A unique full scale water research facility for applied and fundamental research, technology development, education and public outreach

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Abstract

At present in Europe, there is a need, driven mainly by EU environmental legislation, for sustainable, robust and economic water, wastewater and sludge treatment technologies. Furthermore these technologies are required to be increasingly energy efficient, employ new monitoring and control techniques and have reduced maintenance. This will present many opportunities for the water and wastewater industries, cognate companies and research organisations. Local authorities, universities and other stakeholders will also be required to educate and train students and staff in the use and operation of new technologies.

To meet these challenges NUI Galway, with funding from the EPA, and support from Galway County Council, have developed the NUI Galway/EPA Water Research Facility (WRF). The WRF is a full-scale test bed for innovative wastewater and water treatment technologies and comprises a full-scale wastewater treatment plant (treating up to 50 m^3/day), a tertiary treatment facility (treating up to 2 m^3/hr) capable of supporting a number of technologies such as automatic sand filtration, activated carbon systems, chlorine dosing, UV etc., and remote operating, monitoring and control processes.

Keywords

Water Research Facility, WRF, educational facility, full-scale test bed, technology development, water and wastewater infrastructure

1. Introduction

Water and wastewater technologies are required to comply with the stringent regulations such as the the EU Water Framework Directive and the Drinking Water Directive (2000/60/EC; 98/83/EC) while (i) being energy efficient (ii) have low maintenance and (ii) have low operation requirements (Boller et al, 1997). In developing, and developed countries, pollution, over-exploitation of natural resources, damage to aquatic ecosystems and population changes are driving the demand for new technologies, public awareness and the education of highly skilled water professionals. Worldwide over 1.2 billion people do not have access to safe drinking water and 2.4 billion people lack basic sanitation. The treatment of wastewater from small towns in the population equivalent (PE) range of 200 - 2,000 PE can be a particular problem that generates different problems to those encountered in larger conurbations.

For example decentralised wastewater treatment plants can be advantageous as the local value of water and avoiding the cost of water conveyance offset the economies of scale of larger plants (Norton, 2009). However, failure of mechanical components, high energy requirements and the need for full time on site operators are just some of the problems associated with decentralised water and wastewater treatment plants (Norton, 2009). The scale of many of these decentralised water and wastewater treatment systems cannot justify the presence of a full time operator and this has proven to be a particular challenge.

Public concern relating to environmental pollution has been growing in recent years and there is a now a global demand for low energy, low maintenance and versatile environmental technologies for the treatment of waters and wastewaters. However, further to public health protection it is increasingly recognised that research infrastructure is vital for (i) promoting innovation, technology and policy development, (ii) supporting the conditions for leading-edge research (iii) creating sustainable employment and (iii) educating new generations of researchers and innovators (Research EU, 2011). Such research infrastructure can also play a larger societal role by increasing knowledge among the general population on issues relevant to their daily lives. In the water and wastewater sectors, there are a limited number of large scale infrastructures available for the research and industry communities. Examples include the Wastewater Technology Centre in Ontario, Canada and the Institute for Urban Wwater Management (ISA), Aachen University, Germany that provide full scale test facilities and/or certification for water and wastewater technologies. The Questor Applied Technology Unit, Queens University Belfast, comprises a multi-disciplined team that help industry develop new technologies in this sector.

In 2006 the NUI Galway research team carried out a survey across all industry, policy makers, research institutes, 3rd level institutes and public bodies (including local authorities) in Ireland and found 93 % of respondents stated that the construction of a full sale test facility in Ireland stakeholders for the water and wastewater sectors was required (NUI Galway, 2006).

In this context it was considered necessary to construct a facility capable of examining proprietary and novel water and wastewater treatment technologies. Furthermore the facility could be used to (i) test new sensor and analytical equipment in real-life situations, (ii) develop real-time monitoring and control infrastructure (iii) enable the development of on-site educational programs for students, water professionals and the general public. Such a facility was proposed, designed, constructed, commissioned and operated by researchers in Civil

Engineering, NUI Galway – at Galway County Council's Tuam Wastewater Treatment Plant (TWWTP) – and is known as the NUI Galway/EPA Water Research Facility (WRF).

2. NUI Galway/EPA Water Research Facility

The WRF (Figure 1) is located in Tuam, Co. Galway. This site was selected for a number of reasons including: (i) its excellent accessibility from all major population centres on the national motorway network (Galway to Tuam motorway due to commence); (ii) its proximity to NUI Galway; (iii) available space on-site; and (iv) is ideal for influent wastewater is pumped to the WRF from the near-by TWWTP. The TWWTP was commissioned in 1996 with a design PE of 25,000. In 2006, Tuam had urban and environs populations of 2997 and 3888, respectively and average daily flows to the TWWTP of 5,000 m^3/day (CSO, 2010). The WRF was officially opened in February 2010 by Minister Michael Finneran (then Minister for State with responsibility for Housing and Local Services).

Figure 1 – The NUI Galway/EPA WRF.

Prior to entering the TWWTP, raw municipal wastewater passes through a basic 25 mm bar screen at a pumping station about 1 km upstream of the plant and is pumped to the TWWTP. The wastewater then passes through an automatic 10 mm screen located in the open influent channel. A portion of this inflow is pumped at user defined intervals to the WRF from the influent channel of the TWWTP (prior to the storm over-flow location and primary settlement tanks, see Extraction Point in Figure 2). The WRF can currently process a maximum of about 50 m^3 wastewater/day, though this can be varied depending on the work being carried out at any given time and the level of treatment required.

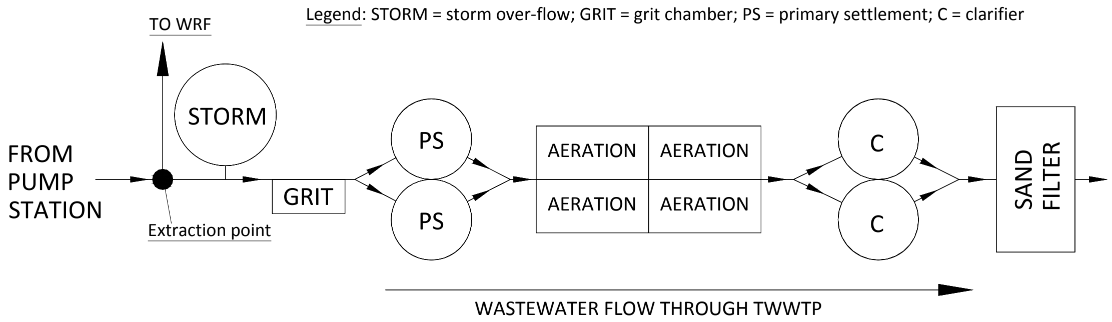


Figure 2 – Location of extraction point for WRF at the TWWTP.

2.1 WRF – plant layout

Wastewater entering the WRF is pumped to the primary settlement tanks of the WRF. From there, it was available for technologies being tested at the WRF that require primary-settled influent wastewater. A general layout of the WRF is shown in Figure 2.

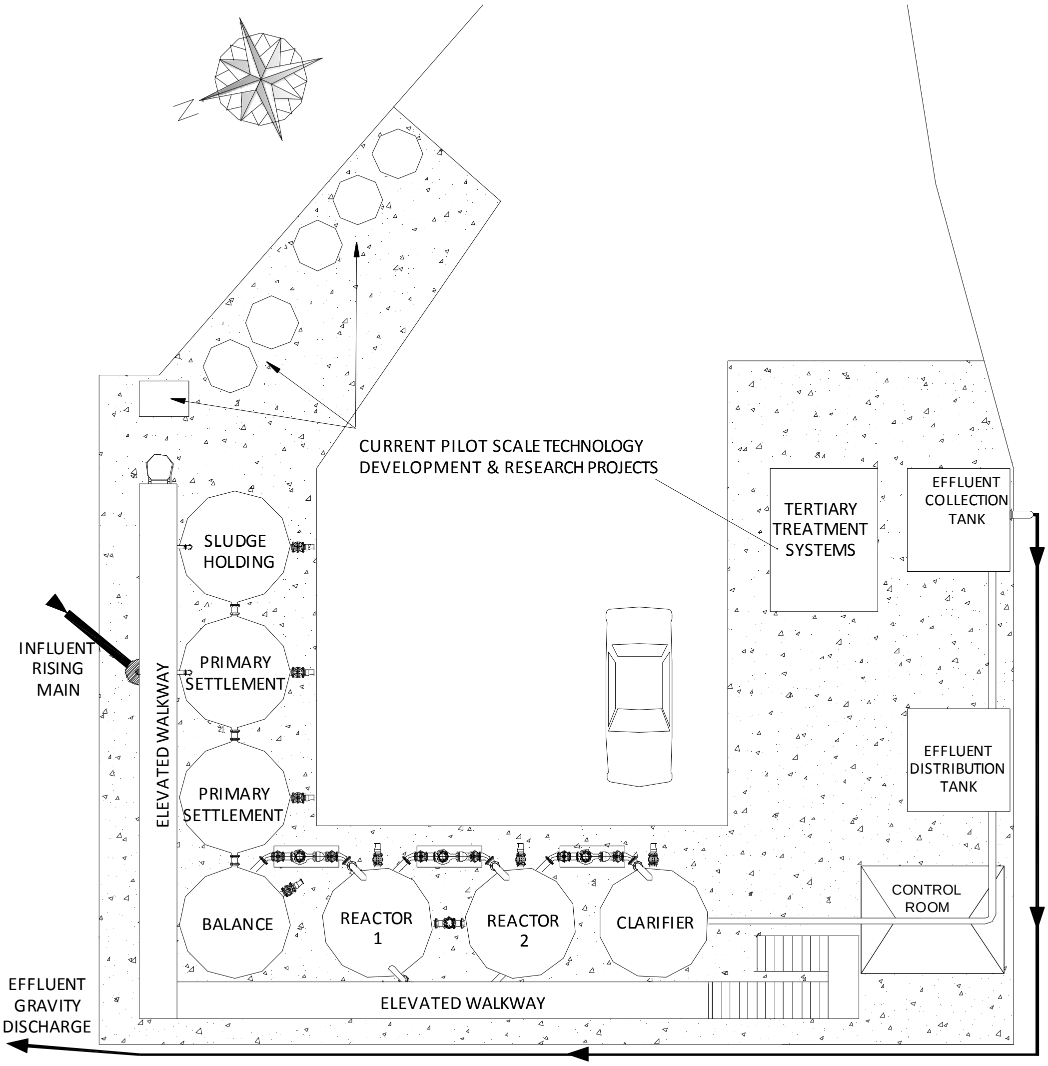


Figure 3 – General layout of the WRF.

The main technology employed to treat the bulk of the wastewater at the WRF is the pumped flow biofilm reactor (PFBR) - a novel attached growth wastewater treatment technology, developed and patented in NUI Galway. Extensively tested at laboratory and pilot scale, the PFBR has proven to be an efficient, robust and cost effective technology that is simple to maintain and operate (Rodgers et al., 2004, Zhan et al., 2005; O'Reilly et al., 2011). The design of the WRF allows the reactor tanks to accommodate other process such as activated sludge and sequencing batch reactor systems (Figure 4).

Figure 4 - Photograph of the PFBR at the WRF. Shown from right to left are; 1 No. sludge holding tank, 2 No. primary settlement tanks, 1 No. balance tank, 2 No. reactor tanks, and 1 No. clarifier.

Each tank in Figure 4 measures 4 m high and 3 m in diameter. An additional 2 tanks (2.5 m square and shown in Figure 3) – the effluent distribution and effluent collection tanks – provide additional storage of secondary treated wastewater for further use in various research and development projects.

Treated wastewater from the main PFBR system can be passed through a number of tertiary treatment systems (shown as ‘tertiary treatment systems’ in Figure 3). Currently, an automatic sand filtration system and a UV disinfection system are installed. The facility has been designed in a plug and play manner allowing technologies undergoing trials to be easily plugged into the system such as chlorine contact tanks, activated carbon filters, zeolite adsorption systems etc. Figures 5 and 6a show a schematic and picture, respectively, of the system, which includes: (i) ports for sampling the wastewater before and after each tertiary treatment system; (ii) automatically controlled backwashing of the filter systems; and (iii) in-line pressure measurement that can provide essential information on system performance and clogging; and (iv) a user-friendly interface and control system.

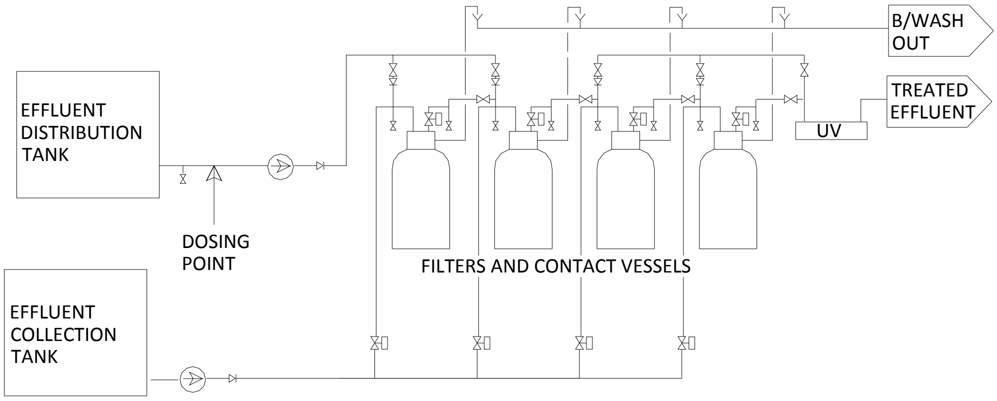
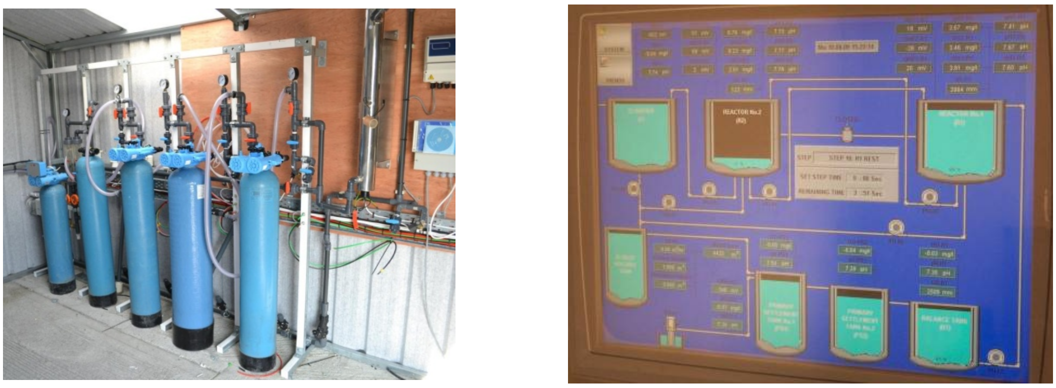


Figure 5 – Layout of tertiary treatment system at the WRF



Figures 6(a) and (b) – The tertiary treatment system installed at the WRF and the HMI installed at the WRF.

2.2 WRF – control and monitoring systems

A bespoke control system was developed for the PFBR at the WRF. A programmable logic controller (PLC) manages the operation of all the mechanical and electrical equipment for the main PFBR wastewater treatment system. A touch screen human machine interface (HMI) allows the operator on-site access to all aspects to the system. All system controls and data are viewable and recorded by the PLC, displayed on a HMI which is linked to PC in the control office (Figure 6b). Using a USB broadband connection and a remote control software package, this PC can be accessed remotely allowing the research team to have full control of the PFBR from any location. For example, the flow rate trough the system, the length of the treatment cycle, the current water levels in the reactor tanks or the operation of all pumps and motorized valves can be viewed in real time and controlled remotely. The tertiary treatment system is controlled by a separate PLC.

Wastewater samples are taken at various points in the treatment system manually or using automatic samplers. Furthermore, real time measurements of dissolved oxygen (DO), pH, oxidation reduction potential (ORP) and flow are combined with operational parameters such as pumps run time and energy usage to optimise the treatment cycle; this can be viewed remotely and in real time. A mobile remote monitoring and control system (MRMC) is available on site and comprises sensors and analysers to measure various water and gas parameters (eg. chemical oxygen demand, ammonium-nitrogen, nitrate-nitrogen, phosphate-phosphorous, carbon dioxide, methane etc). As with the above mentioned sensors, data from the MRMC unit can also be remotely interrogated. It is planned that all operations and process data generated on-site will be centrally linked and available for remote interrogation.

3. Research and development infrastructure utilisation. (Technology development, research, public outreach and education etc?)

3.1 Research and technology development

The WRF is in operation for about 16 months and has significantly enhanced the research and technology development capability at NUI Galway. The pilot-scale PFBR - an example of a technology developed by a universitiy at a laboratory scale before being trialled at pilot and fullscale - featured at a recent WEF/IWA conference (O'Reilly et al., 2010. Academics and industry attending the conference highlighted the lack of such facilities for large scale research infrastructure. Various stakeholders and a number of international academics have visited the WRF

Furthermore the development of the WRF has also allowed for significant collaboration to develop between NUI Galway, industry and other research and third level institutes. To-date the facility has supported two Enterprise Ireland funded technology commercialisation projects (one of which has resulted in the issuing of a commercial license). Currently, a further Enterprise Ireland funded technology development project is located and has been installed on-site at the WRF and undergoing investigation. In collaboration with industry, a novel tertiary wastewater treatment technology will be evaluated funded through the Enterprise Ireland Innovation Voucher scheme,.

A collaborative project with the Marine Institute in Oranmore is currently underway and is utilising the tertiary treatment system. A standardised application system is being developed to allow industry, research groups or other stakeholders apply to carry out research at a pilot scale at the WRF.

3.1 Public outreach and education

The WRF has proven particularly effective as an educational and public outreach tool. Two examples of these include the Engineers Ireland *Engineers Week* at the Galway Museum (February 2011) and the NUI Galway Open Day (April 2011). A model PFBR, fabricated by the research team, was employed at a display in both exhibitions along with a laptop computer showing the WRF in live operation.

For example, visitors and students could view in real-time the wastewater treatment process, watch changing readings from various sensors live and then link these values to the physical process on site, view current and previous energy utilisation rates and, stop and start pumps operating on site. The model, manually operated at the displays, helped visitors visualise the processes they were viewing on the computer screen. In both cases it proved extremely popular with surprising interest being shown by the public. The WRF can help raise public awareness of water and wastewater treatment, reduce public apathy to wastewater and sludge treatment process in particular and aid the public understand their role in helping these systems operate efficiently. The research team are currently developing plans to provide career professional development (CPD) for engineers, scientists and managers based on the technologies at the WRF.

The WRF is also used to show third level engineering and science students a full scale wastewater treatment process. The potential of online sensors and control systems is easily apparent on site visits and the WRF allows wastewater and water treatment theory to be seen in practice. A typical onsite visit, giving an overview of all the on-site systems can be completed in about 1.5 hours.

3.3 Policy development

The operation of the WRF under normal on-site conditions at the WRF can facilitate the formation of formal guidelines for technology usage and policy. An example of this would include the significant variation that can be encountered in daily influent wastewater characteristics both in terms of flow and contaminant concentration. Such information can be vital in helping new and existing wastewater treatment facilities meet new stringent discharge limits and operate more efficiently. However, frequency monitoring of influent may not be in place in most wastewater sites.

The WRF has a large range of sensors and monitoring equipment installed and thus it has been possible to monitor the performance and maintenance requirements of these systems over an extended period of time. It is possible to provide guidelines to other decentralised treatment systems on the types of sensors that may (i) be most robust, (ii) require least maintenance, (iii) be cost effective and, (iv) are reliable. Remote control of the WRF has also shown the potential of developing a standardised control and monitoring system for decentralised wastewater and water treatment systems. These are brief examples of the types of recommendations that have been proposed as a result of the EPA funded large-scale project on small-scale wastewater treatment and are currently in press with the EPA (O'Reilly et al., 2011).

4. Discussion and conclusions

The WRF offers a state-of-the-art world class research facility in Ireland for industry, state bodies, universities, research institutes and other organisations to carry out fundamental and applied research on environmental technologies. The facility can provide an interactive platform where researchers, industry and the public sector can develop synergies that can lead to the protection of health and the environment and to the creation of wealth and jobs in Ireland through the development of new technologies for the home and export markets. New technologies can be trialled in real-life scenarios at a well monitored and managed research facility.

The extensive real-time access to the WRF allows researchers to remotely monitor research activities at the WRF. It is confidentially expected that after an initial start-up period, the WRF can be financially self sustaining. It is envisaged that a number of researchers, engineers and scientists would be employed at the facility and at NUI Galway to carry out and supervise varied research projects and liaise with industry. Thus both fundamental and applied research could be carried out with a unique collaboration between industry, university, state bodies and other organisations.

Open days for the public, students and stakeholders could be a feature of the facility, encouraging interest and enthusiasm for the oft maligned wastewater and water treatment sectors. The WRF has featured on Eco Eye (RTE 1) and it is envisaged a number of animations describing the engineering processes employed at the WRF along with YouTube videos will form part of future open days both on and off site.

The advantages of the WRF include:

- access to wastewater at various stages of treatment allowing for technologies to be trialled for primary, secondary and tertiary treatment. The WRF can process up to 50 m^3/day of wastewater
- a well-equipped site for testing new sensors and analysers for water and gaseous contaminant monitoring at various stages of treatment
- the MRMC can be deployed to technologies on-site or can be used off-site where new technologies are being applied on particular wastewaters e.g., in food processing facilities. The NUI Galway research team have real-time access to data from the MRMC thus allowing instantaneous feedback on process efficiency
- access to wastewater sludge allowing new sludge treatment methods to be tested
- an easily accessible site at Tuam, Co. Galway

- process samples that are regularly taken and monitored and can be tested at the excellently equipped Environmental Engineering Laboratories, NUI Galway
- experienced NUI Galway research staff to operate and maintain the research facility.

A number of upgrades to the WRF are planned and pending funding opportunities these include; (i) an improved broadband connection, (ii) an on-site laboratory, (iii) development of a dedicated website and (iii) a new multi-layered control and monitoring system that links all processes currently on site and allows new projects that are installed on-site to be easily connected to this system. This would allow the relevant stakeholders to access their project details on line and follow progress remotely. It is also envisaged that YouTube videos would be uploaded to provide information on the facilities capabilities.

The NUI Galway/EPA WRF provides a unique research facility with advantages that include: (i) increased opportunities for successful research funding proposals; (ii) world-class fundamental and applied research; (iii) education and training of graduate, postgraduate and post doctoral researchers; (iv) increased collaboration between industries, research and policy-making institutes; (v) public and technical education and training of stakeholders; (vi) high profile dissemination of issues regarding water, wastewater and environmental technologies; (vi) policy planning; (vii) developing and testing novel indigenous environmental technologies and products; and (viii) attracting visiting academics and students from leading international institutions.

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