BHR Group

EXPERTS IN FLUID ENGINEERING

Water and Wastewater Mixing Programme

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Executive Summary

This document is a proposal for Phase 8 of the collaborative research programme called Water and Wastewater Mixing (WWM). Phase 8 concentrates technically on two of the themes identified in UKWIR's Strategic R&D Roadmap (A Road Map of Strategic R&D Needs Ref No. 07/RG/10/3): 'Chemical Free Treatment' and 'Energy Management'. Within these themes a selection of nine possible work areas are presented for the members to vote for:

<u>'Chemical Free Treatment'</u>

- Floc Strength Research
- Coagulation Dose Optimisation toolkit
- Optimised Polymer Dosing
- Primary Sedimentation Tank Optimisation
- Co-digestion and Digestion Technology
- Advanced Anaerobic Digester Design

'<u>Energy Management</u>'

- Pipe Fouling
- Sludge & Sludge Pumping
- Sludge Dewatering

WWM deliverables are Software tools, Design Guides, Research Reports, Seminars and Consultancy. WWM Software Tools include the BHR Sludge Rheology Database (SRDB) and the BHR System Losses Tool (SLOT), which are the most modern available for predicting sludge rheological properties and calculating pipe system losses. WWM Design Guides enable members to assess and upgrade existing plants, and design new plants. All have led to process improvement as well as capital and operating (chemicals, power and labour) cost savings. Mixing Seminars and Mixing Consultancy help the consortium members to implement the benefits of the WWM programme.

To date, the WWM programme has successfully delivered 14 years of unique, cost effective and focused research in Phases 1 to 7. WWM membership comprises Water PLCs, consultants, equipment and chemical manufacturers. New members get access to all earlier programme results and deliverables following the payment of a joining fee.

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1. Introduction

WWM: the Water and Wastewater Mixing Research Programme at BHR Group is supported by Water PLCs, consultants, chemical and equipment suppliers.

The WWM programme is conducted as a series of 2-year phases with members signing –up to each phase and receiving a defined 2-year work programme and deliverables in return. New members pay a joining fee and receive all Design Guides, Research Reports and Software Deliverables from previous phases.

During the first two years (1996-1998) Phase 1 of the programme focused on blending in pipes and channels without dedicated mixers present. During Phase 2 (1998-2000) pipe static mixers, channel static mixers, weirs and stirred tank flash mixers were investigated. During Phase 3 (2000 to 2002) inline dosing of additives into sludge and the effect of additive viscosity on blending rates have been investigated. WWM Phase 4 (2002 to 2004) has concentrated on sludge conditioning, dosing for P removal, sludge blending and mixing in-line, ragging and anoxic zone mixing. WWM Phase 5 (2005-2006) has produced the BHR Sludge Rheology Database (SRDB) and extended work on dosing for P removal, sludge tank blending and anoxic zone mixing. WWM Phase 6 (2007-2009) has produced the BHR Sludge System Losses Tool, Sludge Tank & Digester Mixing Design Guide, significantly upgraded the SRDB, conducted successful site trials on coagulant mixers for P-removal as well as energy benchmarking mixing and flocculation processes. WWM Phase 7 (2009-2011) has produced an upgraded version of BHR Sludge System Losses Tool, an upgraded SRDB, a sludge tank and digester mixing software tool as well as a pilot scale floc strength demonstration project.

The main WWM deliverables to date are Software Tools, Design Guides and Research Reports. The Design Guides (Pipe & Channel Mixing and Dosing, Sludge Tank & Digester Mixing and Anoxic Zones) enable users to select the most efficient equipment within the process, site and cost constraints. The BHR Sludge Rheology Database software tool provides the most comprehensive collection of sludge flow data collected anywhere in the world. The database has enabled correlations for prediction of sludge flow behaviour to be developed for sludge types (such as potable and hydrolysed) for which no prediction could be done before. The BHR Sludge System Losses Tool provides users with easy to use calculation of sludge pipeline headlosses incorporating the latest rheology from the SRDB thereby enabling selection of the most energy efficient pumps.

2. WWM Overall Objectives

To enable members to achieve quantifiable improvements in energy efficiency and reduction in chemical usage through application of mixing technology and fluid engineering. For example, this objective can be achieved by:

- Maximising process efficiency at the same time as achieving design throughput.
- Minimising chemical use by avoiding overdosing.
- Utilising case studies to quantify actual savings.
- Minimising energy usage and reducing Carbon footprint
- Ensuring uniform mixture and flow distribution at flow splits.
- Sampling from well-mixed locations.
- Benchmarking and improving existing installations.
- Optimising new installations at the design stage

3. Programme of Work

3.1 WWM Phase 8 (2011-2013)

The research areas covered in WWM are closely aligned to both the UKWIR roadmap and the themes identified to OFWAT by the water companies as part of the AMP 5 submission. It is clear from the regulatory drivers that the following themes are central to the water industry throughout the AMP 5 investment period:

- Enhanced process efficiency
- Reduction in carbon footprint

The UK is generating and the water industry processing increasing quantities of both wastewater and sludge. This has led to significant ongoing capital expenditure on new and refurbished wastewater treatment plant and sludge treatment facilities in AMPs 4 and 5. In AMP 4 particular attention is being paid to biological N and P removal, chemical P removal, storm water treatment and sludge processing. These operations require a quantified knowledge of the specific process mixing and hydraulic requirements, well-designed and efficient mixing systems and, where applicable, accurate information on sludge flow behaviour or rheology.

Major AMP 5 themes include Asset Stewardship, Environmental & Public Health Protection and Sustainable Development & Climate Change. The EU Water Framework Directive is driving improvements in surface and groundwater quality through integrated catchment management initiatives. Implementation of the WFD demands higher effluent discharge quality and tighter biosolids handling and disposal practices; to achieve this will require significant retro-fitting of existing assets as asset life is extended.

Energy efficiency is becoming of primary importance to the industry due to both rising energy prices and the pressing need to stabilise and reduce carbon emissions. The introduction of the CRC energy efficiency scheme (formerly the Carbon Reduction Commitment Scheme) in April 2010 for energy users above 6,000 MWh, again highlights the need for the utilities companies to prioritise energy efficiency. The industry faces a massive challenge to treat greater volumes of water, wastewater and biosolids to higher environmental standards whilst still minimising energy consumption, frequently with restricted space in heavily populated areas. A better detailed understanding of how the industry uses energy and how to achieve the most energy efficient whole life approach is urgently required. Significant operational savings can be made when current energy usage and options for reduction can be properly evaluated. The upcoming deregulation of sludge processing by OFWAT is also likely to increase the potential for water PLC's to generate efficiencies by an holistic approach to energy.

Renewable energy sources are increasingly being exploited by the water industry. However, there is considerable scope for improved energy generation from sludge as well as other renewable options.

Chemical (particularly coagulant) usage by the industry is increasing, due in part to phosphate removal requirements in wastewater treatment. At the same time coagulant costs are also rising, as the market is more volatile than previously. At the operational level there is a pressing need for chemical dose optimisation and improved dose control tailored to influent water quality. Best operational practice should be defined. This should be coupled with an improved understanding at base level of the fundamentals of chemistry of iron and other coagulants to ensure their more effective long-term use.

3.1.1 Pipe Fouling

Introduction

Pipe fouling is a known issue within the waste water treatment process, in particular the formation of Struvite and Vivianite which under certain conditions can form blocking deposits within process pipelines and can lead to major asset failure. Another main contender for blockage due to fouling within the waste water network is fats, oils and greases or “FOG”. This causes down-time and process disruption to repair the asset and contributes to general inefficiency within the pumping network as the pipe lines become fouled. Improved knowledge of the fouling properties of various waste streams would enable utility companies to produce better investment plans for asset maintenance and replacement. This knowledge would also be of importance in the design stage to better inform the overall design and achieve improved energy efficiency.

Objectives

- Carry out a literature review to identify current knowledge
- Review members priorities to focus work programme
- Identify process “hots-spots” where fouling is likely to be excessive (where the deposition of Struvite/Vivianite is likely to occur and/or where FOG may build-up)
- Obtain real data regarding asset failure rate that has been linked to pipe fouling (data to include pipe material, asset age, waste stream type, throughput etc)
- Develop a model to predict asset failure rate based on the asset data collected
- Assess the effect of changes in sludge chemistry (pH, temperature, conductivity, magnesium, ammonia and phosphorus content) on Struvite/Vivianite solubility Assess viability of a laboratory and plant methods of estimating pipe fouling (ultrasonic device, process tomography)

Scope of Work

- Carry out literature review to cover the main areas of pipe fouling within the wastewater treatment process – from collection to treatment.
- Obtain UKWIR report on phase 3 of the WIDER project (Water Industry Database for Equipment Reliability)
- Construct a database to hold information regarding asset material, age and failure rate.
- Develop a model to predict asset failure rate and potential costs based on asset information – output aimed at classifying assets into high risk, medium risk and low risk.

- Develop laboratory and plant scale methods of assessing pipe fouling using different pipe materials and fouling substances

Deliverables

- Research report on literature review
- Database and model to predict fouling risk
- SLOT pipe fouling module
- Prototype pipe fouling monitoring method

3.1.2 Floc Strength Research

Introduction

Floc strength is a notoriously difficult measure to quantify and apply to practical situations but is of great importance in the design and optimisation of coagulation/flocculation processes and subsequent filtration. Floc strength is a very important operational parameter that is key to the performance of separation processes for the removal of aggregated particles. The aim of these processes should be to minimise floc breakage since it is generally thought that larger flocs can be removed more efficiently via the conventional processes of sedimentation and floatation. It is well known that larger particles of similar density and shape can settle faster than smaller particles. Also, in conventional DAF processes, rising small bubbles can attach themselves more easily to larger particles and thus increase the efficiency of removal.

However in practice, flocs are exposed to a large range of shear-induced fields as they pass from and through various plant processes. In order to maintain the maximum possible agglomerate size and minimize breakage, flocs must successfully resist these shear forces. For a certain imposed shear stress an equilibrium floc size will eventually prevail. This equilibrium size is partially determined by the floc strength, which in turn is a strong function of the floc formation during coagulation and flocculation. Temperature also plays an important part in the equilibrium floc size and strength. Coagulation is a universal process for treating drinking water. It is defined by all the reactions and mechanisms involved during the chemical destabilisation of colloidal particles aiming at the formation of large flocs through flocculation. In some cases flocs are unable to re-agglomerate if they are exposed to a very high shear rate. Therefore the energy required to break the bonds between the flocs is of high control and operational importance.

The type of coagulant and the type of flash mixer used for rapid homogeneous coagulant distribution may have a different effect on the floc strength. For instance, initial literature results suggest that strong hydrolysing coagulants such as PAC give lower floc strength than cationic polyelectrolytes such as polyDADMAC and Zetag. Also a variety of flash mixers e.g. different mixer types and sizes, are currently being used in the water industry that generate different distributions of local energy dissipation, which would eventually result in a range of equilibrium floc sizes. Therefore to address the operational issue of floc strength and to assess and compare the properties of different coagulated systems, this work proposes to establish the effects (subject to scope) of:

- Different coagulant types on the floc strength for a range of shear rates
- Different raw water types (e.g high NOM-low turbidity, high turbidity – low NOM, high iron/manganese groundwaters etc)
- Different flash mixing conditions on the floc strength for a range of flow rates
- Flocculation conditions e.g RTD, time, mixing intensity etc.
- Different suspensions (e.g activated, sewage sludge etc) on the floc strength for a range of shear rates.
- Temperature on the floc strength for a range of operating conditions (e.g. different suspensions, coagulants and mixers).

Scope of Work

- Carry out laboratory based tests using a suitably scaled floc strength test rig (as per WWM7) to test different water types, coagulants and flash mixing conditions
- Assess the floc strength results in terms of floc size ratio as measured by the particle sizer and also a photometric dispersion analyser to compare the two methods side by side
- Identify situations where changing coagulant dose/type/pH or changing flash mixing or flocculation conditions may be beneficial to the system floc strength and hence separation performance.
- Identify potential savings in chemical dose through optimised flash mixing or flocculation conditions.
- Develop a mobile test rig that can be taken to site so that the coagulation conditions onsite can be replicated and alternative doses, coagulants, flash mixing and flocculation conditions may be assessed and compared
- Develop a manual for operation of the test rig

Deliverables

- Research report on effect of variables on floc strength using laboratory based and mobile test rigs.
- Best practice guide for avoiding unnecessary floc breakage and maximising floc size and strength. This will be available online.
- Mobile test rig prototype capable of onsite monitoring
- Case study on a WTW under challenging conditions using the above prototype

3.1.3 Optimised Polymer Dosing

Introduction

Polymeric flocculants have long been used within the water and wastewater treatment process as settlement and filtration aids. Recently there have been cases of retro-fitting polymer dosing units downstream of the clarification stage and prior to filtration in order to optimise filter performance by extending run time and preventing breakthrough. Polymeric flocculants are thought to act as bridging agents, and bind the small micro-flocs carried over from the clarification process into larger and stronger floc particles. It is easier for the downstream filtration processes to remove the larger particles, but there is a cut-off point at which the polymer dose becomes detrimental and filters start to clog. Polymeric flocculants are expensive and generally little attention has been paid to optimising the mixing of the flocculant with the process stream. With improved mixing and a superior method of jar testing for assessing the optimum flocculant type and dose – it will be possible to optimise the polymer dose (tailoring it to the incoming water properties) and thereby reduce costs.

Objectives

- Develop a methodology and design guide specifically for the design of polymer dosing applications, and provide a comprehensive training package in how to use the design guide
- Evaluate a range of flocculants based on jar tests/pilot plant in order to assess the ability to re-flocculate floc that has been subject to a defined shear regime. Identify floc size and strength range that results in good filtration. Identify floc size range that causes filter blockage.
- Use photometric dispersion analyser and clarified water (work would be best done onsite) to assess the extent of re-flocculation onsite with and without flocculants based on existing plant design
- Undertake site audits to identify sub-optimal dosing applications

Deliverables

- Design guide specific for dosing polymeric flocculants
- Training package to deliver design guide
- Research report on use of PDA for identifying optimum flocculant dose
- Case studies to demonstrate cost-savings from optimised polymer dosing

3.1.4 Coagulant Dose Optimisation Toolkit

Introduction

Chemical precipitation is increasingly being used for Phosphorus removal on wastewater treatment plant. Metal salts, such as Ferric Chloride or Aluminium Sulphate, Lime and polymers can be dosed upstream of the primary tanks, upstream of the secondary tanks or downstream of the secondary tanks.

The quantity of metal salts and polymer required for P removal is minimised with effective mixing and flocculation. As with potable water coagulation, rapid mixing is required to enable stoichiometric quantities of dosed chemicals to be used. Flocculation times and hydraulic conditions can also be important for effective P-removal. Long mixing times result in the need to apply higher chemical doses (often nearly double the stoichiometric quantities), treat and dispose of larger quantities of sludge and potentially encounter excessive residuals in the effluent.

Most WWTW have not been designed with the need for chemical dosing, mixing and flocculation in-mind, consequently retrofitting mixers can be problematic. The key issues are:

- Selection of lowest acceptable chemical dose (and control strategy) on a regular, site by site basis with and without optimised mixing.
- Assessing the potential savings from reduced chemical consumption, sludge production etc. in order to justify optimised mixer and control system lifetime costs.

These issues can be addressed by the development of a portable ‘toolkit’ for chemists (or operators) comprising hardware and software for optimum chemical dose and mixing condition determination. The ‘toolkit’ will comprise of laboratory scale chemical dosing, mixing, flocculation and separation equipment to be applied to wastewater or potable water. Crucially, the equipment will be integrated with software enabling the user to accurately scale-down existing and proposed mixing and hydraulic conditions from the site being optimised to the bench scale equipment.

Objectives

- Develop, design and build a 'proof of concept' prototype 'tool-kit', comprising hardware and software, for optimum chemical dose determination on a site by site basis.
- Plan and conduct laboratory and site trials with the prototype 'tool-kit' to test operability functionality and accuracy. Demonstrate potential for realising cost savings.
- Use the trial findings and production requirements to refine 'toolkit' design.
- Identify mechanism for producing the 'toolkit' in sufficient numbers for WWM members.
- Disseminate results within WWM member companies.

Scope of Work

User requirements

WWM members will be consulted regarding the application of the 'tool-kit' on water and wastewater processes, likely users, priority features, functionality and constraints imposed on the proposed equipment. The range of chemical dosing, mixing, flocculation (and separation) processes required to be covered will be reviewed. Likely health and safety issues will be considered.

Functional specification

The user requirements will be prioritised and a functional specification of the 'tool-kit' drawn-up. The specification should cover each of the major steps in 'tool-kit' operation e.g. mapping key parameters from test site into software, charging raw water and chemical containers, setting dose volumes, hydraulic profile and separation criteria.

Hardware design

Size, flows, waters, waste-water and chemical quantities will be determined. The modelling range of hydraulic profiles will be assessed. Assessment methodology for floc separation performance will be designed. The monitored parameters (e.g. pH, temperature) will be identified and instrumentation specified.

Software design

Functionality:

- laptop operation

Input parameters:

- plant flows, full scale mixing characteristics, hydraulic profile, current chemical doses, separation characteristics, separation performance measure.
- ’Tool kit’ test matrix results

Output parameters:

- ‘tool-kit’ settings for test plant mimic and for optimised mixing (based on benchmarking).
- Suggested test matrix.
- Chemical dose optimisation results

Build ‘hardware’ prototype with instrumentation

BHR will construct one or more prototype ‘toolkits’ based on the functional specifications. More than one prototype will only be required if the first prototype is not considered sufficiently operable for on-site trials.

Laboratory testing of ‘hardware’ prototype

The prototype(s) will be subjected to a range of tests in BHR laboratories. The tests will establish the basic functionality of the hardware. Teething troubles will be identified and overcome.

Write ‘software’ prototype

Create software for

- Input and output displays.
- Full scale equipment database.
- Hardware characteristics.
- Hardware setting calculation algorithms.
- Test matrix determination.
- Result interpretation.
- Dose and mixing optimisation.

Plan and conduct laboratory demonstration

A demonstration will be carried out in BHR laboratories for the benefit of WWM members. Member’s comments and views of the proposed equipment will be used to steer the subsequent development and site trials.

Plan and conduct site trials & performance validation

Two sites will be selected from those put forward by Members based on pre-determined criteria. BHR will visit each proposed site as part of the planning process to confirm suitability and establish trial details. The site trials will explore how well the dose optimisation 'tool-kit' can replicate plant performance under known conditions as well as the sensitivity of the established separation performance criteria to plant flow, chemical dose and hydraulic profile. The operability and usability of the 'tool-kit' under real operational conditions will be established.

Report on site trial results

The technical and operational results from the site trials will be detailed in a written report as well as being presented to Members. Conclusions arising from the trials will be drawn and recommendation for improvements put forward.

Incorporate results into revised 'toolkit' design

The 'tool-kit' design will be revised in the light of recommendations from the two site trials. In addition, consideration of series-production requirements and production cost optimisation will be incorporated in the revised design. Either one of the existing prototypes will be upgraded or a new prototype will be built to the revised standards.

Explore Production mechanisms

Options for series-production of the 'tool-kit' will be explored eg BHR production, production under licence by third party.

Write operating manuals for 'tool-kit'

A detailed, but easy to use, Operating Manual for the 'toolkit' will be written and incorporated into the 'tool-kit' software.

Deliverables

- Chemical dose optimisation 'tool-kit' prototype(s)
- Laboratory demonstration
- Site trials & performance validation
- Detailed report on design, development, site trial results, refined design and recommendations for 'tool-kit' production.
- Software 'Tool-kit' operating manuals

3.1.5 Sludge and Sludge Pumping

Introduction

With the impending deregulation of sludge treatment allowing water companies to take and treat sludge from external sources, the implications are that longer sludge pumping mains will be required during AMP 5 to process the sludge efficiently at centralised sludge treatment centres. A major problem with the design of such assets, is that the rheological properties of sludges from the various new external sources are not known. Some knowledge of the rheological properties of the sludge and what pressure surge characteristics and system losses would be exhibited would lead to:

- Improved safety
- Reduced risk of system failure
- Improved energy efficiency through better pump specification

Aqua Enviro have previously developed a method for the quantification and identification of fibres in sewage as both the fibre quantity and fibre type was found to be a critical factor in the performance of sludge dryers. The sampling carried out during these studies found that the fibre quantity and type, found in sludges can vary greatly with the presence of trade, catering/hotels and in particular hospitals (where a large quantity of waste is macerated before being put to sewer) within the catchment had a huge impact upon the fibre composition and hence the drying properties.

However the impact of fibres upon both sludge rheology and dewaterability has never been suitably quantified and so it is not known whether the impact of fibres is negligible or a key factor that should be considered in predicting rheology and selecting and optimising polymer addition for dewatering. Given the critical impact that fibres had on sludge drying (resulting in a number failing installations leading to litigation) then there is suitable justification for research into this area to develop a better understanding as to whether fibres should be considered when characterising a sludge and designing sludge handling facilities. The fibre test involves quantification of the fats, oils and grease (FOG) and so the FOG content would also be recorded to determine if it makes any significant impact upon the sludge properties.

There are a wide range of potential objectives for this work package, they will be narrowed once member interest has been gauged.

Objectives

- Measure rheological properties of new waste stream sludges and mixtures
- Aqua Enviro to carry out fibre analysis on existing sludge types and new sludge types/mixtures
- Evaluate the effect of fibre content, fibre type and FOG on sludge rheology using existing BHR Group procedure, and update the SRDB or new purpose built data base with the data for a range of sludges.
- Assess pressure surge characteristics
- Analysis of sludge cakes with particular interest in rheology upon dilution and fat/fibre content
- Update SLOT where appropriate
- Full scale validation for SLOT
- Additional non-Newtonian fitting losses
- Additional pump start-up and derating work
- Work with pump manufacturers to incorporate pump curves into SLOT

Scope of Work

- Obtain a range of liquid sludges from members and others, particularly those with a suspected high fat or fibre content and those from new waste streams. Analysis of fibre/fat content to be carried out by WWM partner Aqua Enviro, and rheological properties to be analysed by BHR Group and results combined and entered into SRDB or new purpose built database. The same to be repeated for sludge cakes, with an additional dilution and re-suspension method procedure incorporated.
- Full scale site trials could be conducted, with the assistance of a member company, in order to provide additional validation for the SLOT loss curve calculations.
- Specific fitting loss coefficient data could be generated using BHR Group's pilot scale rig.
- Work with pump manufacturer WWM members to combine the system losses calculated by SLOT, with the pump data held by the manufacturers to produce pump curves and a recommended pump model.

Deliverables

- Updated SRDB or new purpose built database to include correlations with fibre content/fibre type and sludge originating from re-suspended sludge cake
- Updated SLOT with new interface between pump manufacturer's data and SLOT to provide members with pump curves

3.1.6 Sludge Dewatering

Introduction

Improvements in sludge dewatering performance provide significant potential benefits through:

- Reduced volumes of dewatered sludge for transport and disposal and hence reduced costs
- Reduced energy consumption and hence costs for incineration or other sludge treatment processes
- Reduced chemical consumption
- Increased sludge throughput

Following on from section 3.1.5 it is proposed that the impact of fibre quantity and fibre type upon sludge dewatering should be quantified. As fibres were shown to heavily impact upon the release of water from sludge through thermal drying processes, it is likely that they may impact upon the retention / release of water during sludge dewatering.

Objectives

- Obtain a selected range of sludges from within the wastewater treatment process, to include thermally hydrolysed sludge and polymer dosed sludge.
- Use WWM partner Aqua Enviro's services to provide capillary suction time (CST) and/or specific resistance to filtration (SRF) tests to provide a benchmark of dewaterability between different sludge types
- Aqua Enviro will carry out fibre analysis on these samples to determine whether there is any correlation between fibre quantity and/or fibre type and sludge dewaterability. If a correlation is found then this could prove to be a key factor in polymer selection and dosage control
- Experiment with a range of flocculants and sludges of different origin and perform CST/SRF test to determine correlations between flocculant type/dose and dewaterability for a range of sludge types
- Construct a new database on de-waterability as expressed by capillary suction time test results
- If fibres are found to impact upon dewaterability then the new database will also be updated with fibre data

Scope of Work

- Critically review literature on sludge dewatering
- Obtain range of sludges from the members, to include SAS. WWM partner Aqua Enviro to perform capillary suction time tests on sludges, and carry out fat/fibre analysis. Aqua Enviro to experiment with a range of flocculants and doses and perform capillary suction time tests to investigate effect of polymer type and dose. BHR Group to update SRDB with rheological properties of sludge, and incorporate new capillary suction time test results into a new database.

Deliverables

- New dewaterability database to include entry point for de-waterability as measured by capillary suction time test, fibre and fat content and rheological properties of flocculant dosed sludges
- Report on effect of flocculant type and dose on sludge dewaterability for different sludge categories

3.1.7 Co-Digestion and Digestion Technology

Introduction

Anaerobic Digestion is key to the sustainable recycling of biosolids as it provides both volatile solids and pathogen reduction as well as biogas production. Rising energy costs have prompted renewed investment in biogas production and electricity generation, with ROCs being seen as a significant revenue stream for the Water industry. Increasing feed solids concentration is one way of maximising gas production, however mixing and heating systems must be properly designed to cope. As of 2011 OFWAT will be likely to de-regulate sludge processing thereby allowing water companies to process waste streams from external sources. Sewage sludge is a relatively poor substrate for digestion as it has a low carbon to nitrogen ratio resulting in a relatively low biogas yield. Therefore the addition of wastes with a higher carbon to nitrogen ratio can be highly beneficial resulting in a greatly increased biogas yield. This means there is a considerable potential cost and energy saving available to water companies by optimising the digestion process to cope with co-digestion of industrial and municipal wastes alongside sewage sludge. In order to fully benefit from this potential saving, more information is needed on:

- Mixing/blending of imported sludges for the design of centralised processing centres.
- Potential for existing plants to accept and process sludge from external sources.
- Typical waste streams available and physical properties (rheology, density), nutrient content etc.
- Effect of co-digestion on the rheological properties of the digestate.

Objectives

- Carry out a survey of new waste streams, BHR to investigate rheology and density and use WWM partner Aqua Enviro to analyse the composition of the materials (i.e. solids and volatile solids, nutrient content – carbon to nitrogen ratio, calorific value)and to carry out biochemical methane potential tests to identify potentially suitable waste streams
- In partnership with Aqua Enviro, operate laboratory scale co-digestion reactors on suitable blends of sewage sludge/waste streams (as identified from the survey) under representative process conditions for 2-3 hydraulic retention times to generate representative samples of digestate from an acclimatised process treating these wastes
- Evaluate the effect of co-digestion on the sludge rheological properties and de-waterability of the resulting digestate

- Determine the potential impacts upon digester design and evaluate the potential for existing process plant to adapt to take advantage of the co-digestion potential

Scope of Work

Obtain sludges of both municipal and industrial origin and, in partnership with Aqua Enviro, undertake analysis to identify wastes with a high potential for good co-digestion performance. Undertake a series of co-digestion experiments and analyse the rheological properties and dewaterability from the resulting digestate. The effectiveness of co-digestion to be determined by biogas production. Members to put forward particular WwTW's as candidates for site audits. BHR Group to undertake a number of site audits to evaluate potential for WwTW's to undertake co-digestion with particular focus on:

- Mixing arrangements
- Reactor design and retro-fit potential
- Upstream asset performance (example primary tank settling performance)

Deliverables

- Update SRDB with raw and co-digested sludge rheological properties.
- Inclusion of de-waterability properties (as measured by capillary suction time test) to new database.
- Report on co-digestion studies
- Report on WwTW retro-fit feasibility (feasibility study)

3.1.8 Advanced Anaerobic Digester Design

Introduction

The desire for sludge treated to an enhanced standard to facilitate recycling to land has led to increasing numbers of hydrolysis plants upstream of digesters. The term Advanced Anaerobic Digestion (AAD) has been coined to describe digestion with higher feed solids (5-12% DSC, frequently pre-hydrolysed), short retention times, loadings of >3kg VS/m3/day and integration with CHP. However, Advanced Anaerobic Digestion can only realise its full potential with improved mixing system design to ensure rapid blending of thick, gassing feeds. All too often digester mixing systems have failed on modern digesters due to poor mixer selection, sizing and understanding of sludge rheology by mixer suppliers. This has resulted in increased foaming due to poor feed distribution, reduced loading rates, and reduced gas production and solids build-up.

The solutions to the issues of mixing with higher digester feed solids are as follows:

- Identify relevant mixing performance criteria e.g. feed blending, active volume & solids suspension.
- Identify feed & bulk sludge physical properties (rheology, density)
- Produce predictive techniques for modelling the performance of relevant mixing systems (impellers, jets, gas etc.) under different operating conditions, sludge rheological properties and digester geometries.
- Provide design software for rating or selection of optimum mixer types and sizes.

BHR Group is ideally placed to provide advanced mixing software for Advanced Anaerobic Digestion. Relevant mixing criteria have been identified (further refinement for hydrolysed feed may be needed):

- Production in WWM 5 & 6 of paper based Sludge Tank & Digester Mixing Design Guide and production of software Design Guide in WWM 7
- Development of the Sludge Rheology Database in WWM 5 to 7 provides unparalleled information for development of predictive mixing models
- Best available validated CFD modelling of digesters and sludge tanks
- Other industry performance modelling of impeller and jet mixed tanks.
- Development of jet, submersible and gas mixing cavern size correlations in WWM 6

However, there is a need for design information to be specifically tailored to retro-fitting of existing digestion assets to cope with either hydrolysed or combined waste streams for co-digestion. In addition, validated CFD models are not currently available for unconfined gas mixed syatems. This workpackage aims to address these deficiencies.

Objectives

- Develop design guidelines (toolkit) specifically for retro-fitting of existing digesters to handle hydrolysed sludge or co-digestion sludge feed.
- Develop physically validated CFD models of digester or sludge tank unconfined gas mixing systems.
- Produce improved software Digester Mixing design guide.

Deliverables

- Design guidelines for retro-fitting of existing digesters to handle hydrolysed sludge or co-digestion sludge feed.
- Physically validated CFD models of digester or sludge tank unconfined gas mixing systems.
- Improved software Digester Mixing design guide.

3.1.9 Primary Sedimentation Tank Optimisation

Introduction

Primary sedimentation tank (PST) suspended solids (SS) removal performance is key to the overall WwTW operation. Poor solids removal leads to excessive loading on downstream process units (activated sludge and tertiary treatment if present), which are generally more expensive to operate per unit flow. SS removal performance usually declines with increasing plant flow towards the PST design maximum, so achieving higher plant throughput can be limited by PST capacity. Enlargement or contruction of new PSTs is very expensive and requires sufficient available land area. Coagulant dosing or CAS to achieve P removal enhances SS removal performance but also places additional solids loads on primary tanks as well as changing the solids settling characteristics. However, many PSTs have poor design features (such as inlet arrangements), which if upgraded can have a significant effect on improving PST hydraulics and SS removal performance. BHR have experience in conducting a series of studies on both rectangular and circular PST hydraulics and SS removal.

Objectives

- Develop PST hydraulic and SS removal model
- Validate PST hydraulic and SS removal model against site data
- Apply PST hydraulic and SS removal model to size and select retro-fit options for underperforming PSTs

Scope of Work

- Review recent (last 10yrs) literature on sedimentation tank performance modelling.
- Develop CFD modelling of PST hydraulics and SS removal to demonstrate impact of retro-fitting design modifications on SS removal under a range of operating conditions.
- Start to populate a database of SS settling characteristics for use in the PST model.
- Select WWTW and make RTD and SS removal measurements for validation of models.

Deliverables

- Primary Sedimentation Tank Design Guide
- Operations Manual for Primary Sedimenation Tanks

Benefits

- Improved asset performance

4. Organisation and Management

4.1 Management

The Water, Environment and Power division of BHR Group will carry out this programme. A suitably experienced and qualified Engineer will be appointed to manage the programme.

4.2 Quality Assurance

The programme carried out under a contract arising from this Proposal shall comply with the relevant quality standards operating in BHR Group. These are specified in the BHR Group's Quality Manual and Quality Procedures and are available for inspection upon request.

4.3 BHR Group

BHR Group is a trading name of VirtualPiE Limited (a company registered in England and Wales with Company Registration Number: 07274578).

5. Rules and Benefits of Membership

BHR Group is hereafter referred to as 'WWM Management'.

5.1 Fees

5.1.1 Fees

The WWM Management will review fees for new and rejoining members on an annual basis.

5.1.2 Joining Fee

New Members will be subject to a joining fee equal to one year's membership. By agreement with the WWM Management, the joining fee can be divided equally between each of the first two years of membership.

5.1.3 Payment of Fees

The Membership Fee for the first year shall normally be paid on the joining date. Fees for subsequent years shall be paid annually on this date. Flexible payment terms can be negotiated.

5.1.4 Back Copies of WWM Reports and Software Tools

New Members will be entitled to copies of WWM Phase 1 to 7 Design Guides, Interim or Final reports as well as SRDB & System Losses Software published prior to the beginning of WWM Phase 8.

5.1.5 Website and Web Based Tools

Members will be entitled to access the WWM website and any web-based tools, such as SLOT and SRDB (subject to their specific usage agreements) for the duration of their paid membership period only i.e. until the conclusion of WWM Phase 8.

On completion of WWM Phase 8, all access will be removed unless a contract for the subsequent phase of WWM or separate written agreement is in place.

The WWM Management reserves the right to monitor, restrict and/or remove access without notice where it believes, at it’s sole discretion, there is sufficient reason to do so in order to protect the interests of BHR Group or the WWM consortium members.

5.1.6 Contributions in Kind

Subject to approval by the WWM Management, contributions in kind will be counted towards all, or part of, the membership fee. Such contributions will typically be assessed at the normal sale price or hire charge of the items contributed.

5.2 Membership Period

Companies are required to commit themselves to a minimum of two years membership of WWM.

5.3 Conditions of Membership

5.3.1 Delayed Publication

The WWM results will be confidential to members for five years from the date of completion of each report or Design Guide. General trends may be published within a shorter period subject to agreement from the WWM Steering Committee.

5.3.2 Release of Information

Members may use the information generated by WWM to improve their product or process; however, they will not be permitted to divulge the results of WWM projects to non-member companies, nor to associated organisations not registered with WWM without prior approval from WWM Management.

The use of information generated by WWM will only be permitted within the company or group of companies on whose published accounts the class of membership was based (see Disclosures made in any patent application will be agreed by the WWM Steering Committee.

5.3.3 Property Rights

BHR Group will retain all property rights arising from the WWM programme. Priority will be given to Members when licences are offered for the exploitation of inventions, processes or improvements.

All information, data, algorithms, correlations, software and CFD models produced by WWM are the property of BHR Group. The use of BHR Group property, other than detailed above, is expressly excluded from this Agreement. Where approval is given in writing for the use of BHR Group property, said approval shall not be construed as implying any degree of fitness for purpose of said property.

5.3.4 Royalties

Royalties accruing from inventions made in the course of WWM projects will be paid to BHR Group and used to supplement the WWM research budget at the discretion of the Steering Committee.

5.4 Free Consultancy

Members will be entitled to 1 day free consultancy each calendar year commencing on 1st of January. Consultancy is defined as desk studies, visits to a member's site at member's request, searches of literature in BHR Group's library etc. It does not include experimental work or operation of rigs. The cost of any literature searches, travel and subsistence etc. outside of BHR Group facilities will be notified to the member for his consideration and charged at cost plus 10% (to cover any administrative fees).

In the case of a member joining or terminating membership of WWM, the consultancy allowance will be pro-rata to the calendar year. Members can ascertain the number of hours remaining of their current year's consultancy from the WWM Management. Consultancy assistance in excess of the annual allowance must be the subject of a separate agreement. Work on the project will commence on receipt of an order number. All consultancy requests must be related to the subject area of WWM.

One nominated individual of the member's staff will have control over the utilisation of the consultancy time and BHR Group engineers will request their approval prior to starting work. Consultancy days must be used in the calendar year. No carry over is permitted.

5.5 WWM Seminars

WWM will arrange training seminars of 1day duration, which will include provision of course notes and demonstrations. There will be a maximum of one seminar per member per year. The seminar will be for a maximum of 1 day; it will involve 2 BHR Group engineers and have an allowed labour expenditure of 4 man-days.

The seminar will be based at BHR Group, Cranfield. In the event of a seminar being requested at a member's site, all travelling and accommodation costs will be charged to the member charged at cost plus 10% (to cover any administrative fees). The costs will be supported by receipts where possible. Travelling and seminar time in excess of the allowed 4 man days will be charged at the current BHR Group rate for the grade of engineer, or deducted from the consultancy man-days allowance for that year.

The seminar will be of a standard format. WWM will be prepared to tailor a course to the member's request, however any time required to do so will be charged at the current BHR Group rate, or deducted from that year's consultancy allowance.

5.6 Reports

Members are entitled to 2 copies of all reports and Design Guides at the time of publication. New members will receive 1 set of all previously published WWM Reports, Design Guides and Software. Interim reports will not be provided where they have been superseded.

Where extra reports etc. are requested at a time other than their publication date or with the initial membership pack, the reproduction and distribution costs will be charged at a rate of £20 per report and £50 per Design Guide. Where more than 1 set of reports are requested with the initial membership pack, a charge of £20 per report and £50 per Design Guide will be made.

5.7 Access to WWM Facilities at No Charge for Contract Research

Members will not be charged for the rental of any WWM facilities when having contract research work carried out. Access will be under the control of the WWM Project manager. Any alterations/adaptations to the WWM rigs will be charged as part of the overall contract research work. WWM free consultancy allowances may not be credited to contract research work. Single client contracts are governed by the agreed contract terms and will not be subject to WWM rules of membership. The WWM facilities are those facilities funded directly by the WWM research programme.

5.8 Copyright

This document is confidential. It contains proprietary information and is made available solely for the purpose of assisting customers to evaluate the Proposal. The document may not be used for any other purpose and may not be reproduced, copied or distributed to any third party without the prior written agreement of BHR Group.