07 - ANSWER (AGRICULTURAL NEED FOR SUSTAINABLE WILLOW EFFLUENT RECYCLING): AN EU FUNDED PROJECT TO ENCOURAGE THE USE OF SRC WILLOW FOR BIOREMEDIATION.

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Abstract

The ANSWER (Agricultural Need for Sustainable Willow Effluent Recycling) project has seven partners including water utilities, local government councils, higher education colleges and science organisations from both sides of the Irish border. The total value of the project is around £2m. Ireland has numerous small rural Waste Water Treatment Works (WWTWs) which are costly to upgrade and are discharging borderline or non-EU compliant discharges. This project has enabled ‘proof of concept’ schemes to be established using Short Rotation Coppice Willow (SRC willow) to treat primary and secondary sewage WWTWs effluents, commencing summer 2014. The process to get to this point has been complex in terms of identification of suitable WWTWs and negotiations with land-lords / land-owners, regulators and the community. The accumulation of scientific data is essential in order to give the environmental regulators and practitioners of these solutions the confidence to proceed with a technology with which they had little or no previous experience. In three of the schemes, SRC willow had to be established and in the fourth case an already mature SRC willow plantation was used. Zoned area irrigation systems were then designed, built and commissioned for irrigation rates of up to approximately 1 mm day^{-1}, (10 m^{3}ha^{-1}day^{-1}, up to approx 3,500 m^{3}ha^{-1}yr^{-1}). A system of environmental controls, water monitoring and data acquisition software was also incorporated to ensure appropriate weather related irrigation and ongoing monitoring of system loading.

Key words: bioremediation, SRC willow, regulations

1. INTRODUCTION

The treatment of wastewater in conventional Wastewater Treatment Works (WWTWs) is highly effective and in modern works will produce an effluent which is compliant when discharged into waterways. Throughout the Island (North & South), there are however many hundreds of small scale WWTWs and septic tanks treating populations up to several hundred, which arguably over the recent decades have been largely ignored and are currently suffering from under investment with respect to upgrading. This is compounded by recent population increases in certain areas putting extra pressure on the treatment works as the load capacity exceeds the WWTWs design capacity. Although the discharge volumes from these treatment works are relatively small, their compounded polluting effects into our environmental waters and catchment basins can be significant (Werner and McCracken 2008). WWTWs are expensive to build and upgrade and the cost/benefit analyses for upgrading small WWTWs is poor. It is therefore desirable to develop cost-effective, environmentally sound, sustainable and low carbon approaches to wastewater management appropriate to rural communities (ANON 2014a). The use of fast growing woody plants for the bioremediation / phytoremediation of wastewater is a potentially effective approach to this problem. Often, when considering environmental solutions to these problems, the demand for land can be a severe obstacle. In this scenario, the agricultural production of an energy crop (SRC willow) can not only assist with uptake of on-farm renewable energy while also facilitating agricultural diversification into the biomass energy supply chain but also carry out a waste water management function. The land area therefore is put to multifunctional uses which can help negate these concerns.

WWTWs are also expensive to run and can require major electrical power inputs to run pumps, aerators and other equipment. Water utilities are, in many countries, the single greatest users of electricity. For example, Northern Ireland (NI) Water which is the sole provider of water and sewerage services for Northern Ireland, consumed almost 300,000 MWh of electricity (mainly non renewable) during 2012-2013 (ANON 2014b). In the UK the water utilities account for 3% of the total UK electricity demand (ANON 2009). In addition to financial costs, most of this energy comes from fossil fuel sources and hence water treatment is therefore contributing large quantities of damaging greenhouse gas emissions to the atmosphere (ANON 2008) and subsequently contributing to climate change. The use of Short Rotation Coppice Willow (SRC willow) energy plantations for the management of wastewater can provide a net positive energy balance when analysing the life cycle analysis (LCA) thus contributing to the reduction of GHG emissions (Fearon et al. 2014).

The EU Water Framework Directive commits EU member states to improve and obtain good qualitative status of all water bodies. In essence this refers to good chemical and biological status and in particular, minimal chemical pollution with regards to environmental quality of river basin systems including groundwater and ecosystems. The removal and reduction of discharges from small rural WWTWs into these river basin catchment districts can help us reach this goal.

1.1 Bioremediation / Phytoremediation

Fast growing plants will utilise available nutrients in the soil. Willow (*Salix spp.*) genotypes bred for high biomass production are particularly productive, consistently yielding in excess of 10 dry t ha^{-1}yr^{-1} on most sites. Willow is a temperate plant well suited to a maritime climate and to wet soils. It has a long growing season, is easily coppiced (i.e. can be cut back regularly to ground level), is tolerant to many soil contaminants and is currently grown commercially for biomass as a fuel for wood-fired boilers producing renewable heat. The fact that willow has a higher water demand than almost any other agricultural crop means that significant volumes of effluent can be applied. The type of willow used in coppice plantations generally has a fine shallow root system with 85% situated in the top 50 cm of the soil profile. This not only improves stability but also provides an excellent receptive surface for the application of effluents and other wastewater streams.

Bioremediation is the use of living organisms to break down or remove toxins and other harmful substances from soil and water. When plants are used, ‘phytoremediation’ is the preferred terminology. Many plants when they are growing actively take up large volumes of water from the soil. This is driven by ‘evapotranspiration’, which is the loss of water from the soil both by evaporation and by transpiration from growing plants. Plants utilise water from the soil, which is then lost to the atmosphere though the stomata in the leaves. If the water that is taken up by the plants is high in plant nutrients such as nitrogen (N) and phosphorus (P) then there will often be increased plant growth. In the rhizosphere (the plant root / soil interface) the plants act as a biofiltration systems which enables soil bacteria and other soil mechanisms to breakdown nutrients and contaminants before they can reach the groundwater. These processes are illustrated in Fig. 1.

2. PROOF OF CONCEPT BIOREMEDIATION SITES

One of the primary objectives of the ANSWER project was to establish at least three commercial scale ‘proof-of-concept’ sites which would be irrigated with effluent from non-compliant WWTWs. Three of the project partners have built effluent irrigation schemes on which irrigation started in spring 2014.

2.1 Clontibret and Knockatallon, Co. Monaghan

The WWTWs at Clontibret (Irish Grid: H752 289) serves a population equivalent (PE) of 200 and the works at Knockatallon (Irish Grid: H558 391) serves a PE of 105.

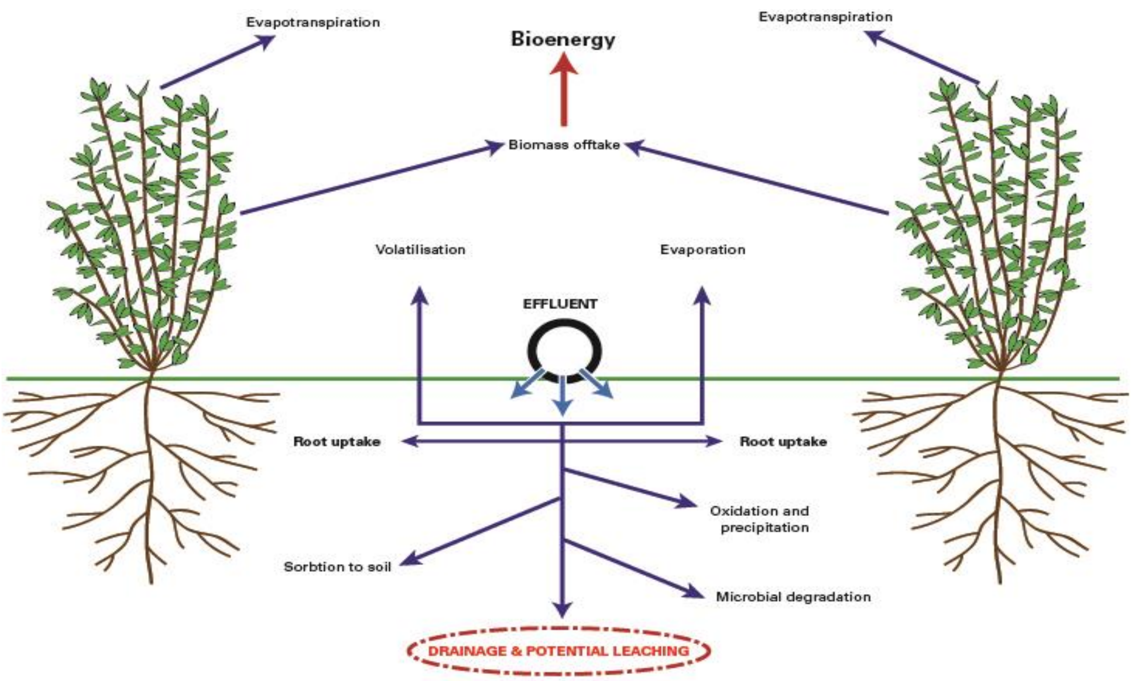

Fig.1: *Principle of SRC willow biofiltration*

2.1.1 Adaptations at treatment works:

In line with requirement of the Environmental Protection Agency (EPA) 205m^3 storage tanks were constructed at both the Clontibret and Knockatallon sites in order to act as the accumulation tank for SRC willow irrigation and as a buffer to store effluent during periods when irrigation to the SRC willow cannot occur. Currently in Clontibret, the effluent enters the works and flows into two primary settlement tanks followed by a Rotating Biological Contactor (RBC) and a final clarifier. The settled effluent then enters an uplift pump sump where duty and standby pumps pump the effluent to the buffer/storage tank. The effluent is irrigated to the SRC willows from this tank. In Knockatallon, the effluent enters through a screen followed by two primary in-line settlement tanks. Previously, the effluent was pumped into Bord Na Mona Puraflow modules through which the effluent was biofiltered and finally discharged to ground water through a gravel bed. Currently the settled effluent enters an uplift pump sump where duty and standby pumps pump the effluent to the buffer/storage tank. The effluent is irrigated to the SRC willows from this tank.

There are approximately 7 days storage at Clontibret (30 m^{3}day^{-1} average Inflow) and 10 days storage at Knocktallon (20 m^{3}day^{-1} average Inflow) at average daily flows. However, if climatic circumstances serve to restrict SRC willow irrigation, the effluent may reach the tank overflow point where it resumes discharge to the stream (as it did before the adaptations were made to the works). The ongoing running of the scheme will serve to quantify the volumes of discharged effluent as a result of these occurrences (eg. heavy rainfall).

2.1.2 Willow planting:

Monaghan County Council obtained long term leases of around 7 ha and 5 ha of land as adjacent to the WWTWs as possible at both Clontibret and Knockatallon respectively. In spring 2012 the ground was prepared according to the SRC willow Best Practice Guidelines (Caslin et al. 2011). A genotype mixture of willows was planted using a step planter, in double rows 0.75 m apart with double rows spaced at 1.50m. An in-row spacing of 0.6m resulted in a final planting density of approx 15,000 cuttings per hectare. The plantation was assessed in winter 2012/13 and in response to poor establishment, partly because of a very wet summer leading to late planting, partial replanting was arranged for the following year. On inspection in Winter 2013/14, a better establishment had been achieved however careful crop management was required and the decision to leave most of the crop un-cutback was taken to ensure the continuation of good establishment. The resultant growth and crop coverage was complete, even and strong by summer 2014.

2.1.3 Irrigation systems (Clontibret):

Irrigation pipes were laid during winter and spring 2013/14 in every forth double row of SRC willow with emitter orifices every 10m. The irrigation system consists of a storage facility, pump, valves, filter, flow meters, rising main, header pipes and irrigation pipe work. The main 90 mm rising main stretches the entire length of the plantation, into which 14 independently controlled solenoid valves were incorporated [Fig.2]. Each valve, controlled by the central computer system, enables individual zones to be independently irrigated according to a pre-programmed irrigation protocol.

The irrigation protocol can be edited simply to enable the most suitable irrigation regime for the plantation (reference crop establishment, climate, season, ground conditions, hydrogeology and other aspects). The following information is measured and data uploaded (SCADA): Incoming and irrigated flow totals and rates, section irrigation totals, rainfall totals and irrigation pump activity times. The following information is also measured and recorded and used to control whether the irrigation system runs or not: irrigation section accumulators, flow rate, flow pressure, clock timing, storage tank level, rainfall intensity and amount and soil temperature. These values can be used to trigger a sms or email alarm to notify of a possible issue for attention.

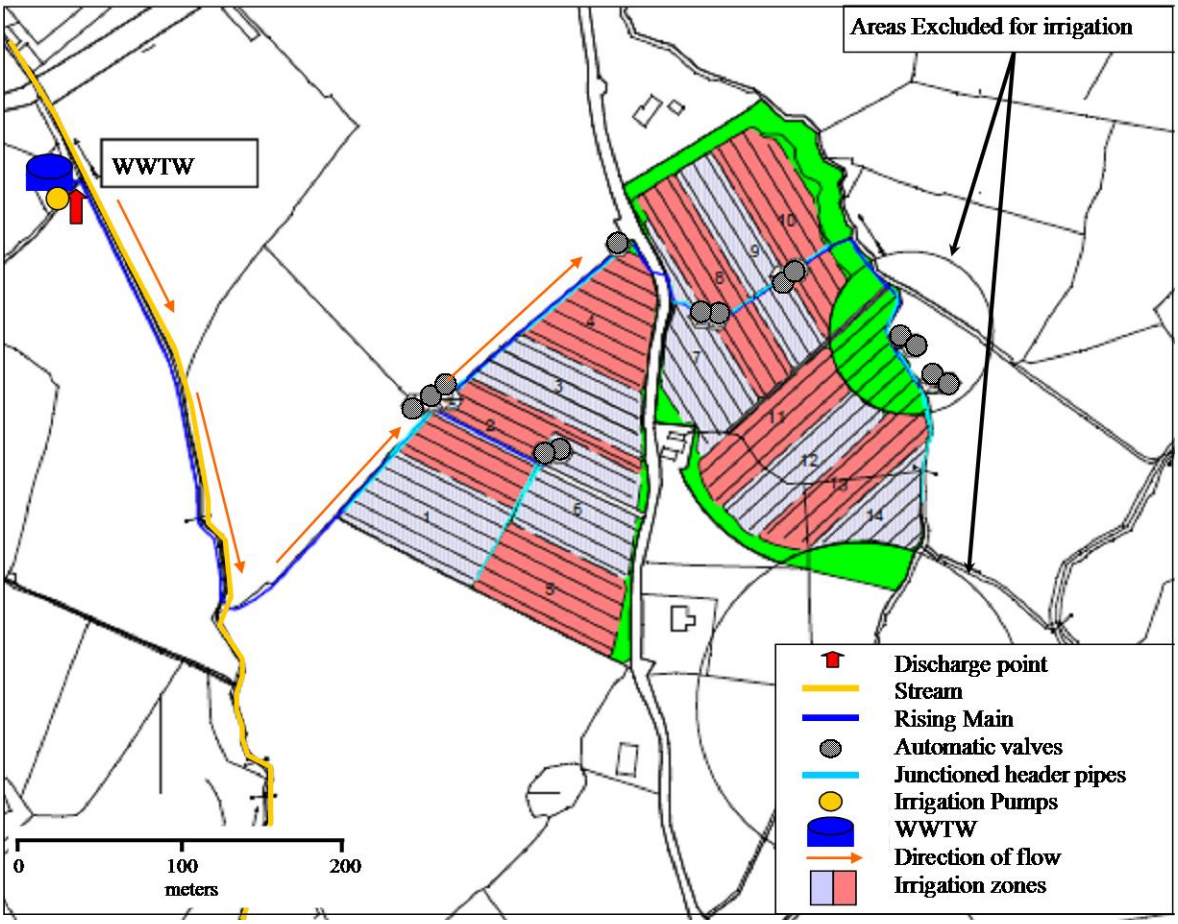

Fig. 2:*The 7 ha field layout at Clontibret indicating the main pipeline, 14 zones and valves.*

2.1.4 Irrigation protocol

Each zone is irrigated for a preset length of time which is a function of its distance from the irrigation pump (flow rate), soil conditions and associated hydrogeology. The current protocol allows for the irrigation of approximately 4.5 $m^3ha^{-1}day^{-1}$ which is split into a number of smaller irrigation subsets. This results in a total maximum daily irrigation volume of approximately 32m^3 to match the normal

WWTWs inflow rate and equates to an effluent application of <0.5 mm over the full 7 ha site. The irrigation cycle is flexible however it is currently set to run 2 times during each 24 hour period. Each cycle irrigates on average $16m^3$. In accordance with the Nitrates Directive, it is recognised that the application of effluent to the SRC willow plantation will be performed in a uniform manner and is not permitted when the soil is waterlogged, likely to flood, has been frozen for 12 hours or longer, is snow-covered or when heavy rain is forecast within 48 hours.

2.1.5 Regulations

Throughout the project planning process the Local Authority Environment Section investigated the proposal thoroughly in order to ensure compliance with regulation and good practice. Local community groups were consulted and their questions and concerns addressed. These questions were predominantly associated with gaining an understanding of what the schemes were about, the potential benefits, the proximity to houses and watercourses and potential for odours. The irrigation system was constructed with these risk abatement factors taken into account and incorporated irrigation area restrictions and methodologies. Potential risks (the consideration of sensitivity of location with regard to site suitability, groundwater vulnerability, sensitive buildings and proximity to populations and protected areas including water supply sources) associated with the irrigation of treated waste waters to a SRC willow plantation were considered in the context of the following pieces of legislation:

- S.I 31/2014 - European Union (Good Agricultural Practice for the Protection of Waters) Regulations 2014
- SI 272/2009 - European Communities Environmental Objectives (Surface Waters) Regulations 2009 (as amended)
- SI 9/2010 - European Communities Environmental Objectives (Groundwater) Regulations 2010 (as amended)
- Article8(1) of the Planning and Development Regulations, 2001 (S.I. No. 600 of 2001)

There are other significant areas of legislation such as the Ground Water Regulations, the Urban Wastewater Treatment Regulations, Environment impact - uncultivated semi-natural areas regulations, Shellfish and bathing waters Directives which are involved but relate more directly to specific situations.

2.2 Bridgend, County Donegal

The WWTWs at Bridgend, Co. Donegal (Irish Grid: C397 244) serves approximately 500 population equivalent (PEs) which produces an effluent inflow volume averaging approximately 80 to $90m^3day^{-1}$.

2.2.1 Adaptations at treatment works

Originally, this WWTWs was constructed to a design capacity of 250 PE where the inflow was subject to aeration followed by settlement and subsequently discharged to a small stream. As the ANSWER project developed, in line with requirements of the Environmental Protection Agency (EPA), a 400 m^3 storage tank was constructed to hold effluent during periods when irrigation to the SRC willow should not occur. Currently, the effluent following aeration and settlement enters a sump where it is regularly pumped to the main storage tank. SRC willow irrigation occurs from this tank. In circumstances where irrigation cannot occur (e.g. climatic or equipment failure), the storage tank will fill to 95% at which point the sump uplift pumps will stop thus allowing treated effluent to overflow from the low level sump and discharge into the stream as the WWTWs did prior to the installation of the SRC willow treatment module.

2.2.2 Willow planting

Donegal County Council obtained a long term lease of around 14 ha of land adjacent to the treatment works. This was in three blocks of 6.5, 4.0 and 3.5 ha and established with SRC willow as outlined in section 2.1.2.

2.2.3 Irrigation system

Irrigation pipes were laid as outlined in section 2.1.3. The rising main stretched the entire 1.4km length of the plantations into which 25 independently controlled solenoid valves were incorporated.

Each valve, controlled by the central computer system, enables zones to be independently irrigated according to a pre-programmed irrigation protocol.

2.2.4 Irrigation protocol:

As described in section 2.1.4, each ½ ha zone is irrigated for a preset length of time which is a function of its distance from the irrigation pump (flow rate), soil conditions and associated hydrogeology. As the distance from the irrigation pump increases to the further most irrigation zones, the pressure and flow velocity drop off requiring a longer irrigation period to irrigate a similar volume of effluent [Fig.3]. The current protocol allows for the irrigation of approximately 5 $m^3 zone^{-1} day^{-1}$ which is split into a number of smaller irrigation subsets. This results in a total daily irrigation volume of up to 130 m^3 or fewer, to match the normal WWTWs inflow rate and equates to an effluent application of up to 0.9 mm over the full 14 ha site. The irrigation cycle is flexible however it is currently set to run 3 times during the day. Each cycle irrigates on average 43 m^3. In accordance with the Nitrates Directive, it is recognised that the application of effluent to the SRC willow plantation will be performed in a uniform manner and is not permitted when the soil is waterlogged, likely to flood, has been frozen for 12 hours or longer, is snow-covered or when heavy rain is forecast within 48 hours.

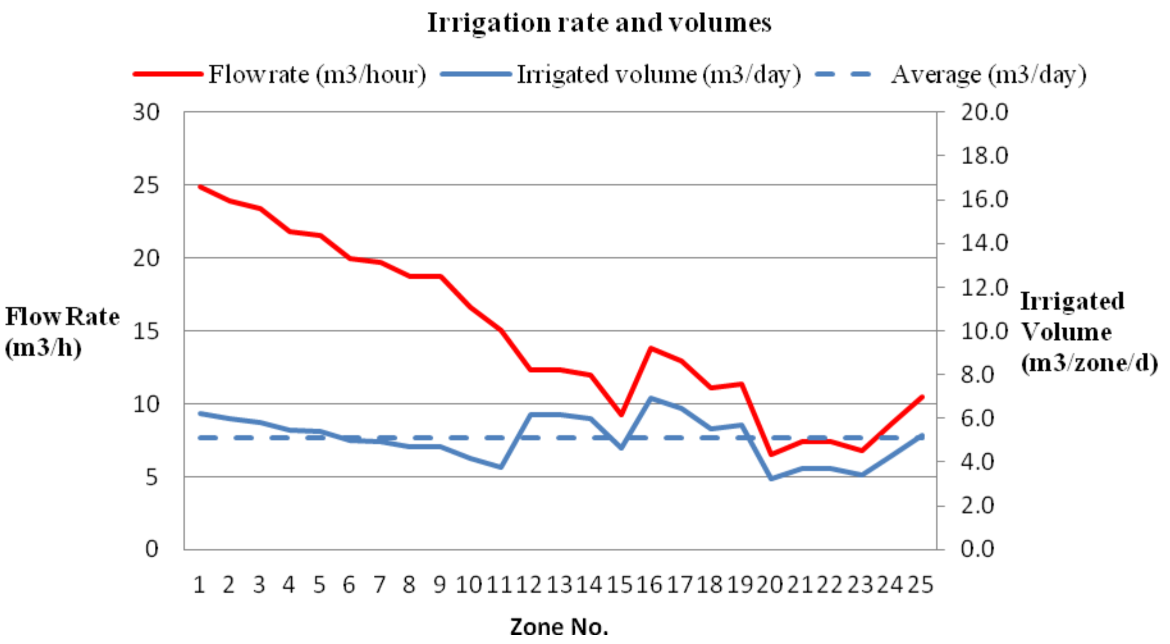

Fig.3: *Flow rate and balancing of irrigated volume per zone*

2.3 Dromore, Co. Tyrone

The WWTWs at Dromore, Co. Tyrone (Irish Grid: H340 671) serves approximately 2,500 PE. Dromore is situated in Northern Ireland, UK and is managed by NI Water as the primary water utility. There were some differences from Donegal and Monaghan (Republic of Ireland) in the ways in which this particular scheme was procured and regulated reflecting some differences between the two EU member states. This SRC willow treatment module is not essential to the regulatory compliance of the Dromore WWTWs however it does provide a very beneficial commercial scale proof of concept scheme for the application of this technology. It is estimated that the SRC willow module will be capable of taking approx. 15% to 20% of the full yearly load (full load estimated 220,000 $m^3 year^{-1}$). In order to make the smartest use of this facility however, NI Water will be investigating the effectiveness of pumping the effluent to the SRC willow during different scenarios as follows:

- During the WWTWs peak loading times (morning and evening), to reduce the flow through the treatment works.
- When the flow in the river is lower - to reduce the impact of discharge on river water quality.

- When there are elevated nutrient levels in the discharge - to reduce the impact of discharge on river water quality.
- Ultimately, at a future date, to investigate the effect that the extraction of primary effluent (reducing the flow through the works) has on the overall running of the WWTWs, the discharge quality and overall energy usage and carbon emissions.

2.3.1 Adaptations at the treatment works

The effluent is presently treated to secondary treatment level at which point it is discharged into the Owenreagh river. The only adaptation at the treatment works required was a pump system for extraction of secondary effluent for irrigation to the SRC willow plantation. This pumping station is flexible for future trials on the extraction of primary effluent for irrigation to the SRC willow plantation.

2.3.2 Willow planting

In contrast with the three schemes in the ROI the SRC willow used for irrigation was already well established. There were 15 ha of SRC willow planted in 2007 and which had been harvested twice on a three year rotation. This approach has many advantages in particular that the root systems of the plants were well developed and there was complete site capture by a well established SRC willow plantation.

2.3.3 Irrigation system and operating protocol

Irrigation pipes were laid as outlined in section 2.1.3 during the Summer of 2014. The rising main stretches from the WWTWs and through the entire length of the plantation into which 28 independently controlled solenoid valves were incorporated. Each valve, controlled by the central computer system, enables zones to be independently irrigated according to a pre-programmed irrigation protocol. As in section 2.1.4, each zone is irrigated for a preset length of time allowing a subset of the total zone application quantity to be irrigated before automatically moving on to the next zone. An estimated 10 $m^3 ha^{-1} day^{-1}$ irrigated in 2 m^3 subsets is the commissioning starting point for this project.

2.3.4 Regulations

The irrigation of waste water from the Dromore WWTWs to this particular SRC willow plantation is licensed and consented to discharge under the "Water (Northern Ireland) Order 1999", as amended by the "Water and Sewerage Services (Northern Ireland) Order 2006" by the Department of the Environment. The Dromore WWTWs is compliant with its licence and in the event that effluent cannot be applied to the SRC willow due to climate, regulation, technical breakdown etc, the effluent can continue to be discharged to the river.

3. RESULTS

3.1 Nutrient and Hydraulic Loadings

The quality of the discharge from the treatment works (Table 1) is from the most recent data available from Donegal and Monaghan Local Authorities and NI Water. The proposed hydraulic and nutrient loadings are calculated (Table 2) and are within recommendations for the application of both nitrogen and phosphorus within the nutrient guidance for SRC willow as advised by Teagasc (Caslin et al. 2010). The current nutrient guidance considered appropriate by the Northern Ireland Environment Agency (NIEA), interpreting the guidance given in RB209 (ANON 2010) and the data available on crop nutrient off-takes, allows for the application of 180 kg N $ha^{-1} year^{-1}$ and 24 kg P $ha^{-1} year^{-1}$. The proposed nutrient loadings are also within these recommendations and guidelines. The application of nutrient represented by the schemes established under the EU ANSWER project represent yearly loadings of between 24 and 70 kg N $ha^{-1} year^{-1}$ and 3 to 8 kg P $ha^{-1} year^{-1}$.

Table 1: *Effluent Discharge Quality from WWTWs*

Parameter	Bridgend[a] (mg/l)	Clontibbret[b] (mg/l)	Knockatallon[b] (mg/l)	Dromore[c] (mg/l)
NH_3-N	10.6	32.3	27.2	1.1
Total-N	31.6	32.3	27.2	11.3
Total-P	1.5	4.7	3.6	1.6
ss	50.0	33	78.0	17.0
BOD	22.4	43	85.0	10.0
COD	93.0	130	180.0	n/a
pH	7.3	N/A	N/A	7.5

[a] Data from Donegal County Council (2012)

[b] Data from Monaghan County Council (2013/2014)

[c] Data from NIWater (2011/2012)

With the nutrient loadings within sustainable application rates reducing the risk of soil nutrient build-up and potential for environmental release via runoff to the environment, the hydraulic loading is important to control to also minimise any potential environmental pollution. Based on average daily flows, the hydraulic loadings within these schemes range from 1,300 to 2,200 $m^3ha^{-1}year^{-1}$, equivalent to between 0.4 and 0.6 mm day^{-1}.

Table 2: *Estimated nutrient and hydraulic loading as irrigated throughout the year.*

WWTW Site	Loading	Est. PE[b] managed	Willow irrigated (ha)	Hydraulic Loading (m^3/ha)	Suspended Solids (kg/ha/y)	Nitrogen (kg/ha/y)	Phosphorus (kg/ha/y)
Bridgend	Total	500		31025	1551	980	46
	Per ha		14	2216	111	70	3
Clontibbret	Total	200		12410	410	401	58
	Per ha		7	1773	59	57	8
Knockatallon	Total	105		6515	508	177	23
	Per ha		5	1303	102	35	5
Dromore	Total	520[a]		32266	549	365	50
	Per ha		15	2151	37	24	3

[a] Estimated as 20% of total loading to works (PE 2600)

[b] Population Equivalents

3.1.1 Clontibret

The Clontibret irrigation system was commissioned mid May 2014 and the irrigated total to 10th October was 3925 m^3 (over a period of 149 days). This is an average application of 26.3 m^3day^{-1} (approximate average daily inflow into the treatment WWTWs [Fig.4]). There has been a total of 35m^3 discharged to the stream during this period which represents a discharge of less that 0.9% of the total in-flow into the WWTWs. At this point in time, the total nutrient recycled to the SRC willow and consequently removed from the river basin was 127kg N and 18kg P. This nutrient quantity is within the crop nutrient off-takes as outlined above and will subsequently be removed when the crop is harvested. The discharged volume represents just 1.1kg N, 0.2kg P and 1.5kg BOD.

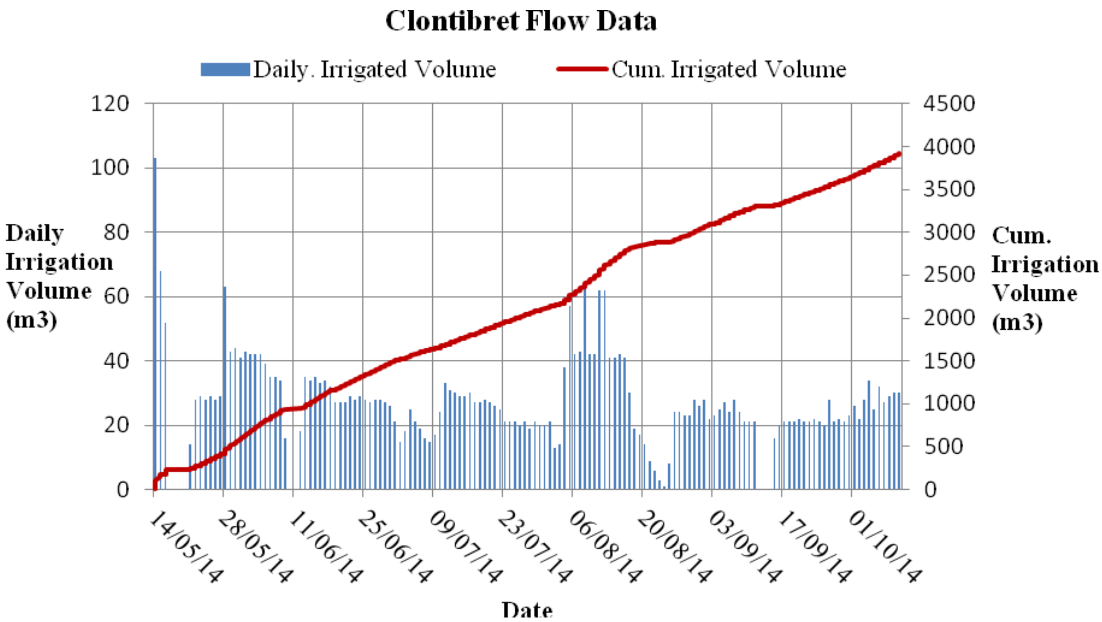

Fig.4: Daily and cumulative irrigation history at Clontibret WWTWs

3.1.2 Bridgend

The Bridgend irrigation system was commissioned during May 2014. The irrigation regime shows the beginning commissioning period at approx 30 $m^3 day^{-1}$, the readjusting between 6th to 8th June and the subsequent equalisation of the irrigation rate to manage the inflow to the WWTWs [Fig 5]. The average irrigation rate since 6th June, post commissioning, has been 91$m^3 day^{-1}$ and the irrigated total from this point to 11th October was 11,638m^3. The volume discharged during this period was 2055m^3. It was established on 8th Oct however that one set point in the controls was causing an overflow so these figures should be improved on in subsequent seasons. The total nutrient recycled to the SRC willow and consequently removed from the river basin during this period was 368kg N and 17kg P. This nutrient quantity is within the crop nutrient off-takes as outlined above and will subsequently be removed when the crop is harvested. The discharged volume represents 65kg N, 3kg P and 46kg BOD.

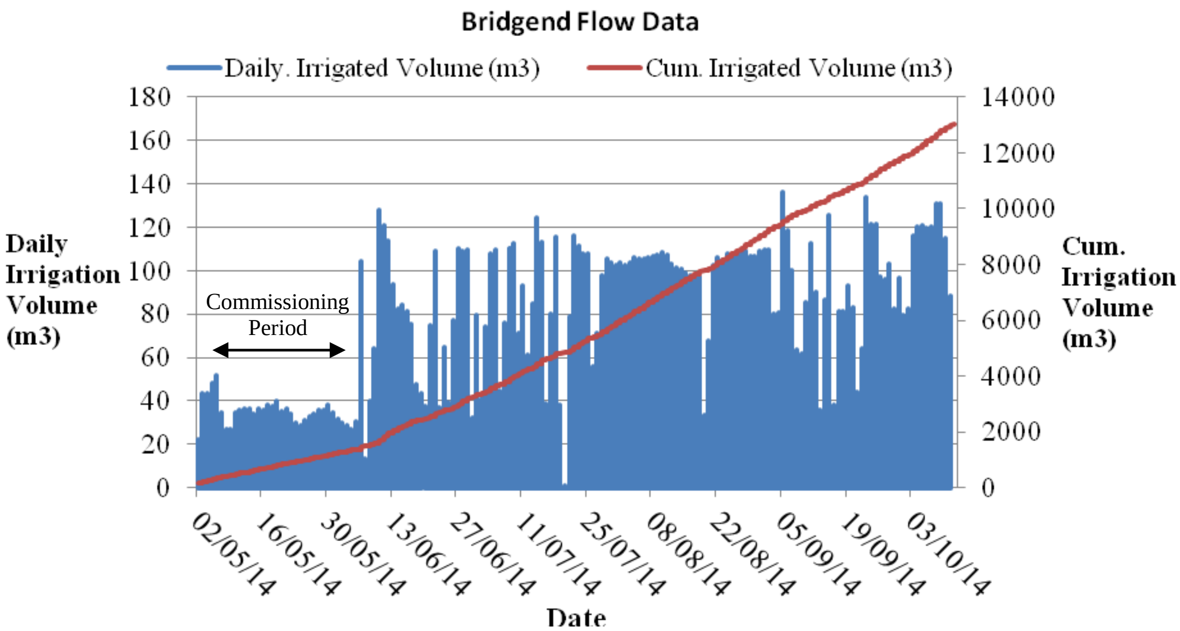

Fig.5: Daily and cumulative irrigation history at Bridgend WWTWs

3.1.3 Knockatallon

The Knockatallon irrigation system was commissioned during July 2014. The average irrigation rate up to 31st October 2014 was approximately $20m^3day^{-1}$ and the irrigated total to this point was $2,016m^3$. The volume discharged during this period was $174m^3$. The total nutrient recycled to the SRC willow and consequently removed from the river basin during this period was 55kg N and 7kg P. This nutrient quantity is within the crop nutrient off-takes as outlined above and will subsequently be removed when the crop is harvested. The discharged volume represents 5kg N, 1kg P and 15kg BOD.

4. MONITORING

Monitoring programmes are in place to ensure that the volume of effluent being applied does not cause any uncontained pollution or indeed soil nutrient or heavy metal build up. The stream water and groundwater monitoring points (bore holes) are tested bi-monthly to ascertain the levels of BOD, suspended solids, Total Nitrogen, Total Phosphorous, pH and Dissolved Oxygen. Also regularly analysed and recorded are the irrigated effluent and stream water quality. Although it is too early to include these scheme data at this point, ongoing research at AFBI using primary WWTW effluent (more concentrated N & P) has indicated no significant elevation in soil, soil water or ground water of these nutrients.

5. CONCLUSIONS

Bio(phyto)remediation of effluents offers a cost effective, environmentally safe, low carbon and sustainable approach to the management of wastewater (Biopros 2008), however the system must be well designed ensuring environmentally safe and reliable operation and the protection of the system's individual components over the long term (Riddell-Black et al. 2008). It has particular application to small scale rural treatment works handling the effluent loading from small (< 500PEs) settlements. In the majority of these cases it is unlikely that it will be economically viable or practical to upgrade such works to make them compliant. Research in Sweden (Hasselgren 1998, Rosenqvist et al. 1997) and in Northern Ireland (Rosenqvist and Dawson 2005, Werner and McCracken 2008) has shown that SRC willow is highly effective in dealing with high volume high nutrient effluents. In a number of trials there has been no evidence of leaching of N to groundwater, or issues of P contamination due to overland flow. Some of the nutrients are taken up by the plants and result in nutrient off-take when the SRC willow is harvested every three years and subsequently utilised for biomass bioenergy. The willow root systems act as a filter to enable soil microbial processes to metabolise the nutrients, while at the same time enriching the soil. Often, the limiting factor to irrigation is the site relief, hydrogeology and the success of the establishment of the SRC willow plantation.

It is best if the SRC willow plantation is adjacent to the WWTWs to reduce pipe and pumping costs and carbon emissions, however if the plantation is within 1 - 2 km it is still viable as the rising main can be laid on top of the ground which reduces costs. In all four sites described within the ANSWER project, the pipe from the treatment works to the SRC willows was mostly above ground. In the Monaghan sites, at Clontibret and Knockatallon, it was necessary to directionally drill the pipes beneath a small country road. This was achieved with minimum disruption and at low cost.

NI Water is Northern Ireland's largest electricity consumer (ANON 2014a) and given N.Ireland's high dependence on fossil fuel imports (ANON 2008), can make a significant contribution to green house gas emissions by incorporating more sustainable waste water treatment technologies and transforming the WWTWs asset base to use less energy and emit less carbon. This can be done while improving compliance in this manner. The only power requirements for SRC willow irrigation of waste water are for running a low specification pump which is required to pump the effluent to the irrigation system and the power to run the small computer control and automatic valve system. NI Water collects and treats 300,000 m^3 of waste water every day which involves the maintenance and operation of over 1,100 WWTWs and around 1,200 pumping stations. If a number of these smaller WWTWs were to be transformed to sustainable low carbon processes such as SRC willow bioremediation technology, the overall energy savings to the water company could be significant along with an increasing input into this sector's contribution to renewable energy production, agricultural biomass energy supply chain employment as well as a beneficial contribution to reducing the pollution caused by the cumulative effect of these small WWTWs within our basin catchment districts.

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