Research developments in the onsite treatment of wastewater

Dr. Edmond O'Reilly,
National University of Ireland, Galway

So I am going to talk briefly about some research developments in onsite wastewater treatment, particularly looking at areas that we are working in in Galway. I will look at the background, although I think a lot of the background has been covered already. So I will skip over that. I will talk a little bit about nutrient removal, nitrogen, phosphorus. Onsite disinfection is getting more and more important. I will then speak about the research facility that we have developed in Tuam in County Galway, that Paul just mentioned there, and how that has led to technology development in the area of onsite wastewater treatment.

So the background, a lot of this has been gone through before. So I will just skip through it. A couple of points here on this slide. From our point of view one of the main drivers in the research side is to provide technologies that can treat for nitrogen and phosphorus and sometimes pathogens, and particularly where houses are abstracting water for drinking very close to where their wastewater system is located. A big area is the need for low maintenance and low energy systems, and cost effective systems that can meet the standards required. Looking at nitrogen removal, again this has been covered in more detail by others here, by Vincent in particular. So a two-stage process, nitrification and then denitrification. So the main thing here is that the denitrification process generally requires an electron donor in the form of carbon. I suppose this happens generally speaking within the wastewater treatment system. But it can also occur in the percolation systems. And that work is ongoing elsewhere. Although the carbon can be limited in these areas. The package systems can be developed and can be designed that you can include an anoxic phase, a denitrification phase within the process. However, where carbon is a problem, or where you don't have enough carbon in terms of BOD, we have to look at other methods there. So one technology in particular that we have developed, is called the horizontal flow biofilm reactor or HFBR. And this has been developed and patented within NUI Galway, work led by Michael Rogers, over the last number of years.

So the system comprises a stack of horizontal sheets. Two thirds of the influent is pumped on to the top sheet and allowed to flow down from the top sheet down through the system. Biofilm grows on these sheets then. And in the first section there, you will see the area labelled carbon removal. You get your BOD removal in those sheets. As the wastewater passes through the second set of sheets the carbon is gone, which is crucial for nitrification to occur. So generally speaking ammonium won't be reduced until the carbon has been depleted to a certain level. So you get nitrification occurring in the middle section of the reactor there. And by the end of the middle section you

have your effluent which is currently high in nitrate and very low in carbon. So you want to incorporate some conditions or develop some conditions where you can get denitrification to occur. And this is achieved by including or step feeding one third of the influent at this point. So what you are doing here, you are developing anoxic conditions, and dissolved oxygen has been reduced dramatically as raw influent is being introduced. And two, you are introducing carbon for denitification to occur. So in the section of sheets there, at this point, you are getting denitrification occurring. And then the remaining sheets then you would nitrify any remaining ammonium that may be in the influent.

So there's a number of advantages to this type of system. The main one is that you have only a very small pump involved. So that pumps periodically to the top sheet and to the step feed point. So it's very low energy, very low maintenance. You can have a situation where you have no pump, and you can control the flow into the system. And in that case you have no energy requirement.

You can install a system for a number of different conditions. For pure carbon removal, the system is very straightforward. You can have nitrification as I described, and then also a step feed for denitrification. So with the step feed mechanism the carbon is used as the electron donor, as we described there. So total costs range from €0 where you are not using a pump to about €20 per year, where you are using a pump. So it's a very cheap system to run.

And just I suppose a comparison there to other systems that are available. In terms of BOD there in the centre columns, you are looking at a 97% removal rate of BOD, which compares very well with other systems. But I think the main thing there to take is the loading rate which is quite high, 141 grams per sq.m. per day. So that would mean that your system can be very compact and requires a lower footprint than other systems.

Similarly with total nitrogen the removal is about 61%-62%. Your ammonium leaving the system is generally less than 1, even lower. But again the same point applies there, that you have a relatively high loading rate, so you have quite a compact system.

So this system has been licensed now to an Irish company which we hope to commercialise in the European and American markets. So as I mentioned there earlier on, that if carbon is limiting, we are looking at work currently where we are using additional carbon sources within wastewater treatment to effect denitrification. Some of these include organic media such as woodchip, biopolymers which will release organic carbon over time, cardboard and other such media. Also autotropic denitrification where you are using a sulphur based media as the carbon source….or sorry as the electron donor in the denitrification process.

So you can use these alternative media in a number of different parts of the treatment process. So we have our septic tank there in the first box here and our settled wastewater. As that's passing through the secondary treatment system, you have your traditional system, you can then incorporate your new biodegradable media within the system. So you are providing a carbon

source if it's needed there, if carbon is low entering the system in the first place. Alternatively you can have a dedicated denitrifying reactor, where effluent from your secondary system can be applied to these denitrifying filters in effect. And finally, that you have your effluent, where you can get further treatment with these filters. So areas that we need to consider here is the cost of the media. If the media has a high cost it's not going to be taken on. How often do you have to replace the media? Because it will have a certain lifespan as the carbon is being released. It's a finite supply of carbon that you are providing.

The ease of reactor operation, so here you could be looking at needing to recirculate the water within the dedicated reactors, the denitrifying reactors. And this can then lead to higher costs of operation. So all these areas need to be looked at. But the fundamentals are there, that we can provide an organic material if carbon is limiting.

Looking then at phosphorus. I am not going to go into too much detail here. We have seen how the need to remove phosphorus can be required. So you are looking at biological removal in the form of plant growth. So removal here can be limited. And it's reliant on plant growth in effect, and the removal of that growth from the location where it's grown. Alternatively you can look at a physical or chemical removal process, namely through absorption. So I have mentioned wetlands here. I won't go into wetlands. Because that's being spoken about tomorrow. But we have also looked at absorption technologies where you have a high capacity media that can take up P to a very high extent. Issues here then are the cost of that media, again how often do you have to replace the media, can you generate this media? And is it applicable to single house systems or small scale systems due to this cost?

So pathogen removal, again we have had talk of that again today. So the challenges here, the provision of cost effective systems. I suppose these can be expensive in certain cases. The cost of monitoring is also an issue here, that you know usually monitoring occurs in laboratories which can be often times expensive. A necessity for high quality upstream treatment, that's also an issue, and I will speak about that a little bit more later on.

So UV technology, sand, soil filtration, wetlands. I will skip on then to the water research facility which we developed over the last I suppose four or five years at this stage, with EPA funding, myself, Eoghan Clifford and Michael Rogers. So the site is in Tuam, Co. Galway. And we, as I say, got funding from the EPA and we also got considerable support from Galway County Council. The site is on the Tuam municipal wastewater treatment plant. So we take in a portion of their influent, their raw influent and we pump it to our primary tanks. We then treat the influent onsite using currently our own technology, which is the pump flow biofilm reactor. And I will speak about that in another minute or two if I have time. We also have a tertiary treatment system there where we can trial tertiary technologies onsite. We have a control cabin where we control the whole site and we can interrogate that remotely. We also have space onsite for testing of pilot scale systems.

So in effect there you have access to wastewater at every different stage of the treatment process. You have raw influent, you have settled, primary wastewater in settlement tanks, you have secondary effluent, you have tertiary effluent. And this allows you to gain access to water at the different stages when you are testing particular technologies. And we have found ourselves over the last number of years that you can test these systems to death really in the laboratory, but it's only when you go out onsite that you really learn how the system is going to work. And a site like this provides you that facility.

So there's the controls which we can interrogate remotely and log all the data onsite. That's the tertiary system which is a plug and play system, and we can incorporate a number of different filters. So I have made that point already there.

So then in-house technologies. I have mentioned the horizontal pump flow biofilm reactor…or sorry, the horizontal flow biofilm reactor. Also the pump flow biofilm reactor which is for larger populations. Again the water research facility enabled us to develop this technology further by carrying out full scale trials before it was installed at sites. And currently it's installed in a site in Co. Offaly, in Moneygall.

Another technology is air suction flow biofilm reactor, which we are in the developmental stage. And we also are looking at new sampler technologies and also sensors and wastewater treatment plant controls. And again all this work can be carried out at the research facility in Tuam.

So I have spoken about the HFBR. Then something small about the PFBR, to give an example of how technology development ultimately gets to the final stage. And in this case it's the full scale installation at Moneygall, Co. Offaly. We installed a 750 PE plant. I know it's slightly off topic. It's a collaboration between ourselves, NUI, Galway, Molloy Precast and Offaly County Council. And that's the system as it currently stands in Moneygall, where it's treating wastewater from the village and discharging to a local stream. One of the main advantages here is the low energy requirement. Because we are not pumping air into the system the energy requirement is vastly reduced. Low maintenance, the only moving parts in the system are pumps. So that's the only maintenance requirement on that. It has a low sludge yield as it's an attached growth process. And a low sludge yield is a common advantage there. And ease of operation, you are just pumping water, so that's the essential control element of the system.

So some results then from the initial stage of operation. And it's in operation for about two months now. And we are getting very high BOD removal, 98%, solids removal 97%. We are getting good nitrification. Effluent is about 3 at the moment and we plan to improve that through a number of studies we are going to carry out. Some of that study will involve the incorporation of an anoxic phase within the system to reduce the total nitrogen there from 10 down to lower than that.

Estimated load is 578PE. And that's being operated at about €3.60 per person per year. So it's a relatively low cost in terms of energy usage. So then to finish up then on some …I suppose a possible focus for further research. With nitrogen removal, the use of passive technologies with the step feed, to achieve nitrogen removal, I think is an important area to look at. Another area is, when I talk about a carbon source for denitrification, one area can be the use of primary settled solids. Mark spoke about recirculating nitrate back into the primary tank. This might be a variation where you are bringing the sludge from the primary tank into a dedicated denitrification zone, thereby introducing your carbon. The use of biodegradable polymers is also another area for carbon denitrification …or as a carbon source for denitrification. Phosphorus then, I think significant work is required for the absorption processes to scale down and to make it cost effective in its pure sense. The use of wetlands is obviously an area here which is being looked at and will be spoken about I think tomorrow. Biological removal then is also another area that requires further development. Pathogen removal, technology combinations here can achieve disinfection of wastewater here. But again work needs to be done on how cost effective this can be, and we have been working at this at the research facility in Tuam. I have just some examples here which I am not going to go through, but it gives an idea of the technology that's carried out, a lot of it in Tuam, and some in the laboratories in Galway.

And I believe that these slides will be available after the conference, and that people can flick through them in their own time and see examples of the research being carried out, and the funders.

These are I suppose the people we work with in terms of funding. I am not going to leave it up for long, because I know I have forgotten people in it. But again it can be looked at there. So thanks very much for your attention.