IWA Specialist Group Impact | *Review*

Contents

1 | Overview

IWA specialist groups represent the core vehicle for issue-based interaction on scientific, technical and management topics. The specialist groups facilitate collaboration and product generation, including conferences and publications. The specialist groups within IWA are self-managed and include groups covering all-important topics in the water management sector. Spread across IWA's membership in more than 130 countries, IWA's specialist groups are an exceptionally effective means of international networking, sharing information and skills and making good professional and business contacts.

The purpose of this document is to try to assess and review the impact that a sample of IWA's specialist groups has had on policy, practice, and implementation in specific areas of the water sector. The motivation for this task is to provide examples and evidence that will demonstrate the value, and enhance the appeal, of IWA membership to both existing and potential members.

A shortlist of potential specialist groups for consideration in the assessment was produced following consultation at the London office of IWA. A series of telephone interviews with the leaders and / or secretary's of these groups was completed against a pre-determined set of probing questions. Narratives from each of the discussions were produced, and combined with a third party search of literature references and examples of impact from group activities. The results of this assessment are organized in the following document, which concludes with a tabulation of types of change brought about by the specialist groups in question.

Points of consensus emerging from the review include:

- There are selected examples of significant impact that have brought about changes in *state* – in policy, practice or scientific thinking. In general, these are derived as a result of networking or other coordinated, member led events, or in bringing together leading experts in dedicated working groups;

- On occasion, IWA's specialist groups have been instrumental in bring about changes in *scale* of operation (such as nationwide, inter-regional or international adoption) or changes in *longevity* of practice (such as new standards that become industry norms);

- An important impact reported via the narratives has been in *intangible* elements – where specialist groups provide a basis for network, thinking / awareness raising and in capacity development;

1 | Instrumentation, Control and Automation (ICA)

Introduction

This group seeks to provide a forum to exchange information and experience internationally on all aspects of sensor technology, instrumentation, control and automation for water and wastewater treatment and transport systems. Practical experiences, case studies, management problems, operator aspects and integrated solutions of those systems will be important parts of the activities.

Some of the specific topics the group addresses includes: sensors and instrumentation systems; modelling and simulation for control and operation; control systems for transport and treatment systems; detection and early warning systems; diagnosis systems; plant wide control and integrated control; control as means of obtaining better sustainability; practical experience of instrumentation and control; information systems for operation; decision support systems; risk assessment; optimising operation.

Activities

The ICA specialist group has three key types of activity; conferences, which take place every four years (the most recent (and ninth), taking place in Busan, Korea in June 2005); project work, such as the development of an IWA Simulation Benchmark model for wastewater treatment plants; and finally through publications.

Outputs

- *Publications*

The IWA Scientific and Technical Report No. 7 (STR, No.7) on respirometry was the first structured overview on respirometric measuring principles and respirometry-based control strategies. The classification of respirometric measuring principles has lead to a standardised nomenclature that is now widely used in scientific papers.

Impact

- *The Benchmark model*

This benchmark model for wastewater treatment plants has influenced the development and assessment of control strategies for wastewater treatment systems. The model has contributed to a change in practice in the field, allowing a more objective evaluation of control strategies and the development of novel control approaches.

STR, No. 11 on respirometry formed the basis for the development of a benchmarking model promoted by the European Commission's Directorate-General for Research in 2000. STR, No.15 on *Instrumentation, Control and Automation in Wastewater Systems*, published in 2005, is expected to have similar significant impact on the ICA of wastewater systems.

2 | Anaerobic Digestion (Task force on Mathematical Modelling of Anaerobic Digestion)

Introduction

The IWA specialist group on Anaerobic Digestion is an international forum for activities related to anaerobic conversion processes, such as: process technology, microbiology (physiology, ecology, population dynamics, and genetics), reactor development, integrated approaches (including complementary technologies), stimulation of implementation and appropriate technology for developing countries. The group is one of the largest international networks on Anaerobic Digestion, with each of three specialist group conferences attracting 400 – 500 people from academic and private sectors.

The Task Force on Mathematical Modelling evolved from a workshop designed to discuss policy issues, and in 2002 successfully established the Anaerobic Digestion Model No 1 (ADM1) as the standardised modelling product within the Anaerobic Digestion field. The purpose of this model is to provide a unified basis for anaerobic digestion modelling by establishing common nomenclature, units and model structure.

Activities

As well as the aforementioned international conference, which rotates location around the world every three years, the group also coordinates smaller scale events with a more specific agenda. The recent *4th International Symposium on Anaerobic Digestion of Solid Waste* is a good example of this, where 200 experts in the field travelled to Copenhagen, Denmark to participate in this specialist, technical meeting. Furthermore, following a query raised within the group's newsletter, the Task Force has also organized a workshop specifically geared towards the ADM1 model, an event which was attended by 70 participants.

- *Anaerobic treatment of sewage in developing countries*

The group has been at the forefront in shifting thinking and practice in challenging western conventions about treatment of sewage. This shift is led by the work of the *South and Central American Specialised Conference for Anaerobic Digestion*, a regional network evolving out of the specialist group's international conferences, arising from the recognition of differences in anaerobic digestion in different regions in the world. These conferences provided the impetus for such a paradigm shift, helped develop an international platform for exhibition of the technology, demonstrated its capability and affordability and facilitated international dissemination of practice.

Impacts

- *Task force on mathematical modelling*

The task force within the wider specialist group has had considerable impact on the field of mathematical modelling of anaerobic processes. By establishing a standardised model, there has been a shift to smaller-scale applications. Prior to the publication and development of ADM1 there were a multitude of anaerobic models conceived over a period beginning in 1969. This meant commercial software packages utilised within industry generally did not include an anaerobic model, or alternatively they included one of a series of different models each with their own separate applications. The ADM1 provided an accepted compromise, an industry standard, and subsequently no other model has been used in the last five years in this regard.

A smaller scale application focus has increased accessibility to anaerobic modelling as a whole. Although this has led to an assortment of interesting results, the learning curve is

becoming less steep, with more Masters students able to use the model. Previously, second year PhD students represented the lowest academic level of user.

Part of the significance of the model's impact is its longevity and sustainability. The model provides a solid basis from which modification and adaptation can be made. As a result the model can be quickly adopted by other fields – for example, those interested in activated sludge modelling have been able to access the methodology without having to know the process knowledge.

Reviews and testimonials

- *General use and impact*
  - *ADM1 will "…allow researchers to concentrate on specific aspects instead of the overall process, identify key limitations in this field of research, and widen the scope of application of anaerobic digestion. In particular, it was intended to stimulate discussion and interaction between research and practice, and move the field of anaerobic digestion modelling to a new phase of intensive, widespread application, such as was seen with publication of the popular Activated Sludge Models (ASM1-ASM3)."*
    http://www2.er.dtu.dk/adm1/why.html

  - *"Since publication of the IWA Scientific and Technical Report in 2002, and presentation of the model in Antwerp at AD2001, the ADM1 has been implemented in most common wastewater treatment simulation platforms, used to simulate a wide range of process types, has had extensions developed to simulate new processes such as sulphate reduction, and ion precipitation, and has received detailed critical analysis, both positive and negative. One positive aspect we have seen is transfer of the physicochemical model as described in the ADM1 technical report to commercial packages for simulation in aerobic systems."*
    http://www2.er.dtu.dk/adm1/why.html

  - *ADM-1 has been made available in a number of commercial simulation packages, such as WEST, SIMBA, GPS-X and others.*

- *Specific use and impact*
  - *Water Science Laboratories (WSL) Consultants in Australia has recently purchased WEST process modeling software that uses the most recent IWA models (such as ASM2d, ASM3, ADM1) to model most wastewater treatment processes, including activated sludge, trickling filters, and clarifiers. The software is used by researchers, process engineers and WWTP operators worldwide. The biological and hydraulic model base uses an open structure, allowing the modeler to adjust model equations and parameters to suit the exact application. WSL has used WEST to design an IDEA lagoon for BOD and SS removal, a wastewater treatment plant to remove nitrogen, and is using the software to research process modeling of anaerobic treatment plants, including lagoons and anaerobic SBR's.*
    http://www.wsl.com.au/WslNews/WSLNews-29072003-newprojects.htm

3 | Efficient Operation and Management of Urban Water System

(Performance Indicators Task Force (Water Supply)

Introduction

The Efficient Operation and Management specialist group focuses on the operation, maintenance and rehabilitation of supply and distribution systems. In detail it considers performance indicators for distribution systems, unaccounted for water and leakage control and methods for the renovation and replacement of pipelines.

The Performance Indicators task force was established in 1997 and was designed to establish (a) a system of performance indicators for water supply services, and (b) the feasibility of applying such indicators. Helena Alegre is the leader of the task force.

Activities

After the publication of the first edition of the manual *Performance Indicators for Water Supply Services*, the task force took part in extensive field testing of the indicators; over the course of three years and following a series of periodic meetings, the system of performance indicators was gradually refined and confirmed. The process of testing and affirmation necessitated a further revision; the second edition adopts a more user-friendly, teaching-style text.

The performance indicators system is deliberately designed to be multi-functional; the basic motivation behind its development was as use as a management tool. The indicators can be used as benchmarks; in the framework of regulation; for internal utility use, and to define and set targets.

Impacts

- *International scale*

IWA's performance indicators system is widely recognised as *the* definitive system; it is considered to be at the leading edge in terms of international use and reference. *Performance Indicators for Water Supply Services* has been translated in full into four languages from English (Spanish, Portuguese, French and German) and specific parts translated into another three (Japanese, Czech and Italian), illustrating the demand for a standardised international system on the subject.

The European Union's 5th Framework Programme adopted in 2003 the IWA performance indicators system as the basis of two work packages focusing on water distribution and wastewater network rehabilitation.

- *National scale*

IWA's performance indicators system has been widely adopted by national regulatory bodies in forming the basis for specific evaluations of national based utilities (examples include Portugal and Germany). In Germany, two performance indicator systems have been developed, one specifically in Bavaria and another for more general use across the Federal Republic, emphasising the flexibility of the system in its application to different conditions, specific and more generalised.

Reviews and testimonials

- *The Institute of Municipal Water Management in the Czech Republic is working on implementing a proposed national system of Performance Indicators. The choice of PIs was made from the International*

Water Association's 'Performance Indicators for Water Supply Services' (IWA PIs), modified to suit Czech conditions.
http://www.ib-net.org/asp/resources_benchmarking_publications/2_5/naismith4.asp

(Water Loss Task Force)

Outputs

- In 2000, the Water Losses Task Force published *Blue Pages – Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures*
    - This publication summarizes the conclusions of the Water Losses Task Force, with particular emphasis on standard terminology and preferred Performance Indicators for assessing operational performance in control of real losses (leakage and overflows) in transmission and distributions systems.
        - The most significant of these are "Non-Revenue Water" (replacing 'Unaccounted-for Water') and the Infrastructure Leakage Index.
    - Using these terms and indicators, the group created a method for Water Balance calculations for Transmission systems and Distribution systems.

Impacts

- *"The IWA methodology for the Water Balance and Performance Indicators is recognized as the current best practice method for quantitatively monitoring water use and water loss in drinking water systems."*
  www.cuwcc.org/Uploads/committee/WSO_Presentation_2004_2008.pdf

- *In August 2003, AWWA Water Loss Control Committee Report recommended North American utilities standardize on the IWA method of assessing water loss control performance measurement. AWWA's M36 manual on water loss and audits is being re-written to reflect these techniques and is due out in late 2006*
  www.pnws-awwa.org/Conference/PDF/Water%20Loss%20Mgmnt%20LIBERATOR.pdf

- *Canada's National Guide to Sustainable Municipal Infrastructure also adopted the IWA method;*
    - *Infraguide, a national network of experts, built on this methodology to produce "Water Use and Loss in the Distribution System"; in Hallifax, adoption of these best practices has led to the reduction of the leakage of potable water from its distribution system by 6 million gallons per day (about 30 million litres per day), which equals savings of half a million dollars a year.*
    - *It ha also led to deferral of capital investment because reduction in leakage meant that did not have to increase plant capacity*

  http://www.infraguide.ca/newsletter_v2_1/files/English_Newsletter_2.pdf

- *In Germany, the IWA Blue Pages "Losses from Water Supply Systems" served as basis for DVGW (Deutsche Vereinigung des Gas- und Wasserfaches e.V. - Technisch-wissenschaftlicher Verein = DVGW German Technical and Scientific Association for Gas and Water); Its technical rules are the basis for safety and reliability for German gas and water supply) Worksheet W 392 "Monitoring of Pipework and Water Losses- Measures, Procedures and Analyses" and thus included in the DVGW standard documentation.*
    - *The data in IWA Blue Pages led the DVGW to change in previously accepted water losses figures from .05 to .6 m 3/h x km to .25 m 3 /h x km*

  www.dvgw.de/pdf/iwa_wloss.pdf

Reviews and testimonials

- *"It [the ILI] is considered the most reliable measure of annual performance in managing Real Losses"*
  www.oocur.org/Proceedings?Presentations/Laville1.pdf

- *"These methods are gaining rapid international acceptance."*
  www.environment.gov.jo/weda4.html

- *General use and impact*
  - *The American Water Works Association (AWWA) asserts that "these features allow water utilities to make a meaningful assessment of their water loss standing, benchmark themselves with other water utilities and set performance targets."*

  - *The California Urban Water Conservation Council (CUWCC) advocates use of the IWA Water Balance Method because its Technical and Financial Performance Indicators allow "target-setting and benchmarking."*
    www.cuwcc.org/Uploads/committee/WSO_Presentation_2004_2008.pdf

  - *"Although not intended to be a benchmarking exercise, the scheme is being field trailed by utilities and some appear to be establishing national benchmarking exercises based on the IWA indicators."*
    www.ip3.org/pub/publication2002_008.htm

  - *"The performance indicators developed by the IWA, like the Benchmarking IBNET Toolkit have been used as a basis for helping to start national performance comparison schemes."*
    www.ib-net.org/asp/indicators_iwa_performance.asp

  - *"Last but not least through the efforts of the International Water Association/IWA, performance indicators have become a frequently used instrument to assess the condition of facilities and their efficiency in national and international comparison."*
    http://www.aquamedia.at/templates/index.cfm/id/15121

- *Specific use and impact*
  - *The American Water Works Association (AWWA) adopted new IWA audit in August 2003*
    www.wsaa.asn.au/pdf/2004/WSAAjournal022004.pdf

  - *In Canada, the use of "Non-Revenue Water" terminology and the Infrastructure Leakage Index has allowed water utilities to measure water losses consequently set benchmarks and share practices and improve water loss management.*
    - *This in turn has led to a mission to use Benchmarking data more proactively for performance improvement; in March 2005, a National Benchmarking Summary Workshop was held in Montreal where results of performance improvement initiatives and best management practices were presented and discussed.*

    http://www.nationalbenchmarking.ca/docs/CanadianBenchmarkWaterLoss_Abstract.pdf

  - *The International Water Balance Method is being applied in South Africa, New Zealand, Australia, and other places.*
    www.cuwcc.org/Uploads/committee/WSO_Presentation_2004_2008.pdf

4 | Health-Related Water Microbiology (HRWM)

Introduction

This group covers all aspects of microbiology of water and associated materials where it impacts on human health. Through its activities, the group aims to foster cooperation in health-related water microbiology, coordinate the exchange of information (with a view to minimising duplication of research effort) and to encourage younger scientists to partake in the development of its activities as part of the IWA family. As part of the IWA World Water Congress in April 2002, Melbourne, Australia, the group held a successful Symposium with the Proceedings appearing as Water Science & Technology (2003) volume 47(3). The group holds a specialised Symposium every two years, produces a regular electronic members' Newsletter and has a dedicated web page at www.iwa-microbiology.org.

The Health Related Water Microbiology group was formed in 1977 under the auspices of the former IAWPRC; the group now boasts a stable membership of 500, with an average of around 200 attendees at the biennial group symposium.

Activities

The group's symposium represents both the biggest output of the group and its biggest impact. Held biennially, the event takes place over 4 or 5 days, the most recent being in Swansea (2005) with an attendance of 200. In 2007, the event will be scheduled for Tokyo, while a venue for 2009 is already under review. The proceedings from each symposium are published and serve as a snapshot of the position of the group; there is an archive of 20 years worth of documentation that represents a historical reference in the evolution of water microbiology and an important tool to those new to the field.

- *Water Safety Plans (WSP)*

The biggest impact deriving from group activities in recent years has been the development and adoption of water safety plans, a shift away from simple monitoring activities. The plans represent a new approach in dealing with managing water safety that examines the water cycle holistically and promotes early hazard identification and use of targeted control methods.

This shift in thinking and practice, which has taken place over the last 2 to 3 years, clearly represents the future for HRWM; the entire last day of the Swansea Conference in 2005 was dedicated to discussion on this topic. WSP are becoming an industry norm, and represent an approach with worldwide application in both developed and developing countries. Although there is clearly room for modification and adaptation, the fundamental principles governing WSP have now been established.

Impacts

- *Collaboration with the World Health Organization (WHO)*

The group's interaction with WHO has been fundamental. It has covered group member participation on a multitude of WHO technical committee; significant technical input to WHO guidelines (including: Drinking Water Guidelines; Desalination; and Water Reuse) and in the publication of an academic journal, *Journal of Water and Health.* IWA inputs on the Drinking Water Guidelines focused on the areas of microbiological quality, protection and good management practice in distribution systems.

Reviews and testimonials

- *"The WHO drinking water guidelines offer advice to national and local governments, public authorities, and large and smaller water suppliers. They define internationally accepted "good professional practices" in drinking water hygiene".*
  http://www.umweltbundesamt.de/uba-info-presse-e/2004/pe04-096.htm

- *"WHO's updated Guidelines for Drinking-water Quality (GDWQ) will help regulators and water service providers the world over maintain and improve the quality of their drinking water".*

- *"The updated Guidelines represent a paradigm shift in advice on how to manage the provision of drinking water, both in the developed and developing world, in large urban settings and in the rural areas or villages. Henceforth, according to the revised GDWQ, the recommended approach for regulators and operators is to manage drinking water quality in a holistic, systematic fashion from source to tap."*
  http://www.cepis.ops-oms.org/bvsacg/i/guias3.pdf

5 | Use of Macrophytes in Water Pollution Control

Introduction

This group sets out to: (a) act as a link between scientists working on the scientific and technical aspects of macrophyte usage in wetland systems (Constructed Wetlands, Reed Beds, Treatment Wetlands and converted natural wetlands) for water pollution control and resource recovery; (b) contribute to co-ordinating research activities, defining research needs and promoting exchange of results; (c) develop a commonly-accepted model on the functioning of macrophyte-based wastewater treatment systems and produce guidelines; and (d) establish standardised guidelines for reporting performance of macrophyte-based wastewater treatment systems.

The group was formed at the IOWPA Biennial Conference in 1988. Originally a group focused on European expertise and knowledge, it has sought to expand its geographic boundaries to include, amongst others, the work of Americans and Australians in this field.

Activities

The group will host its tenth biennial conference in Lisbon, Portugal in 2006. Accompanying each conference, the group produces technical proceedings which represent a key knowledge product in the sector; approximately 50 per cent of the citations and references within the literature originate from these biennial conferences.

- *The newsletter*

The group's newsletter presents one of its main achievements – it provides technical information, feedback, articles and news. A total of thirty publications have been produced.

Impacts

- *Impact on the practitioner*

One of the most significant impacts of the group comes from its biennial conferences. With considerable growth in systems utilising macrophytes for water pollution control in Europe and the US, the need and value of professional, technical networking remains essential. The technical proceedings produce a permanent record for reference which has allowed for standardisation of direction and approach within this field. Attendances at the conferences fluctuate, but range from 250 to a high point of 700 participants.

- *STR15*

Developed in 2000, *STR15* has six authors drawn from international backgrounds across the membership. Adapted from a set of guidelines drawn together at the 2nd Biennial Conference in 1990 (as well as two other sources) this has subsequently been translated into five different languages, illustrating the international reach and appeal of the publication.

6 | Activated Sludge Population Dynamics

Introduction

The aim of this Specialist Group is to strengthen the co-operation of engineers, chemists, microbiologists and plant operators in establishing science-based effective approaches for solving practical problems.

The focus of the group includes the following technical subjects: biomass separation, i.e. bulking, foaming and dispersed growth, identification by the modern biological molecular tools of the micro organisms causing problems; proliferation mechanisms of relevant bacterial populations, i.e. floc-forming, nitrifiers, denitrifiers, polyphosphate and glycogen accumulating bacteria, novel microbial populations involved in nutrient removal processes; population dynamics of systems combining cultivation of suspended and attached biomass.

Outputs

- Between 1987 and 2000, the Task Group on Mathematical Modelling for Design and Operation of Biological Wastewater Treatment of the Activated Sludge Population Dynamics published the *Activated Sludge Models* (*ASM1, ASM2, ASM2d* and *ASM3*).
    - In 1980, IWA (then IAWQ) formed a task group to promote development, and facilitate the application of, practical models for design and operation of biological wastewater treatment systems.
    - *ASM1*, a mathematical model having the capability of realistically predicting the performance of single-sludge systems carrying out carbon oxidation, was the result of this undertaking.
    - The model has since then been added to and improved in subsequent models, for instance to incorporate more fractions of COD, to accommodate new experimental observations to describe growth and population dynamics of, and to include new processes for describing enhanced biological phosphorus removal.
- Scientific and Technical Report No. 16, *Activated Sludge Separation Problems: theory, control measures, practical experience*. Tandoi, V., Jenkins, D. and Wanner J. Eds, IWA Publishing, 2006, 1-201

Impacts

- The activated sludge models developed by the group have become industry standards for wastewater treatment

Reviews and testimonials

- *"IWA models (ASM1, etc.) are the worldwide industry standard"* http://216.239.59.104/search?q=cache:ET-OzU_YT9cJ:www.hydrosoft.co.kr/5/documents/Detail_Apps.ppt+ADM1+IWA&hl=en

- *"The IWA group proposed the Activated Sludge Model no1 (ASM no1, [Henze et al., 1987]) many years ago, which has been internationally accepted as the model of reference for carbon and nitrogen removal."* http://www.tdx.cesca.es/TESIS_UdG/AVAILABLE/TDX-0107103-181044/tjcm1de2.pdf

- *"Although the model has been extended since then…the original model is probably still the most widely used for describing WWT processes all over the world. Due to its major impact on the WWT community it deserves some extra attention and it can still be considered as a 'state-of-the-art' model when biological phosphorus removal is not considered."* http://www.syscon.uu.se/Education/MSc/Courses/WWT98/asm1-2004.pdf

- *"In this context the activated sludge model number 1 (ASM1) of Henze et al. (1987) has become rather popular in the wastewater treatment field and applied successfully for dynamic simulations of the treatment plants."*
  http://biomath.ugent.be/~qurkan/research.html

- *"The introduction of the ASM model family by the IWA task group was of great importance, providing researchers and practitioners with a standardized set of basis models."*
  http://server.oersted.dtu.dk/publications/views/publication_details.php?id=1153

- *"There exist a number of mathematical models describing the microbiological processes in biological wastewater treatment plant. The activated sludge model ASM (International Association of Water Quality) for instance is frequently used."*
  http://environ.chemeng.ntua.gr/wsm/Uploads/Deliverables/ThirdYear/Deliverable_21_3.pdf

- *General use and impact*
  - *"Since the publication of the first IWA (formerly IAWPRC, then IAWQ) Activated Sludge Model (ASM) in 1986 (Henze et al. 1986), the ASM1 and its successors (Henze et al. 2000) have become increasingly popular. Among other applications ASMs have been used successfully for design assistance in planning or upgrading WWTPs and for process optimization. As compact and transparent archives of knowledge about biological processes in activated sludge systems they facilitate the communication among scientists and engineers. In addition they provide an important platform for further model development."*
    http://stat.ethz.ch/~rbrun/publications/pbrun2002a.pdf

  - *"Since the appearance of ASM1 four years ago, 'this model has greatly encouraged the use of mathematical models.'"*
    http://www.ceu.hu/envsci/journal/Index.htm

  - *"Nowadays, there exist several commercial simulators for wastewater treatment processes. Among them, the GPS-X software, developed by [Hydromantis, 1995], includes all the models developed by the IWA group and some modifications of those."*
    http://www.tdx.cesca.es/TESIS_UdG/AVAILABLE/TDX-0107103-181044/tjcm1de2.pdf

- *Specific use and impact*
  - *Hydromantis, a global environmental consulting and software firm, uses International Water Association (IWA) models.*
    http://216.239.59.104/search?q=cache:ET-OzU_YT9cJ:www.hydrosoft.co.kr/5/documents/Detail_Apps.ppt+ADM1+IWA&hl=en

3 | Impact matrix – summary

IMPACT MEASUREMENT CATEGORIES AND INDICATORS			
Fields of Change	*Categories*	*Indicators*	*Indicative examples from specialist groups*
Change in state	Policy	Legislation, regulation, strategy documents, work-plans, budgets, legal precedent	▪ *EOM (PI)* – adopted by national regulatory bodies in Portugal and Germany; adopted and adapted in Czech Republic ▪ *HRWM* – Drinking Water Quality Guidelines represent paradigm shift for regulators and operators
	Practice	Programme course, approaches, funding levels, standardization	▪ *ICA* – STR No. 11 on respirometry (formed basis for benchmarking model promoted by European Union) ▪ *Anaerobic Digestion* – ADM1 accepted as industry standard ▪ *EOM (PI)* – recognized as definitive system; extensive language translation ▪ *Activated sludge* – ASM1, etc accepted as worldwide industry standard
	Science / Technology	Bibliometric indexes, data quality, new or improved products (registered design, copyrights, new patents), services, or processes	▪ *Anaerobic Digestion* – ADM1 increased accessibility to anaerobic modelling as a whole; widen scope of application of modelling; implemented in other common wastewater treatment simulations
Change in scale	Horizontal	Number of countries / institutions participating	▪ *Anaerobic Digestion* – ADM1 accepted as industry standard ▪ *EOM (PI)* – recognized as definitive system; extensive language translation ▪ *Activated sludge* – ASM1, etc accepted as worldwide industry standard ▪ *EOM (WL)* – internationally accepted method of assessing water loss control
	Vertical	Type and hierarchical status of government / institution affected	▪ *EOM (PI)* – adopted by national regulatory bodies in Portugal and Germany; adopted and adapted in Czech Republic ▪ *ICA* – STR No. 11 on respirometry (formed basis for benchmarking model promoted by European Union) ▪ *HRWM* – Drinking Water Quality Guidelines represent paradigm shift for regulators and operators ▪ *EOM (WL)* – triggered rewriting of national association best practice guides (North America)
	Membership	Growth and spread	
Change in sustainability	Longevity		▪ *Anaerobic Digestion* – ADM1 accessed by other communities in order to access the modelling knowledge (ref: activated sludge modelling)
	Infrastructure	Building of effective institutions	
Changes in intangibles	Awareness	Conferences, publications	▪ *Macrophytes* – biennial conferences and technical proceedings provide record of standardisation of direction within the field
	Networking	Collaborative projects, improved communication and working relationships	

	Increased Knowledge / Human Capital	Narratives, business development	▪ *Anaerobic Digestion* – ADM1 increased accessibility to anaerobic modelling as a whole; widen scope of application of modelling; implemented in other common wastewater treatment simulations ▪ *HRWM* – collaboration with WHO in developing internationally accepted good professional practice