Aquavalens Project

"Protecting the health of Europeans by improving methods for the detection of pathogens in drinking water and water used in food preparation."

Grant agreement number: 311846

Deliverable D13.1

Indicators to evaluate impact from Aquavalens on water safety plans and improved water safety

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Version 2, 29th March 2016

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Implications of the results of Deliverable Report 13.1

Implications of the results for the Work Package (WP13)

This deliverable has identified a set of possible indicators to be used in the evaluation of impacts of Aquavalens techniques on preventive management systems like water safety plans and on water safety in drinking water supplies. Indicators will be chosen for each test site according to circumstances and availability. The Aquavalens technologies are to be tested in seven European countries in large and small water supplies and in food companies. The tests are the responsibility of WP10, WP11 and WP12 in Cluster 3 whereas WP13 is responsible of evaluating the impact from the trialled techniques.

Implications of the results for this Cluster 4, Improvement of Public Health

This deliverable is an important part of Cluster 4 whose objective is to assess improvements of public health through safer drinking water. A toolbox of indicators that will be used to assess impact from the project on water safety and thereby on public health as well as impact on how to improve performance of preventive management in running a water supply is provided by D13.1.

Implications of the results for the whole project.

This deliverable gives tools to assess the techniques that have been developed in Cluster 1 and 2 and its capability to have impact. When the technique has been assessed at the end of the testing period the results will assist in promotion and marketing.

Indicate key external stakeholders interested in the results of Deliverable Report 13.1

This report will be of interest to the FP7 programme to follow progress and to other EU projects and national and international organizations involved in preventive management to secure health, drinking water, and food safety. Other external stakeholders are water suppliers, food companies and laboratories that perform the control of drinking water from source to tap.

Which internal partners should your deliverable be sent to?

All the 39 partners involved in Aquavalens should receive a copy and it will be particularly important to those active in Clusters 3 and 4 as it is an important element for work in both clusters.

Introduction

Safe drinking water is one of the fundaments of public health and thereby of prosperous society. The main threat to water safety is pathogens transmitted with faecal contamination. It is the reason for most waterborne outbreaks and the detected outbreaks are considered to be just the tip of the iceberg of the water related illnesses that occur in most society (Figueras & Borrego, 2010). The practice today is to measure indicators of faecal pollution with the drawback of a long analysing time and infrequency of sampling. *Cryptosporidium* is currently the only pathogen directly tested for in routine monitoring and only in few countries. The World Health Organization (WHO) has been promoting use of a systematic preventive management system named Water Safety Plan (WSP) to prevent or minimize risk of contamination. The ideology is preventing rather than rectifying and sustainable use of resources.

The aim of the Aquavalens (AQV) project is to increase drinking water safety. This will be achieved with placing emphasis on direct monitoring of pathogens in drinking water systems instead of relying solely on the discontinuous monitoring of indicators. This will be accomplished by online analysis of indicators as an early warning system and by the detection of pathogens with the technique developed by partners of the Aquavalens project. The knowledge gained on pathogenic risk to water safety will help to improve preventive management and trace pollution. The AQV techniques are also to be assessed in their ability to detect failure in the integrity of a water supply system from catchment to consumer. These failures can vary in scale from severe incidents to minor events that may have until now gone unnoticed and they can be caused by contamination somewhere along the chain.

This deliverable D13.1 report describes a set of indicators that can be used to measure performance of the AQV technical platforms developed in the project to influence water safety and WSP. First, there is background information on the WSP methodology explaining the important steps of the process. This is to evaluate where AQV developed methods and platforms can have influence. An overview of the technologies that are to be used in the trials is given in an attempt to understand the performance and limitations of each technique as well as how it is planned to be tested in Cluster 3. Within the WP13 a questionnaire has been developed to gather information to assess the AQV impact and to gather data from the trial sites involved in Cluster 3. Some preliminary results from that are given in this report. The information derived from the evaluation of the WSP process and the questionnaire has been used to derive a set of indicators in line with one of the objectives defined in WP13.

Objective

The objective of deliverable D13.1 is to describe a set of indicators that can be used to measure if the use of Aquavalens technical platforms will enhance water safety and will have a positive impact on the implementation of the water safety plan methodology. Data for the indicators will be obtained from the water supplies that participate in the trials testing AQV techniques and platforms. The indicators will be chosen according to availability of data and type of water source at the participating sites.

Information on water safety plan methodology

A water safety plan (WSP) is a proactive approach for protecting drinking water. The methodology is a preventive management built on the principle of systematically preventing occurrence of unwanted events. It is a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer tap water. As in most management systems this is a continuous process and the aim is to consistently ensure the safety and acceptability of drinking water. It can be depicted with the quality control circle with the concept of self-control to achieve various goals and continuous improvement of processes (Gryna, 2001).

This approach has proven to be beneficial for both drinking water quality and public health by reducing, non-compliance with drinking water regulation and incidence of diarrhoea in regions where water supplies have implemented WSP, having also a positive effect on utility culture and attitude of staff to water safety issues (Gunnarsdottir et al., 2012a; 2012b; Summerill et al., 2010). Some researchers have also shown financial gain (Howard et al., 2005; Hasan & Gerber, 2010). WHO has been promoting this approach for a decade and it has been a part of the WHO Guidelines for drinking-water quality since 2004 and is now widely used all over the world (WHO, 2004; WHO/IWA, 2015).

WHO has published several field guides and other publications to promote the use of WSP e.g. a WSP manual more intended for large supplies, simplified documents for small supplies both in developed as in developing countries, for distribution network and now recently a guide for the auditing of WSP (WHO, 2004; 2011; 2012; Davisson et al., 2005; Bartram et al., 2009; Rickert et al., WHO, 2014; WHO/IWA, 2015). The application of WSPs has also been advocated by the International Water Association (IWA). The IWA has launched the Bonn Charter for Safe Drinking Water and has actively participated in promoting the implementation of the WSPs (IWA, 2012). The WHO WSPs model is developed from and share many similarities with HACCP (Hazard Analysis Critical Control Points) management system. Pre-dating the first WHO manual for WSP many water supplies followed the HACCP approach which is largely used in the food industry and later included into ISO 22000. This is especially the case in countries where drinking water has been legally considered foodstuff.

The WSP presented in the WHO guides include five main components that are: 1) the preparation stage; 2) system assessment; 3) monitoring performance; 4) management and communication; and 5) feedback and improvement. For the large supplies these components are divided on eleven modules. The first component is the preparation phase with assembling and setting the agenda for the WSP team. The second is assessing the system describing it from catchment to consumers and mapping places where water quality problems could arise (defined as critical control points), doing the risk assessment, deciding on action needed to prevent pollution and carrying them out. The third phase is monitoring performance of control measures both with internal measurement and external regulatory surveillance. The fourth phase is planning management with procedures that have water safety highest on the agenda and supporting programs with training and communication to users and stakeholders. The fifth phase is the feedback both regular and in case of incidents or near misses/close calls. Every step has to be documented and recorded in templates and files. The WHO's WSP components and the eleven modules with key actions are shown in Appendix 1.

Methods

The new techniques and methods that have been developed in the AQV project are to be tested on site in seven European countries. The carrying out of the tests is the responsibility of WP10, WP11 and WP12 in Cluster 3 whereas the responsibility of WP13 in Cluster 4 is to assess the significance of Aquavalens in improving water safety and impact on WSP.

The method used to identify potential Aquavalens impact on WSP is to analyze each WSP module and evaluate possible influence of the AQV technique on performance of WSP. The focal point for the evaluation is the WSP manuals published by WHO for the large supplies as shown in Appendix 1. The principles in preventive management are more or less the same in all management systems so this should apply to other form of preventive management system based on the principle of the quality control circle and applies to HACCP and ISO 22000 as well as other similar systems. Impact on WSP is also assessed based on responses to extensive WP13 questionnaire given to the water supplies that participate in trials on possible indicators for AQV platforms at their supplies.

Technique used in trials

In Cluster 1 and 2 a number of techniques for concentrating the water samples, for detecting pathogens and online alert measurement systems, have been developed for the AQV platforms. Several of these techniques have been chosen for trial in Cluster 3 with the choice of suitable recovery and detection technologies either alone, or in combination as needed, for each site. This is further explained in D16.4 (Bouzid et al., 2016).

There are several concerns regarding the techniques for recovery and detection of microbes that have to be considered as; 1) stability and performance of the method, 2) time of getting results, 3) cost of maintenance and operation of the trialled technique, and also 4) portability of the AQV platforms and accessibility of the sampling site. Standard operational protocols should be available for all techniques. Some of the techniques have been validated by WP9, the standard and validation work package in the AQV project. Standard operating protocols are now available for several methods.

Concentration is a challenging state in monitoring waterborne pathogens. The conventional concentration methods are time consuming, need large water samples (1000 litres) and efficiencies of recovery vary depending upon the type of pathogens (viruses, parasites, bacteria). It has been determined that traditional sampling process is with a recovery efficiency of *Cryptosporidium* of around 30-40% (Kerrouche et al., 2015). For concentration techniques now on offer from Cluster 2 are; glass wool filtration, dead-end hollow fibre, and monolithic affinity. No single technology has emerged that achieve good and stable recovery efficiencies for all kingdoms of pathogens and monolithic affinity technology has its limitations, mostly in only being able to work with small sample size, so it can only be used in the secondary stage of concentration performed in laboratory. Therefore recovery technology has to be chosen according to selected pathogens of concern. Currently work is still ongoing trying to improve abstraction from filters in the recovery techniques.

The most probable techniques for laboratory detection of pathogens that will be chosen are molecular detection devices, qPCR, and the FISH technique (fluorescent in-situ hybridization technique). The PCR kits that have been chosen have been developed with new probes able to detect the pathogens selected within AQV. The major advance of PCR are high sensitivity and specificity, and relatively rapid response compare to the traditional microbiological methods such as plate counting and cell culture whereas the disadvantage is that it is not possible to differentiate between viable and non-viable organisms (Samendra et al., 2014). Another disadvantage of PCR is that the potential for online monitoring is limited because of the need to use disposable kits that increases mechanical complexity (Lopez-Rodan et al., 2013) and AQV has not found a practical solution to that problem. FISH technique has as advantage that it is able to account for all viable cells. The processing time for FISH is 6 hours and is considered to be lengthy and the process requires a microscope which might not be available at all sites.

For early warning and thereby more water safety online monitoring seems to be the ideal method but to adapt it to autonomous operations is a challenge (Lopez-Rodan et al., 2013). For online detection two methods are likely to be chosen depending on availability. The detection of an enzymatic reaction considered specific for *E.coli,* Coliform and total activity by fluorescence and ATP luminescence techniques, both only providing surrogate measures of biological contamination. The online enzymatic detection technique provides surrogate measure of faecal pollution with measuring separately the faecal indicators *E.coli* and Coliform in source water or treated water. This online system is to be installed at the same sites where selected pathogens will be monitored and as such investigating correlation between pathogens and indicators. ATP technique measuring biomass will be installed at the treatment stage and also in the distribution network measuring integrity of treatment within the network. The ATP assay method has a very short response time in detecting ingress in drinking water contaminated with wastewater or surface water (Vang et al., 2014). However, this system does not give information on pathogens and considerable amount of biomass for detection is needed.

A device is being developed for sampling in the small supplies, capturing a water sample when higher than normal turbidity occurs in the system. The sample will be refrigerated for later analyzing with molecular technique at a laboratory.

Microbial Source Tracking (MST) is used to determine the sources of faecal indicator bacteria in the environment. MST techniques attempt to determine whether faecal bacteria are being introduced into water bodies through human, wildlife, or different types of domestic animal sources. In the trial some selected markers for MST will be monitored to trace pollution to source (human, porcine, ruminant bacteroides and F-RNA bacteriophages).

Table 1 shows the SMEs that are providing the technique most likely chosen for trials. The table also shows which microbes are likely to be recovered and tested with each technique in the trials as well as some examples of performance information and challenges as explained in deliverable D16.4 (Bouzid et al., 2016).

WP10 Large water supplies

The trials in WP10 will include five large water supplies in four countries, Denmark, Germany, Spain and UK (two demo sites) and they start in June 2016. Locations have been selected to provide a representative range of water types from across Europe. Water sources are upland surface water, surface river water and groundwater.

The pathogen detection techniques 4 to 7 in Table 1, are likely to be used for monthly pathogen monitoring for a period of 12 months. The concentration techniques are yet to be chosen. Technique 8 and 9 that correspond to an online monitoring, could also be applied for 12 months. Technique 8 and 9, depending on the demo site, could monitor at the source, in the process or at the output of the treatment plant as well as throughout the distribution network. The last one is a fast alert of the integrity of the system. Online devices will be moved between sites in the water supply as needed. Microbial Source Tracking (MST) methods developed in Aquavalens will be tested in UK (demo site 2) in a water supply where groundwater is suspected to be influenced intermittently by surface water with faecal contamination.

Currently WP10 is preparing details of its experimental plans and protocols for the field trials for the large supplies so information on pathogen choice for each site will be available in June 2016. Table 2 shows the preliminary plan for choice of microbes to be tested at each state depicted by WP10 in deliverable D16.4 (Bouzid et al., 2016).

Table 1 Number of techniques developed by the SMEs that could be trialled in Cluster 3

(Adapted from Bouzid et al., 2016, Material provided at the AQV Technology Transfer Workshop (V3) in Lisbon 22nd Sept 2015, BACTcontrol User Manual version V1.2).

No.	SME'S name	PARTNERS NO	TYPE OF TECHNIQUE	Tested Organisms for concentration and detection	Performance and Challenges with the technique
Recovery					
1	DTU + UB	5 & 2	Glass wool filtration	NoV, Hepatitis A, MNV, C.jejuni	Recovery NoV 2-27%, C.jejuni 10-36%. Method effective, cheap and easy to use. Inhibition during amplification of genomes.
2	NFA	22	Hollow fiber dead-end ultrafiltration	Campylobacter coli, E.coli O157, Salmonella enteritidis, Cryptosporidium, Giardia, Viruses	Recovery: bacteria 40-95%, crypto 13-67%, giardia 31-61%, NoV GI+GII 44+ 43%, MS2 89%. Large volume as 600-700 ml of elute is needed in secondary concentration. High turbidity interfere. Consumables are expensive.
3	DTU	5	Monolithic affinity filtration MAF-DEAE	NoV, MNV, Hepatitis A, C.jejuni	Recovery NoV 2-6%, C.jejuni 30-90%. Only small volumes of water and not in surface water therefore only useful as secondary concentration technique. Method proofed useful in outbreak investigation.
Laboratory detection monitoring					
4	CEERAM	8	Molecular with real time PCR detection kit	NoV (GI+GII), Hepatitis A +E, astrovirus, rotavirus, enterovirus, adenovirus, crypto, giardia. Bacteroides and F-RNA bacteriophages for MST	Robust, sensitive (5 copies/reaction), 100% specificity. Time 1-1.3 h. Cost 10 €/reaction. Already in use in the water industry.
5	GPS	20	Molecular with qPCR	Campylobacter coli & jejuni, Vibro cholera, Pseudomonas aeruginosa, Salmonella enterica Typhi, E. coli O157:H7, Leginella pneumophila, Listeria monocytogenes	Detection limit <5 genomes. 100% specificity and sensitivity. Time: 1h30. Cost 3.18€/run. Effectiveness depends on purification. Should be performed together with an inhibition control.
6	VERMICON	30	FISH (Fluorescent in-situ hybridization) in combination with automatic single cell detection	Thermophilic Campylobacter spp, E.coli, Coliforms, Pseudomonas aeruginosa and total viable cells	100% specificity and sensitivity. All viable cells counted Long time 3-6 hours. Dirt in water can interfere performance
7	PHL & MR1	4 & 15	Molecular with qPCR. New genome sequences for Crypto has been developed	PHL for all crypto spp, c. parvum, c. hominis and all giardia spp, g duodenalis A, g.duodenalis B. MR1 for Toxoplasma gondii.	99-100% specificity, 93-100% sensitivity Time: 1h30 – 2h24. Cost 0.8-1.2 €/ reaction. Sensitive to inhibition from substances present in water but can largely be overcome by addition of BSA.
On-line monitoring					
8	MicroLan	41	BACTcontrol system with ceramic filter for concentration and measuring enzymatic activity with fluorescence of specific enzymes	E.coli, Coliform and total activity	Only one spp of microbe at a time. Time 1 h. Cost – not given. Clogging and bubble affect performance but overcomed by pressure and bubble sensors
9	Epigem Ltd (with DTU-ENV, IPU, HW)	25 (5,37,7)	Onsite microfluidics recovery and detection of biomass with ATP (Adenosine triphosphate) luminescence technique	biomass in samples	Short response time – real time measurements Considerable amount of biomass needed for detection Clogging and bubbles affect performance

Table 2 Possible microbes planned to be monitored in WP10 in the large supplies

(Information provided by Claudia Puigdomenech Serra WP10 lead developed by WP10 partners during the AQV Lisbon Workshop, September 2015)

Country	Type of water	Test	Place of sampling		
			At source	**In treatment**	**In distribution network**
DE	SW – river	Lab test	Virus	Virus	
			Bacteria	Bacteria	
			Crypto, Giardia, Toxoplasma	Crypto, Giardia, Toxoplasma	
		On-line test		BactControl for Coliform after filtration	
DK	GW anaerobic	Lab test			Virus
			Bacteria	Bacteria	
			Giardia, Toxoplasma	Giardia, Toxoplasma	
		On-line test		BactControl for Coliform after sand filters and ATP for biomass	
ES	SW – river + GW	Lab test	Virus	Virus	Virus
			Bacteria	Bacteria	Bacteria
			Crypto, Giardia, Toxoplasma	Crypto, Giardia, Toxoplasma	Crypto, Giardia, Toxoplasma
		On-line test	BactControl for total activity and ATP for biomass	BactControl for total activity and ATP for biomass	BactControl for total activity and ATP for biomass
UK	GW with influence from SW, karstic	Lab test	Virus		
			Bacteria	Bacteria	
			Crypto, Giardia, Toxoplasma	Crypto, Giardia, Toxoplasma	Toxoplasma
		On-line test	BactControl for E.coli		

WP11 Small water supplies

The trials in WP11 are planned in 9 to 14 water supplies in 3 countries. The small water supplies are in Portugal (3-6), Serbia (3-4) and Scotland (3-4) and start in March 2016.

Layout for trial in WP11 is planned as follows: molecular detection kit from GPS for bacteria and Ceeram for viruses and protozoa are provided to laboratories at University of Belgrade (Partner 27) in Serbia, IST in Portugal (Partner 11) and James Hutton Institute (Partner 32) in Scotland. WP11 held a training workshop at University of Belgrade on the 12th February to train staff of the laboratories in concentrating samples for bacteria, viruses and protozoa and in using a molecular tool from the SMEs GPS and Ceeram to detect the pathogens. Commercially available techniques will be used for concentration of the samples.

Two sampling programmes will be carried out in WP11. In year 1 samples will be taken from the trial sites once a month for nine months. Before the second sampling round in year 2, water treatment devices will be installed by Enkrott (Partner 29) at one site in Serbia and one or two sites in Portugal. The devices will include online monitoring of turbidity and when over a pre-set value it will take a sample and refrigerate for later analysing with the PCR kits. Before the trial the background turbidity value will have to be set for each site.

WP12 Food production

WP12 is going to provide a list of risk factors particularly linked with water used in irrigation, ready to eat food processing and for bottled water in a deliverable, D12.1, in March 2016. Selection of trial sites in food companies is ongoing.

WP13 Questionnaire

WP13 has developed a questionnaire to gather information and shed light on impact from the technique and methods developed in Aquavalens at each water supply participating in the project on water safety and WSP. One questionnaire for large supplies and one for small supplies were prepared. The questionnaires have been tested in the field at four water supplies (2 large and 2 small) in Iceland and Spain. At the end of the project, a second set of questionnaires will be sent out to gather information on lessons learned during the trials. The important part at this stage of the project is to acquire information on how the trialled techniques are expected to influence WSP and water safety and what indicators are available at each site.

The main elements of the questionnaire are: general information; legal framework on water safety in the country; information of the water supply system from catchment to consumer; functionality; benefits and challenges with the WSP; water quality; and inquire about where the AQV platforms could influence the system. Over two third of the questions are related to water quality. The last questions ask for are suggestions on possible indicators to measure improvement in preventive management and water safety.

This questionnaire was sent out to the participating large water supplies on 10th of February 2016 and deadline for answering was 24th of February 2016. Questionnaire had also been developed for the small supplies trialed in WP11 but it had to be adjusted to a Sanitary Survey that is to be used by WP11, to avoid duplications. A new version of the WP13 questionnaire for the small supplies was sent 7th of March to AQV country representatives in WP11 in Portugal, Scotland and Serbia. Information from the questionnaire will be included at a later stage.

Results

The evaluation of the WSP process gave at least thirteen possible indicators and several others came forward as suggestions in answers to the questionnaire by the large supplies. At least 15 possible indicators have been recognized. The result from the WP13 questionnaires are also used to assess availability of indicators at each trial site in the large supplies in WP10 and it revealed that at each site there are at least 4-6 possible indicators already available.

Selection of possible indicators in the WSP process

The evaluation of the WSP process together with the AQV platforms to be installed revealed that AQV technique can influence most of the modules in WSP as shown in Figure 1, though not all can provide measurable indicators. Figure 1 is based on WHO's WSP training material and impact is further explained in Appendix 2. Several of these modules can give measurable impact and actions that can be taken were established as potential indicators and are listed in Table 3.

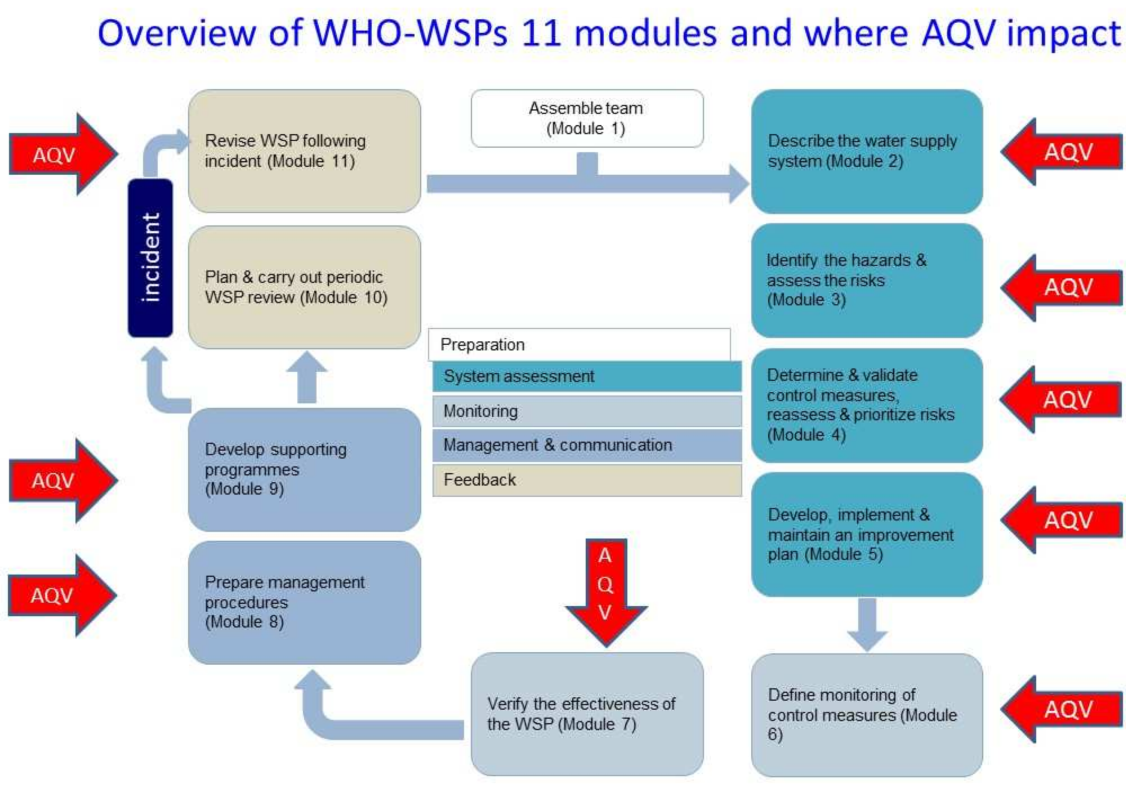

Figure 1 WHO's- WSP modules and possible impact from Aquavalens technique (red arrows)

Table 3 Possible indicators for improved WSP and water safety with Aquavalens platform

	Indicator	Possible influence from AQV platform on WSP
1	**Water quality data – operational and surveillance**	Improved monitoring will: 1) Assist in identifying water quality problems, 2) result in fewer incidents of non-compliance, and 3) supports validation of control measures Improves verification process in operation monitoring
2	**Raw water data**	Choosing pathogens according to activity on catchment will help to trace pollution Online monitoring minimizes use of contaminated raw water MST will help to trace pollution in catchment
3	**Pipe brakes**	Supports improvement plan and prioritises maintenance
4	**Pressure loss**	Indicates integrity of the network
5	**Near misses**	Indicates integrity of the network and supports improvement plan
6	**Complaints**	Decreases when intermittent contamination has been traced and fixed
7	**Risk scores**	Early warning with online monitoring should decrease likelihood of hazardous event and lower risk scores on critical control points.
8	**No of alarms incidents**	Online monitoring warns on surface water intrusion, e.g. during flooding or snow thawing. Will then increase alarm to trigger shutoff and also on need to clean of tanks etc.
9	**No of failure detected in the system**	Pathogen and online monitoring of surrogates reveals integrity of the supply chain and supports maintenance plans and upgrading of infrastructure
10	**Treatment performance data**	Pathogenic detection after treatment is an extra barrier for water contamination
11	**No of incidents/events**	Should result in fewer incidents or events and decrease non-compliance in water quality
12	**Health surveillance data**	Recognizing pathogenic risk should reduce incident of sporadic or endemic water borne outbreaks and thereby positive impact on public health
13	**Sold medicine for diarrhoea**	If health data is not available the possibility to gather sale of antidiarrheal drugs from pharmacies could be investigated
14	**Pathogens detected in raw water**	Supports agreements with stakeholders on catchment
15	**No of boil advisories**	Could increase when testing direct for pathogens

Answers to WP13 questionnaire

A preliminary analysis of answers to the questionnaire was carried out to investigate links with the indicators listed in Table 3, and two indicators (14 and 15) were added as proposed by the participants in the questionnaire. In Table 4 a comparative analysis of the supplies participating in the trial (Germany, Denmark and Spain) derived from the answers are provided. Table 4 also includes the indicators suggested by the water supplies for measuring the improvement of WSP. However, not all information that was asked for is available so different indicators will have to be chosen for the four countries. Table 5 shows which indicators have already been provided with the questionnaire.

Table 4 Some preliminary results from the WP13 questionnaire from the large supplies

Questions	DE	DK	ES	UK[2]
Type of ownership	Municipal – public	Municipal- public	Multinational-private 85% and public 15%	
Type of supply	Wholesale (100%)	Direct to users (65%) and wholesale (35%)	Direct to users (99%) and wholesale (1%)	
No of employee	276	100	1000	
No of people served	3.000.000	200.000	2.800.000	
WSP	WSP	ISO 22000	ISO 22000	
WSP External audit document provided	No	No	Yes	
Main challenge	Old infrastructure Water quality Water shortage	Old infrastructure	Water quality Water shortage Old infrastructure	
Complaint documented	Yes	Yes	Yes	
Complaint document provided	No	Yes (2015)	Yes	
Failures documented	Yes	Yes	Yes	
Failure document provided	No	Yes	No	
Near misses documented	Yes	No	Yes	
Near misses document provided	No	No	No	
Compliance document provided	Yes (2011-2015)	No	Yes	
List of incidents of non-compliance 2010-2014	No	Yes (2014)	Yes	
National GII[1] surveillance	Yes	Yes	Yes	
Indicators suggested	Pathogens in raw water	T.coliform, E.coli, No of boil advisories, Fewer non-compliance incidents	T.coliform, E.coli, Turb, Cl residual, ATP T.biomass, GII, Fewer non-compliance, Improved treatment and distribution management, Biofilm control	

1) GII Gastrointestinal illnesses
2) In progress

Table 5 Indicators data provided with answers to the WP13 Questionnaire

No	Indicator	DE	DK	ES	UK
1	Water quality data – Compliance	1	1	1	
2	Raw water data	1	1	1	
3	Pipe brakes	1	1	1	
4	Pressure loss				
5	Near misses				
6	Complaints		1	1	
7	Risk scores				
8	No of alarms incidents				
9	No of failure detected in system with the AQV technique				
10	Treatment performance data	1			
11	No of incidents/events		1	1	
12	National health surveillance			1	
13	Sold medicine for diarrhea				
14	Pathogens detected in raw water				
15	No of boil advisories				
	SUM	**4**	**5**	**6**	

Summary

At least 15 indicators have been identified directly by comparing the action steps in WSP with the capability of the AQV platforms and the suggestions from the WP13 questionnaire delivered from the large water supplies. Of these 4-6 are already available. Indicators are listed in Table 3 with explanation of impact on preventive management procedures. For each trial site in Cluster 3 and at different stages of the water supply, from raw water to consumer, a subset of these indicators will be utilised depending on technique employed. The choice of indicators will also be based on responses from the small water supplies as they become available.

The next steps are finding suitable indicators for each trial site and gather answers from all participants before testing starts. At the end of the testing period a new questionnaire will be sent out to be able to establish the effectiveness of the developed AQV platforms as a part of a preventive management tool as WSP and impact on water safety. This will be presented in a deliverable D13.2 in July 2017.

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Appendix 1 WSP framework and modules as described in the WHO/IWA manual 2009

	Module	Key actions of WSP
Preparation	**Module 1**	**Assemble the WSP team** Set up a small inclusive team with a clear mandate that works with everyone within the supply and outside when needed depending on catchment and system complexity (e.g. hydrologist, health workers, locals, and microbiologist). Decide on the methodology to be used in WSP, particularly in risk assessing.
System assessment	**Module 2**	**Describe the water supply system** Describe and assess the status of the water supply system from catchment to consumers using e.g. maps, flow diagram and on-site visits. Identify water quality problems by assessing e.g. monitoring results, pipe break history, leakage, age of infrastructure, dead ends, proximity to sewage and customer's complaints.
	Module 3	**Identify hazards and hazardous events and evaluate the risks** Identify the potential hazards following possible hazardous event in each stage of the supply chain and the level of risk it presents. Assess the risk by weighting likelihood with consequences giving risk scores for each hazard.
	Module 4	**Determine control measures, reassess and priorities the risks** Document existing and decide on potential control measures and consider whether the controls are effective to mitigate risk. Reassess risk.
	Module 5	**Develop, implement and maintain an improvement/upgrade plan** The risk assessment can reveal that infrastructure change is needed. The improvement plan can be short-medium- or long-term according to risk scores.
Monitoring	**Module 6**	**Define monitoring of control measures** Monitoring of the effectiveness of control measures are needed. These can include direct measurement of parameters and inspection of integrity of control measures e.g. well cover, fence and vermin control.
	Module 7	**Verification** These include compliance (surveillance) and operational monitoring, monitoring consumer satisfaction and auditing of WSP both internal and external.
Management and communication	**Module 8**	**Prepare management procedures** Document and develop existing and new standard operating procedure (SOPs) for example with reservoir cleaning, pipe repair, chlorination, and emergency response plans e.g. boil advisory.
	Module 9	**Develop supporting programs** Supporting program should include training of staff, communication with customer and stakeholder's, customer's complaint protocol.
Feedback	**Module 10**	**Plan periodic review of WSP** Regularly review WSP through analyzing of data and other performance indicators.
	Module 11	**Revise WSP following incident** Reassess risk and control measures following any incident, emergency or near-miss event and included into improvement plan if needed.

Appendix 2 Aquavalens impact on WSP modules and indicators

Module	Key actions with Aquavalens impact	Possible indicators
Module 1	**Assemble the WSP team** Secure knowledge on AQV monitoring included in the WSP team.	Team skills
Module 2	**Describe the water supply system** Assists in identifying water quality problems. Activity on catchment can influence pathogens chosen to be measured by the AQV platform.	Water quality data History of pipe breaks, pressure loss and complaints
Module 3	**Identify hazards and hazardous events and evaluate the risks** On-line monitoring minimizes use of contaminated raw water. Microbial source tracking (MST) can reveal point source of contamination and improve water quality.	Water quality data of raw water used Risk scores
Module 4	**Determine control measures, reassess and priorities risks** On-line monitoring gives lower risk scores when reassessing WSP as it lessens the likelihood of hazardous event to introduce hazard into water e.g. in rain events. It also reduces severity by improved treatment. Can increase alarm to trigger shutoff and cleaning of tanks.	Lower risk scores when reassessed No of alarm incidents
Module 5	**Develop, implement and maintain an improvement/upgrade plan** Improved and on-line monitoring reveals integrity of the supply chain and supports renewal plans and upgrading of infrastructure.	No of failure detected in the system
Module 6	**Define monitoring of control measures** Improved monitoring supports validation of control measures. Can help to detect pathogens that will support e.g. during maintenance and sizing protection zones. It can also improve performance of treatment.	Water quality data Treatment performance data
Module 7	**Verification** Better verification process in operation monitoring and surveillance.	Water quality data
Module 8	**Prepare management procedures** New and revised SOPs e.g. improved monitoring can reveal intermittent surface runoff into aquifers and change SOPs.	None
Module 9	**Develop supporting programs** Update training of staff with information on AQV platform.	None
Module 10	**Plan periodic review of WSP** No known influence.	None
Module 11	**Revise WSP following incident** Should result in fewer incidents of non-compliance to regulation and support reduction or eliminate incident of sporadic or endemic waterborne outbreaks. Impact on compliance and public health.	No of incidents Water quality data Health surveillance data Sold medicine for diarrhea