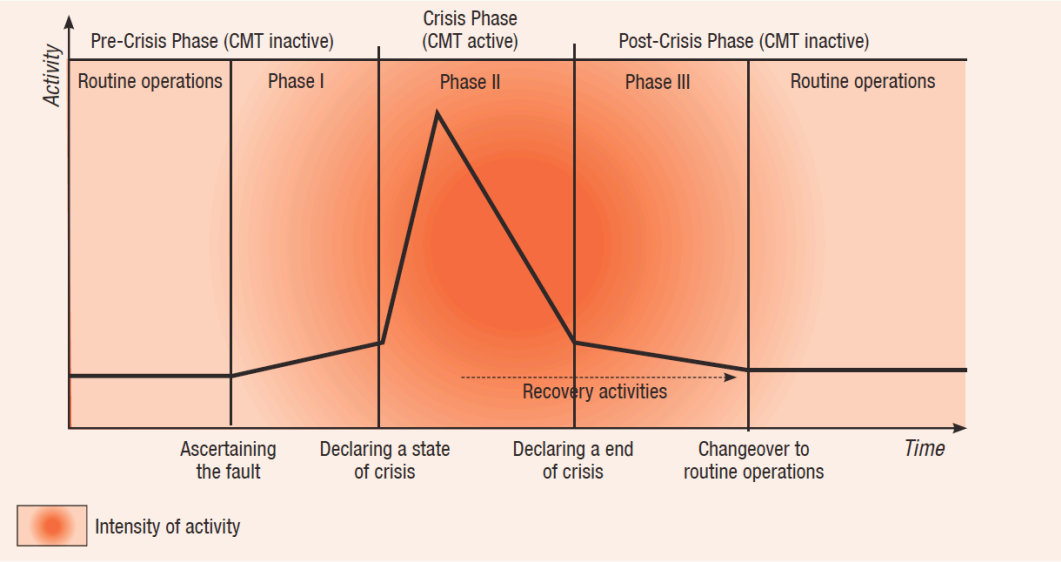

Figure 1: Management activities over the course of a crisis (ISO 2011).

Figure 2: GSM communication module (left) and Kapta™ 3000 OT3 (right)

Figure 3: Picture of the Kapta™ 3000 RAD1 (Courtesy from CEA List)

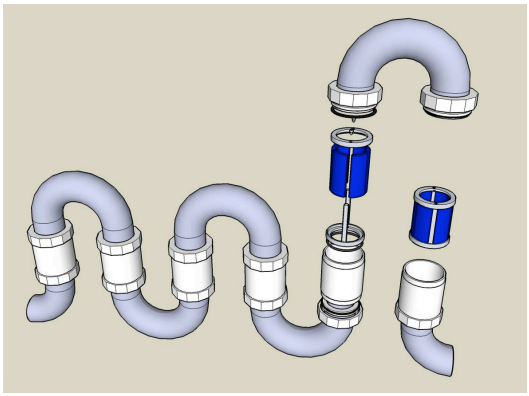

Figure 4 : Drawing of sentinel coupons (Courtesy of Martin Strathmann, IWW Water Centre).

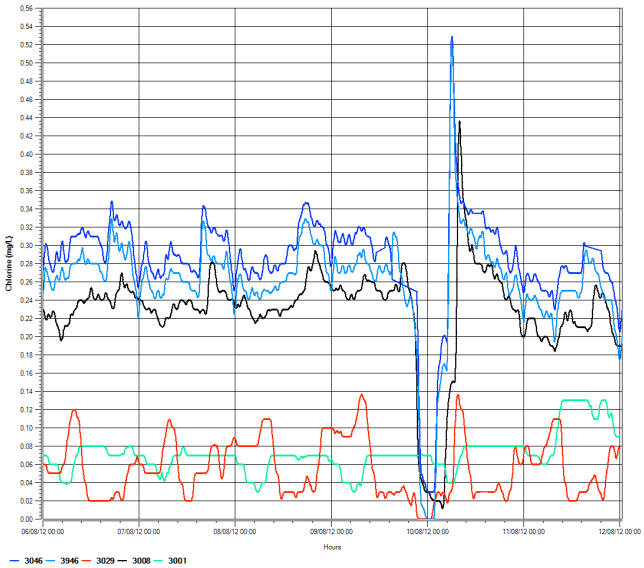

Figure 5: Sudden variations of chlorine level at different locations in a drinking water

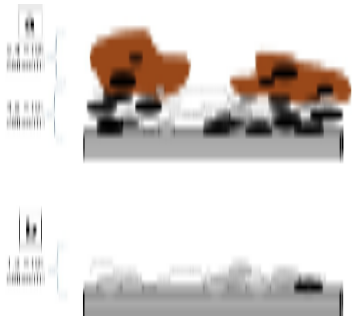

Figure 6: Biofilms and soft brown deposits before (a) and after (b) high chlorination treatment. Sybr II-stained biofilms showed non-damaged highly fluorescent (in black) or damaged slightly fluorescent (in grey) bacterial cells.

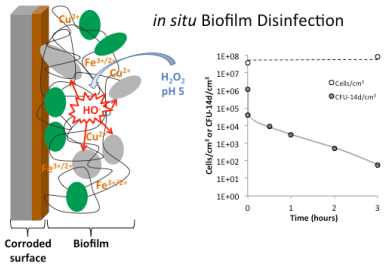

Figure 7: *In situ* biofilm disinfection buy adding H_2O_2 in pipes which reacts with iron and cupper in biofilms.

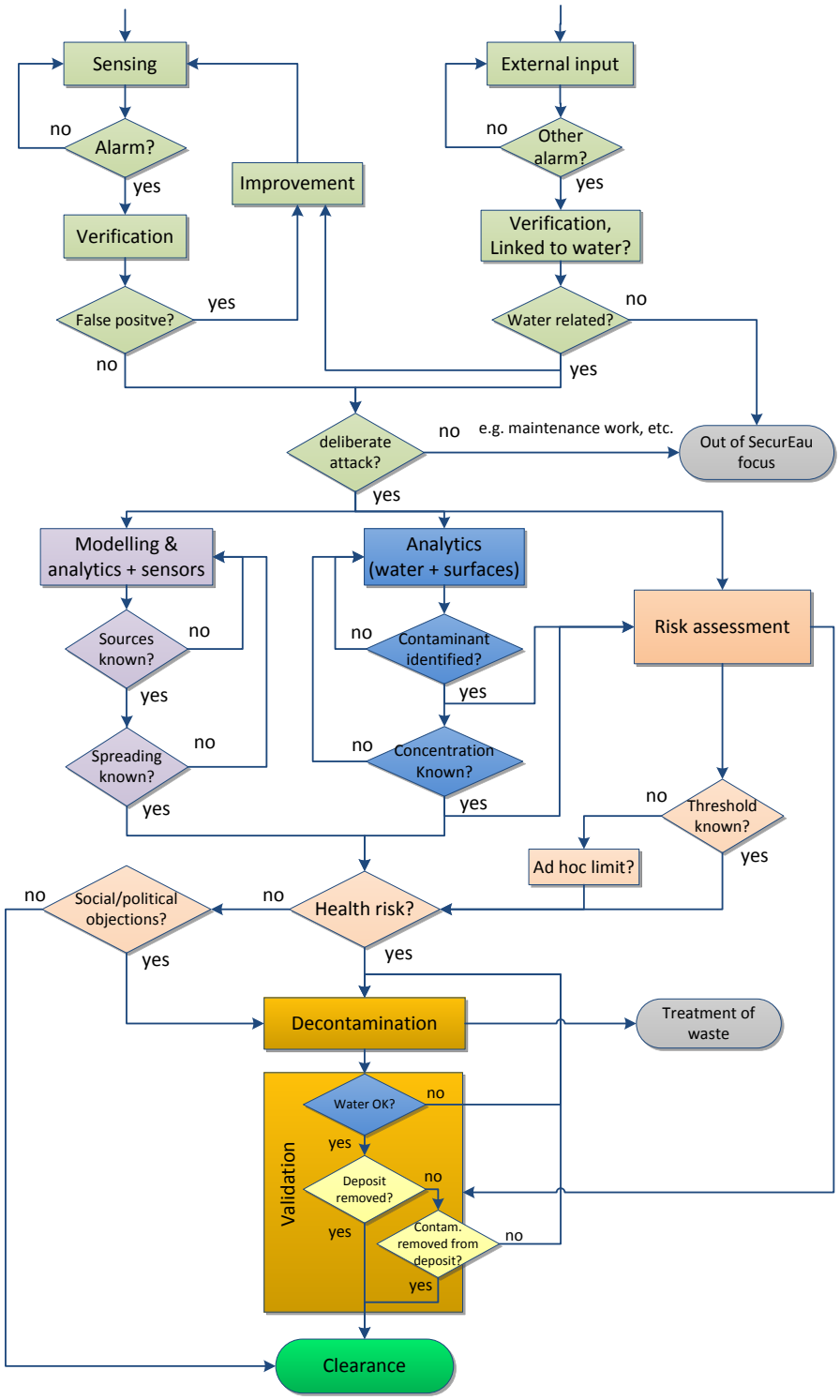

Figure 8: Decision flow scheme including all steps covered by the SecurEau project

Table 1: General information on water quality sensors and on deposit accumulation devices

Sensor	Manufacturer	Status	Price in € (*)	Maintenance	Application
Kapta™ 3000 AC4	Endetec (http://www.endetec.com/en/)	Commercial	3,500	Low (every 12 months). Probe and Communication	Water
Kapta™ 3000 OT3	Endetec (http://www.endetec.com/en/)	Pre-industrialization	Not defined	Low (every 12 months)	Water
Kapta™ 3000 RAD1	Endetec & CEA	Prototype	Not defined		Water
OptiQuad	Krohne Optosens GmbH	Prototype	Approx. 30,000	Not self washing. Low (every 12 months)	Surface
FS-900	NeoSens S.A.	Commercial	Approx. 5,000	Not necessary	Surface
SkidSens	NeoSens S.A.	Commercial	Approx. 2,000	Not necessary	Surface
MSS	Enkrott Quimica	Prototype	3,000-4,000	Low. Does not need washing	Surface
Sentinel coupons	Home made	Not commercialised	Approx. 1,000 (**)	None	Surface

(*) Prices are approximate for 2012 and are subject to change. Prices are for the sensors only, and do not include the cost of installation and consumables.

(**) Price is for a device with 5 holders of 6 coupons. It is approximate for 2012 and is subject to change.

Table 2: Kapta™ 3000 AC4 specifications (product finalised, available on the market)

Parameter	Range	Resolution	Fidelity	Maintenance	Precision	Response time
Active chlorine	0–2.5 mg/L	0.01	± 5%	The multi-parameter probe should be replaced once a year.	± 10%	<30 s
Conductivity (µS/cm)	100–1,000	1	± 5%		± 5%	Not reported
Pressure	1–10 bars	1 mbar	± 2%		± 10%	Not reported
Temperature	0–40°C	0.1°C	± 5%		± 5%	<15 s/°C

Table 3: Kapta™ 3000 OT3 specifications (pre-industrialization, not available on the market)

Parameter	Range	Resolution	Fidelity	Maintenance	Precision	Response time
Organic matter TOC equivalent	0.1-10 mgC/L	0.1 mgC/L	± 5%	The multi-parameter probe should be replaced once a year.	± 10%	<6 s
UV absorbance (254 nm)	0.01-0.3 AU/cm	0.01 UA/cm	± 5%	dito	± 10%	<6 s
Turbidity equivalent	2-50 NTU	1 NTU	*Not evaluated*	dito	*Not evaluated*	<6 s

Table 4: Kapta™ 3000 RAD1 specifications (prototype, not available on the market). LoD: limit of detection (Bq/Kg)

Radionuclide	LoD	Maintenance	Response time
241 Am	984	Not evaluated	Not evaluated
137 Cs	492	Not evaluated	Not evaluated
60 Co	25	Not evaluated	Not evaluated

Table 5: Specifications for biofilm sensors (assays done over a short time period of about one month)

Sensor	Parameter measured	Resolution	Accuracy	Maintenance	Response time	Price in € (*)
OptiQuad	Fluorescence, scattering, reflection and transmission	Early events	Not appropriate	Once a year.	<1 min	Approx. 30,000
FS-900	Heat transfer resistance	10-1,000 µm	Not appropriate	Once a year	2-4 h	Approx. 5,000
SkidSens	Heat transfer resistance	10-5,000 µm	Not appropriate	Once a year	1 h	Approx. 2,000
MSS	Amplitude and damping of propagated wave	0.076 mV	± 2%		Instantaneous (30 ms)	3,000

(*) Prices are approximate for 2012 and are subject to change.

Table 6: Availability and additional work to adapt models for partners outside of SecurEau consortium

Mathematical treatment	Availability	Work to be done for the models to be used in other distribution systems	Status
Generation of contamination events by a Monte Carlo process, to train the model	C source code + executable + link with the Epanet DLL (***)	Need an INP (**) file for the network model and the accurate hydraulics	The software is free of charge. No access right for the source code. Contact: Irstea
Formulation of a multi-stage INLP (*) problem	Executable available	Need the generation of contamination events described previously	The software is free of charge. No access right for the source code. Contact: Irstea

* INLP Integer Non-Linear Programming ---- ** INP is an Epanet ASCII format file ---- *** DLL Dynamic Link Library

Table 7: Availability and additional work to adapt models for partners outside of SecurEau consortium

Mathematical treatment	Availability	Work to be done for the models to be used in other distribution systems	Status
ILP (*) formulation that is a maximum coverage problem	A C- code preparing the objective and constraint description ready to use with GLPK (***)	Need an INP (**) file for the network model (network topology) and the accurate hydraulics (node demand calibrated)	The software is free of charge. No access right for the source code. Contact: Irstea

* ILP Integer Linear Programming
** INP is an Epanet ASCII format file
*** GLPK Gnu Linear Programming Kit

Table 8: Models for partners outside of SecurEau consortium.

Mathematical treatment	Availability	Status
1. Solves the inverse transport equations on the network graph by a method of characteristics for potential sources enumeration	A C-code that solves the inverse transport problem and assembles the Input / Output transport matrix and gives a potential contamination list (location + starting time + duration)	The software is free of charge. No access right for the source code. Contact: Irstea
2. Solves a Minimum Relative Entropy problem in order to get a stochastic estimation and explore the solutions	A Matlab code that solves the minimization problem	
Evaluates which contamination sources could be responsible for each detection and crosses that information to determine the possible contamination sources (determinist estimation, very high calculation time)	Matlab routine that identifies contamination sources based on the information given by positive readings of the sensors.	The software is free of use. Access right for the source code. Contact: UPORTO
Application of artificial neural networks (ANN). (acceleration of the mathematical treatment compared to the determinist estimation)	Matlab routine that identifies contamination sources + Matlab routine that trains the ANN to estimate the time of contamination at each node from the time of detection at each sensor.	The software is free of use. Access right for the source code. Contact: UPORTO
Online – Divides the network into a series of nodes and tracks changes in concentration at the nodes. Movement of contaminant is tracked using data from flow direction sensors. **Offline** – Uses Lagrangian transport mechanism. Tracks movement of contaminant along with flow and interaction with walls in discrete water volumes. **Combined model** – Applies the online algorithm to the sections of the network fitted with flow direction sensors, and the offline algorithm to the other sections.	**Online** – A Delphi code that uses data provided by flow direction sensors to track contamination travelling from node to node. **Offline** – A C-code that solves a system of equations representing mass conservation and reactions.	The software is free of use. Access right for the source code. Contact: RTU

- INP is an Epanet ASCII format file

Table 9: Chemicals tested, methods of analysis in water, limit of detection

Contaminant	**Method**	**Linearity range**	**Limit of detection**	**Time needed for analysis**	**Precision**	**Accuracy**
Paraquat	DI-HPLC-DAD	0.1-80 mg L^{-1}	0.01 mg L^{-1}	4 min	21%	98-101%
Paraquat	SPE-HPLC-DAD	0.1- 100 µg L^{-1}	0.05 µg L^{-1}	8 h	3% (repeatability)	To be concluded
Chlorfenvinphos	DLLME + GC-MS	0.01–10 µg L^{-1}	0.0014 µg L^{-1}	30 min	10%	74%
Carbofuran	DLLME + GC-MS	0.01-10 µg L^{-1}	0.0023 µg L^{-1}	30 min	15%	83%
BDE-100	DLLME + GC-MS/MS	0.1-10 µg L^{-1}	0.5 ng L^{-1}	30 min	21%	116%
Methylmercury	LLE + derivatization + GC-HRMS	1- 50 ng L^{-1}	0.21 ng L^{-1}	150 min	10%	103%

BDE-100: 2,2',4,4',6- pentabromodiphenyl ether; DLLME: Dispersive liquid-liquid micro extraction

Table 10: Chemicals tested, methods of analysis in biofilms / deposits, limit of detection

Contaminant	**Adsorption**	**Desorption method**	**Extraction rate**	**Method**	**Limit of detection**
Paraquat	Very high	hot acidic reflux with concentrated sulphuric acid	70%	EAM	0.13 mg/g of kaolin
Chlorfenvinphos	75%	acetonitrile	93%	HPLC-DAD	4.30 µg/g of kaolin
Carbofuran	50%	Not available yet	Not available yet	HPLC-DAD	Not available yet
BDE-100	Not available yet				
Methylmercury	High with some deposits	Dichlromethane-hexane from acidified deposit leachate	15-66%	GC-HRMS	Biofilm 8 ng/L. Ferrous deposits 1.7-2.9 ng/g dws

Table 11: Summary of method development findings for each target bacterial group in water ("-" denotes where the method did not work; "not tested" means the method was not used for the bacterial species considered)

Target bacteria	Limit of detection in water (cells/ml)			
	PNA-FISH	DVC-PNA-FISH	qPCR	PMA-qPCR
Escherichia coli O157:H7	2×10^4	2×10^4	1	1
Bacillus cereus E33L (surrogate for *B. anthracis*)	2×10^4	2×10^4	10	-
Francisella tularensis sups. novicida	-	-	5	5
Francisella philomiragia (surrogate for *F. tularensis)*	-	-	1	1
Yersinia pestis	quantity not tested	quantity not tested	5	5
Yersinia pseudotuberculosis (surrogate for *Y. pestis*)	2×10^4	2×10^4	20	20

Table 12: Summary of method development findings for each target bacterial group in biofilms ("-" denotes where the method did not work; "not tested" means the method was not used for the bacterial species considered)

Target bacteria	Limit of detection in biofilms (cells/cm^2)			
	PNA-FISH	DVC-PNA-FISH	qPCR	PMA-qPCR
Escherichia coli O157:H7	2×10^4	2×10^4	2×10^1	2×10^1
Bacillus cereus E33L (surrogate for *B. anthracis*)	2×10^4	2×10^4	2×10^2	-
Francisella tularensis sups. novicida	-	-	2	2
Francisella philomiragia (surrogate for *F. tularensis)*	-	-	4	4
Yersinia pestis	not tested	not tested	2	2
Yersinia pseudotuberculosis (surrogate for *Y. pestis*)	2×10^4	2×10^4	5.5×10^1	5.5×10^1

Table 13: Summary of method development findings for each target bacterial group in deposits ("-" denotes where the method did not work; "not tested" means the method was not used for the bacterial species considered) ---- * The lowest concentration tested.

Target bacteria	Limit of detection in deposits (cells/g)			
	PNA-FISH	DVC-PNA-FISH	qPCR	PMA-qPCR
Escherichia coli O157:H7	2×10^4	2×10^4	2×10^1	3×10^2
Bacillus cereus E33L (surrogate for *B. anthracis*)	2×10^4	2×10^4	2×10^2	-
Francisella tularensis sups. novicida	-	-	1.1×10^3 *	1.1×10^3 *
Francisella philomiragia (surrogate for *F. tularensis)*	-	-	3.3×10^1	3.3×10^1
Yersinia pestis	not tested	not tested	1.1×10^4 *	1.1×10^4 *
Yersinia pseudotuberculosis (surrogate for *Y. pestis*)	1.7×10^6	1.7×10^6	5×10^3	5×10^3

Table 14: Summary of the amount of time each analysis requires

Type of analysis:	Time delay before results:	Information provided:
PNA-FISH	2–3 h	Total target bacteria
PNA-DVC-FISH	16 h	Total and viable target bacteria
qPCR	2–3 h	Total target bacteria
PMA-qPCR	4 h	Total and viable target bacteria

Table 15: Radionuclides considered in SecurEau and analytical method principles and limits. LoD: limit of detection.

Nuclide	**Half life**	**Main decay mode**	**Main emission energies (keV)**	**Max permitted activity conc. [Bq/L][2]**	**Rapid analytical technique**	**Typical LoD in water**	**Typical LoD in deposits Bq/g**
Cobalt-60	5.27 years	Beta / gamma	β318 (99.89%) γ1,173 (99.86%) 1,333 (99.98%)	1,000	LSC	4	0.3
Strontium-90	28.64 years	Beta	β546 (100%)	125	LSC	2	0.1
+Yttrium-90	2.67 days	Beta	β2,279 (100%)		LSC		
Iodine-131	8.04 days	Beta / gamma	β606 (89.4%) 334 (7.36%) γ364 (81.2%)	500	LSC	4	0.3
Caesium-137	30.17 years	Beta	β512 (94.6%)	1,000	LSC	4	0.3
+Barium-137m	3.53 min	Gamma	γ661 (90.1%)		LSC		
Iridium-192	73.83 days	Beta / gamma	β536 (41.6%) β672 (48.1%) γ317 (83%)	1,000	LSC	4	0.3
Polonium-210	138.38 days	Alpha	α5,304 (100%)	1,000	LSC	3	0.3
Radium-226	1,600 years	Alpha / gamma	α4,602 (5.55%) 4,785 (94.45% γ186 (3.28%) (also multiple daughter progeny)	1,000	LSC	1	0.1
Americium-241	432.7 years	Alpha / gamma	α5,443 (12.8%) 5,486 (85.2%) γ59.5 (35.9%)	20	LSC	3	0.3
Californium-252	2.645 years	Alpha	α6,076 (15.2%) 6,118 (81.6%)	20	LSC	3	0.3

[2]Maximum permitted levels of radioactivity in drinking water supplies in the event of a radiological emergency.

Table 16: Techniques for decontaminating a drinking water distribution system contaminated with biological agents

Method	Principle	Biological target	Efficiency
Shock chlorination (Ct value = 30,000 mg·min/L); 6 to 10 mg/l for few to 24 hours	Introduction of the disinfectant for a selected contact time. Flushing of the system.	Spores of *Bacillus subtilis; Yersinia pestis; Y. pseudotuberculosis; Francisella tularensis; Francisella philomiragia;* Adenoviruses	A 5 $\log_{10}$ decrease of spores after a 3 hour chlorination period. Majority of the cells are dead, but some viable cells are detectable with qPCR
Alternated chlorination and alkaline treatments	Introduction of the agent NaClO→NaOH→NaClO for a selected contact time. Flushing of the system.	Spores of *Bacillus subtilis* attached to the surface of the pipes	After first chlorination (3 h), the amount of spores able to form colonies on R2A agar decreased by 1 $\log_{10}$. After the second chlorination (NaOH was used in between), the amount of spores decreased by 2 $\log_{10}$.
Fenton's reaction	Advanced oxidation with copper or iron salt as a transition metal and ascorbic acid, or H_2O_2 as catalysts.	Spores of *Bacillus subtilis;* Autochthonous biofilm	Not pH correction necessary (using copper and ascorbic acid). Presence of salt and surfactant benefit Fenton reaction.
5 nM to 50 mM NO concentrations	Introduction of nitric oxide using the donor molecule, sodium nitroprusside (SNP), as a biofilm dispersal agent.	Drinking water biofilm. *E. coli* O157 and *Bacillus cereus* E33L spores (closest molecular surrogate for *B. anthracis*)	No significant effect was observed for either general biofilm release nor for the release of specific pathogens
Peracetic acid (5 mg/l)	Introduction of peracetic acid solution into pipeline	*Y. pseudotuberculosis; Adenoviruses*	50% removal of bacteria (qPCR) from biofilms within 2 hours. 2.5 log removal of viruses from biofilms within 1 hour, total removal within 24 hours

Table 17: Techniques for decontaminating a drinking distribution system polluted with organics

Method	**Principle**	**Action on…**	**Efficiency**	**Limits**
Fenton's reaction	Advanced oxidation with iron salt as catalyst and hydrogen peroxide as oxidant	Chlorphenvinphos sorbed on deposits (kaolin)	One hour was required to completely oxidise the pesticide in the water phase.	Longer time is necessary for action in the fixed phase Acid pH improves the efficiency of degradation
Fenton's reaction	Advanced oxidation with real deposits/steel pipes or iron salt as catalyst and hydrogen peroxide as oxidant	Paraquat dichloride.	Steel pipes increases the oxidation process. The gradual addition of hydrogen peroxide showed to be the best option in the oxidation process. 8 hours were enough to degrade all the pesticide.	Acid pH improves the efficiency of degradation

(1) Experimental conditions: $[FeSO_4] = 5 \times 10^{-4}$ M; $[H_2O_2] = 1.5 \times 10^{-2}$ M; $pH_0 = 3$; room temperature, [CFVP] = 2.78×10^{-4} M; (batch reactor; slurry system; lab scale)
(2) T ≈ 20 ºC; $pH_0 = 3.0$; [PQ] =3.98×10^{-4} M $[H2O2]_0$ =1.5×10^{-2} M; [Fe] =5.0×10^{-4} M; (recirculation reactor; pilot scale)

Table 18: Techniques for decontaminating a drinking distribution system polluted with chemicals

Method	**Principle**	**Target**	**Efficiency**	**Limits**
Flushing with water then with 10 mg/l of mg L^{-1} chlorine for 1 hour	water flushing	Mercury sorbed on biofilm coated PEX plastic	Eighty-two percent mercury removal from the pipes	Longer flushing time needed for better Hg^{2+} removal, or acidic conditions.
Mechanical removal of contaminated corrosion layer	Mixing with ice cubes	Mercury sorbed on a piece of corroded cast iron pipe	Sixty percent mercury removal from the section of pipe	Mercury not removed from deeper parts of corroded surfaces. More shear stress needed.
Flushing with air-water / or with water / or mixture of water with crushed ice	Flushing and application of crushed ice, stones	Biofilms, layers and deposits from different type of pipe material	Air-water Comprex® flushing with velocity up to 15–20 m/s removed 99% of the biofilms and ice pigging 99.999%	The higher the shear force, the more efficient the removal of biofilms + sediments. Incrustations are difficult to remove

(1) Experimental conditions: $[FeSO_4] = 5 \times 10^{-4}$ M; $[H_2O_2] = 1.5 \times 10^{-2}$ M; $pH_0 = 3$; room temperature, [CFVP] = 2.78×10^{-4} M; (batch reactor; slurry system; lab scale)
(2) T ≈ 20 ºC; $pH_0 = 3.0$; [PQ] =3.98×10^{-4} M $[H2O2]_0$ =1.5×10^{-2} M; [Fe] =5.0×10^{-4} M; (recirculation reactor; pilot scale)