastewater-fed fishponds.</p>
2.	<p>Aquaculture</p> <ul style="list-style-type: none"> ❑ The farming of aquatic organisms, including fish, molluscs, crustaceans and plants. ❑ Most aquaculture occurs in the developing world and involves the production of freshwater fish low in the food chain, such as tilapia or carp. 	<p>Aquaculture means ‘water farming’, just as agriculture means ‘field farming’, and so we’re talking about the farming of aquatic organisms such as fish, but also molluscs, crustaceans and plants. However, in developing countries, especially those in Asia, aquaculture is most commonly the production of freshwater fish that are quite low in the food chain – for example, tilapia and carp.</p>
3.	 <p>Aquaculture in northern Europe: Salmon farming in net-cages</p>	<p>Aquaculture occurs in all parts of the world, and this slide shows salmon farming in cages in a seawater loch on the west coast of Scotland.</p>
4.	 <p>Wastewater-fed Aquaculture</p>  <p>Nile tilapia</p>	<p>But it’s wastewater-fed fish culture in developing countries that we’re going to consider in this presentation.</p>

5.	 <div data-bbox="352 197 746 454" style="border: 1px solid blue; padding: 5px;"> <p>❑ Most people in SE Asia get most of their animal protein from fish grown in wastewater- or excreta- fertilized fishponds</p> <p>❑ So wastewater- and excreta-fed aquaculture is extremely important in terms of global food supply</p> </div>	<p>And this is very important as most people in southeast Asia, the most densely populated part of the developing world, get most of their animal protein from fish grown in wastewater- or excreta-fertilized fishponds, so in terms of global food production this process is hugely important.</p>
6.	<div data-bbox="320 568 778 667" style="background-color: yellow; border: 2px solid blue; padding: 5px; text-align: center;"> <h3>Wastewater-fed fishponds – design</h3> </div> <div data-bbox="328 703 515 880" style="margin-top: 10px;"> <p>DESIGN AIM: minimal treatment of wastewater with maximal production of microbiologically safe fish</p> </div> <div data-bbox="531 703 786 880">  </div>	<p>We're going to look at the design of a wastewater-fed fishpond system, and our design aim is the <i>minimal</i> treatment of the wastewater with <i>maximal</i> production of <i>microbiologically safe</i> fish.</p>
7.	<div data-bbox="328 990 770 1093" style="text-align: center;"> <p>Guidelines for microbiological quality of treated wastewaters used in</p> <p>AQUACULTURE</p> </div> <p>Principal health risks are:</p> <ol style="list-style-type: none"> 1. TREMATODES (not nematodes): <i>Schistosoma</i> spp, <i>Clonorchis sinensis</i> and <i>Fasciolopsis buski</i> 2. Faecal bacteria 	<p>The 2006 WHO guidelines for wastewater use in aquaculture are concerned with the eggs of trematode worms, in particular schistosome eggs and those of <i>Clonorchis sinensis</i>, the Oriental liver fluke, and <i>Fasciolopsis buski</i>, the giant intestinal fluke; and also with faecal bacteria.</p>
8.	<p>Massive asexual multiplication in snail host, so guideline quality has to be:</p> <p>❑ ZERO viable trematode eggs per litre of treated wastewater,</p> <p>And also, to prevent transmission of bacterial infections (WHO 2006 guidelines):</p> <p>❑ ≤1000 <i>E. coli</i> per 100 ml of fish pond water</p>	<p>Now there's massive asexual multiplication of the trematodes in their first (or only) aquatic host which is a freshwater snail; so the guideline quality has to be zero viable eggs per litre of treated wastewater. And to prevent the transmission of bacterial infections, there should be no more than 1000 <i>E. coli</i> per 100 ml of the water in the fishpond.</p>

9.	<p>DESIGN PROCEDURE</p> <ol style="list-style-type: none"> 1. Design an anaerobic and a secondary facultative pond for minimal treatment of the wastewater 2. Calculate the concentrations of total nitrogen and ammonia-nitrogen in the fac. pond effluent 3. Calculate the fishpond area and retention time: 	<p>The design procedure we use is as follows. First, we design an anaerobic pond and a secondary facultative pond in the normal way, and we then calculate the concentrations of total nitrogen and ammonia nitrogen in the facultative pond effluent. For these calculations we use Reed's equation and the Pano & Middlebrooks equation, and details of these (and all the other equations) are given in the Design Summary document for this presentation.</p>
10.	<p>FISHPOND</p>  <p>Design criterion: $\Lambda_s = 4 \text{ kg total N / ha d}$</p> <p>Too much N: too much algal biomass → risk of deoxygenation at night and consequent fish kills</p> <p>Too little N: too little algal growth → low fish yields</p>	<p>Next, we design the fishpond, which receives all the fac. pond effluent; and the design criterion we use is a total nitrogen loading of 4 kg per ha per day. If there's too much nitrogen, then there's a correspondingly high concentration of algal biomass and therefore risks of deoxygenation at night and thus fish kills.</p> <p>And if there's too little nitrogen, then we get low fish yields.</p>
11.	<p>Design procedure, cont.</p> <ol style="list-style-type: none"> 5. Determine fishpond area: $A_{fp} = [10 \times \text{conc. of total N in fac. pond effluent} \times \text{flow}] / [4 \text{ kg total N/ha d}]$ 6. Determine θ_{fp} taking net evaporation into account 7. Check the <i>E. coli</i> level in the fishpond This must be ≤ 1000 per 100 ml 	<p>So the fishpond area in m^2 is given by $10 \times$ the concentration of total N in the fac. pond effluent, which is the fishpond influent, in $\text{mg/l} \times$ the flow in m^3/day, divided by 4, the total N loading in kg/ha day.</p> <p>We then calculate the retention time in the fishpond, taking net evaporation into account; and then we determine the <i>E. coli</i> count in the fishpond, and this must be no more than 1000 per 100 ml.</p>
12.	<p>Design procedure, cont.</p> <ol style="list-style-type: none"> 8. Check the concentration of ammonia-N in the fishpond 9. Determine the percentage of the total ammonia-N present as 'free' ammonia – i.e., dissolved ammonia gas (NH_3); then determine conc. of free ammonia in the fishpond This must be $\leq 0.5 \text{ mg N/l}$ to avoid fish toxicity. 	<p>Next we calculate the concentration of ammonia-N in the fishpond, using the Pano & Middlebrooks equation; and then finally we determine the percentage of this that is 'free' ammonia, i.e. dissolved NH_3 gas, so that we can then calculate the concentration of free ammonia in the fishpond, and this has to be no more than 0.5 mg N/l in order to avoid any toxicity to the fish.</p>
<p>Note: Design details (including all required equations) are given in <i>The Design of Wastewater-fed Fishponds: A Summary</i>, which is available in 'Supporting material'.</p>		

<p>13.</p>	<p>KOLKATA, INDIA ~3,000 ha of fishponds ~555,000 m³ wastewater per day</p> 	<p>This slide shows some of the wastewater-fed fishponds in Kolkata in India. All of the city's wastewater, some 550,000 m³/day, is used to feed around 3000 ha of fishponds, and these produce just under 20% of the fish consumed in the city.</p>
<p>14.</p>	 <p>Kolkata</p> <p>FISH YIELDS</p> <p>Fish grown:</p> <p>(a) India major carp <i>Catla catla</i> <i>Cirrhinus mrigala</i> <i>Labeo rohita</i> ("catla, mrigal & roho")</p> <p>(b) Tilapia <i>Oreochromis mossambicus</i></p>	<p>The fish they grow are mainly three species of Indian major carp, with some tilapia as well.</p> <p>The slide shows the fish being harvested. This is normally done at around 5 o'clock in the morning, to get the fish to the markets early in the day.</p>
<p>15.</p>	<p>Stocking density: 3 fingerlings (~20 g)/m² In three months these grow to 150–250 g (say, 200 g).</p> <p>Allow for a 25% loss (poaching, consumption by fish-eating birds, mortality):</p> <p>❑ yield per harvest = 28 t from 6.25 ha</p> <p>❑ 3 harvests per year → 13 t/ha year (probably closer to 10 t/ha yr)</p> <p>❑ Average yield in Kolkata = ~4–5 t/ha yr, but ~8–9 t/ha yr in better managed ponds</p>	<p>The ponds are stocked with fingerlings, which weigh around 20 g, at a density of ~3 per m², and in three months these grow to 150–250 g – not a large size, but they are sold at a price the poor can afford.</p> <p>Allowing for a 25% loss, due to poaching, death and consumption by fish-eating birds, the yield per harvest is just over 4 tonnes per hectare. With three harvests per year, the yield is ~13 t/ha per year, although it'll usually be closer to 10 t/ha year. The actual average yield in the Kolkata ponds is 4–5 t/ha year overall, but the better managed fishponds produce 8–9 t/ha year.</p>
<p>16.</p>	<p>GIFT: 'Genetically Improved Farmed Tilapia'</p> <p>~75% faster growth</p> <p>The future of wastewater-fed aquaculture</p>  <p>Normal tilapia</p> <p>GIFT</p>	<p>GIFT stands for 'genetically improved farmed tilapia', and the GIFT strain of tilapia, which was developed by very careful selective breeding of wild and farmed strains, grows ~75% faster than non-GIFT strains, so really it has to be the future of wastewater-fed aquaculture, although (somewhat curiously) very little work has yet been done on growing the GIFT strain in wastewater-fed fishponds.</p>

17.

Integrated agriculture and aquaculture

- In Kolkata the effluents from the wastewater-irrigated fishponds are used to irrigate rice paddies (and vegetables near the fishponds)
- China: integrated ag. & aq. reuse practised for 1000s of years



FAO, 2001

Integrated agriculture and aquaculture is also clearly important as the wastewater is used twice: first in aquaculture, and then secondly using the fishpond effluent for crop irrigation. In Kolkata, for example, the fishpond effluents are used to irrigate rice paddies; and in China the integration of aquaculture and agriculture has been practised for around 4000 years.