DELIVERABLE 6.1

Protocol to establish a laboratory system, run with drinking water and additives and generating defined deposits

Dissemination level: **PUBLIC**

WP6

Controlling the efficacy of decontamination in deposits

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SecurEau Drinking Water

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Summary

For systematic investigations on the interaction of deposits with contaminants as well as on the success of decontamination and/or cleaning procedures in a first step the generation of defined deposits as a basis for laboratory studies is necessary. Therefore, in Task 6.1 a suitable flow cell system and a laboratory piping system was designed and established which allows for the defined generation of deposits. The system is equipped with a dosing station which allows for the addition of scale forming substances and of biologically degradable substances for biofilm formation.

With the flow cell system (FEUP) deposits on small coupons can be generated. In the laboratory piping test system (IWW) deposits were generated on pipe samples. Exemplary protocols for the generation of biofilms as well as of inorganic deposits have been developed.

For deposit formation on coupons, the coupon devices developed in Task 6.2 will be implemented in the laboratory piping test system during the further steps in WP6 (Task 6.4). Additionally, in Task 6.4 the sensors optimized in Task 6.3 will also be implemented in the laboratory piping test system to compare the sensor data with off-line laboratory measurements and to calibrate the sensor signals.

1 Introduction

In a contaminated system, not only the water phase is of importance but also the deposits at the inner surfaces, consisting of mineral precipitations, corrosion products and microbial biofilms. An intruding contaminant will interact with the deposit and possibly be sorbed and even accumulated in this complex matrix. Thus, the deposits can act as sinks for the contaminant in which it possibly can be accumulated, later turning into sources when plaques of the deposits are released into the water phase.

Therefore, in WP6, the focus lies on deposit removal or minimization as a means for successful decontamination. Success must be assessed by investigation of deposits.

For systematic investigations on the interaction of deposits with contaminants as well as on the success of decontamination and/or cleaning procedures in a first step the generation of defined deposits as a basis for laboratory studies is necessary. Therefore, in Task 6.1 a suitable laboratory piping system has to be designed and established which allows for the defined generation of deposits. The system can be quite simple and has to be equipped with a dosing station which allows for the addition of scale forming substances and of biologically degradable substances for biofilm formation.

In laboratory piping test system, defined deposits will be generated either on pipe samples as well as on coupon surfaces. For deposit formation on coupons, the coupon devices developed in Task 6.2 will be implemented in the laboratory piping test system during the further steps in WP6 (Task 6.4). Additionally, in Task 6.4 the sensors optimized in Task 6.3 will also be implemented in the laboratory piping test system to compare the sensor data with off-line laboratory measurements and to calibrate the sensor signals.

2 Flow cell system

For the simple generation of deposits on coupon surfaces for lab experiments a flow cell system was previously designed by partner 7 for use in combination with the Mechatronic surface sensor (MSS) during the EU project SAFER (FEUP) (see fig. 1).

The Flow Cell has a semi-circular cross-section and the coupons are placed on the flat surface. Its dimensions may vary according to the type of application envisaged, but typically its diameter is 2.5-3 cm and its length is 80-100 cm, including an entrance zone long enough (30 cm) to permit the stabilization of the flow.

The material of the flow cell for laboratory use is normally transparent (acrylic) and the coupons can be made of any material (PVC, stainless steel, etc)

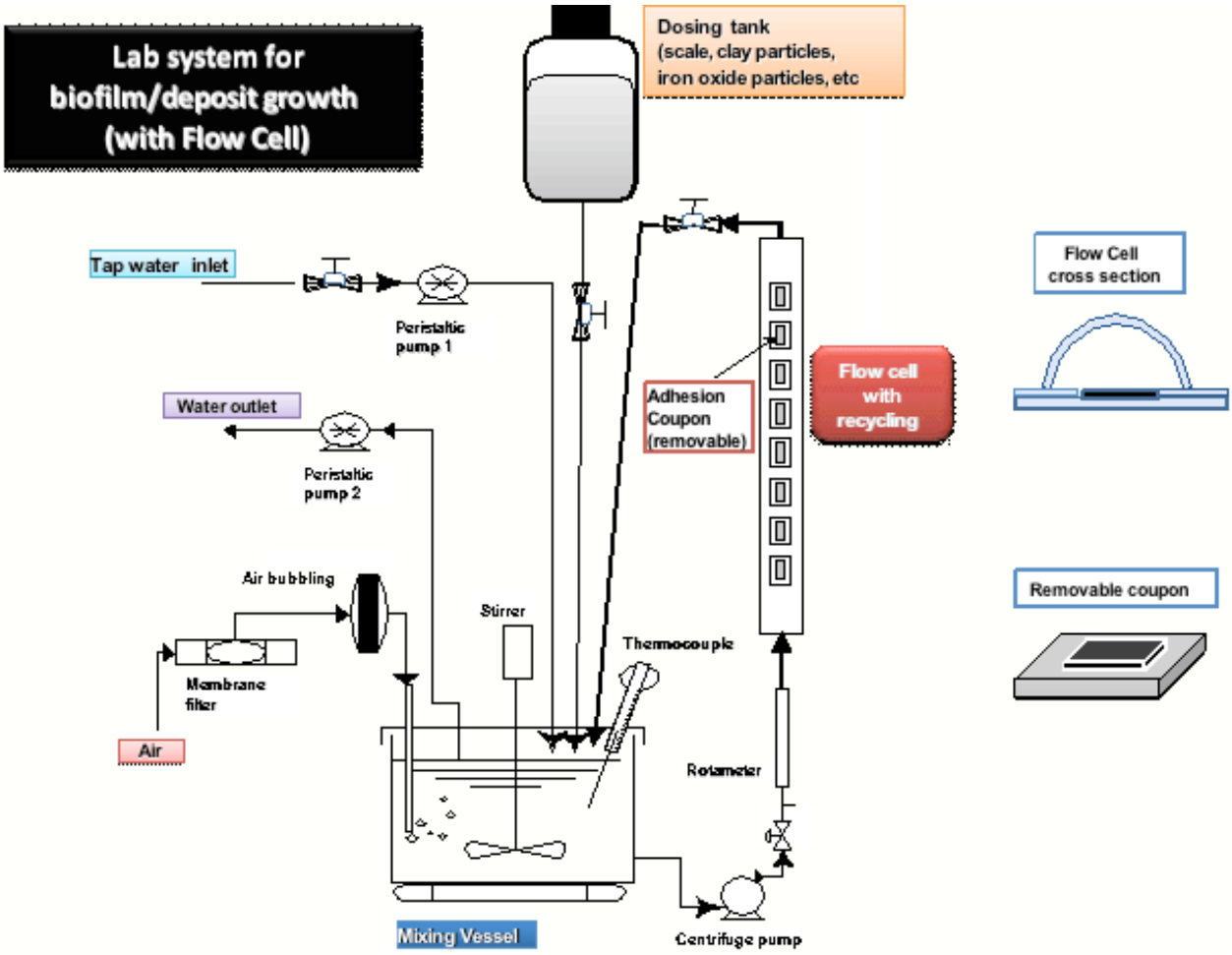


Figure 1: Schematic depiction of the flow cell system designed in Task 6.1 by FEUP

The Flow Cell can operate with laminar as well as with turbulent water flow. Due to the recycling of the water stream from the Flow Cell, it is possible to control and vary the water velocity inside the flow cell independently from the residence time of the inlet water in the system: for a fixed make-up flow of the water entering the system, the higher the recycling, the higher will be the velocity of the water inside the Flow Cell.

3 Laboratory piping test system

3.1 Principle

With respect to the requirements of Task 6.1 and Task 6.4, a laboratory piping was designed and established by partner 4 (IWW) which allows for the defined generation of deposits. The system is supposed to be simple and to allow for the dosing of scale forming substances and of biologically degradable substances for biofilm formation. Additionally, implementation of coupon devices from Task 6.2 and of sensor systems from Task 6.3 must be possible. Furthermore, the possibility to integrate pipes extracted from real drinking water distribution systems with natural deposits will be helpful.

A schematic depiction of a simple setup to generate deposits in pipes is given in figure 2. The main necessary components are: a reservoir tank, a circulation pump, the pipe segment assembly, a flow control valve and a dosing station for scale forming substances and nutrients comprising a pump and stock tanks. If more than one pipe is be treated in parallel, a manifold is necessary before and after the pipes to allow for a equal distribution of the water flow to all pipes. The requirement to include coupon devices and sensors in the pipe test system leads further parallel tracks. Additionally, a flow meter and temperature control is included in the actual version of the laboratory piping test system. A schematic drawing is shown in figure 3.

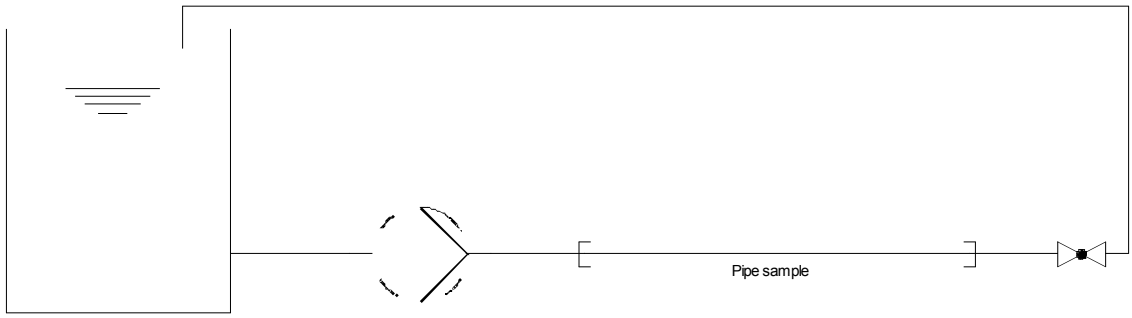


Figure 2: Schematic depiction of a most simple setup to generate deposits in pipes

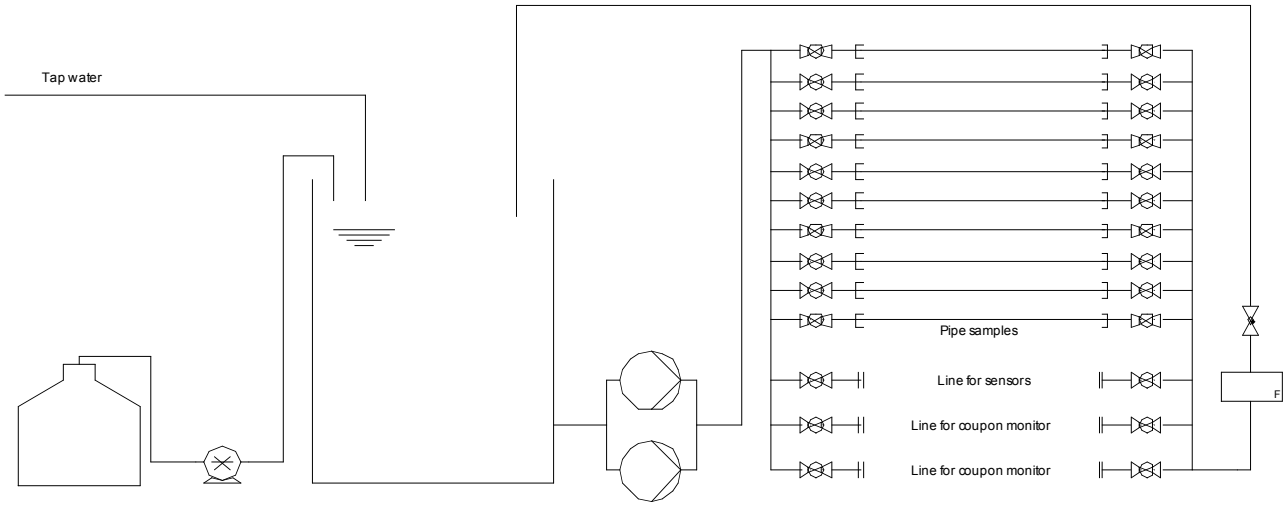


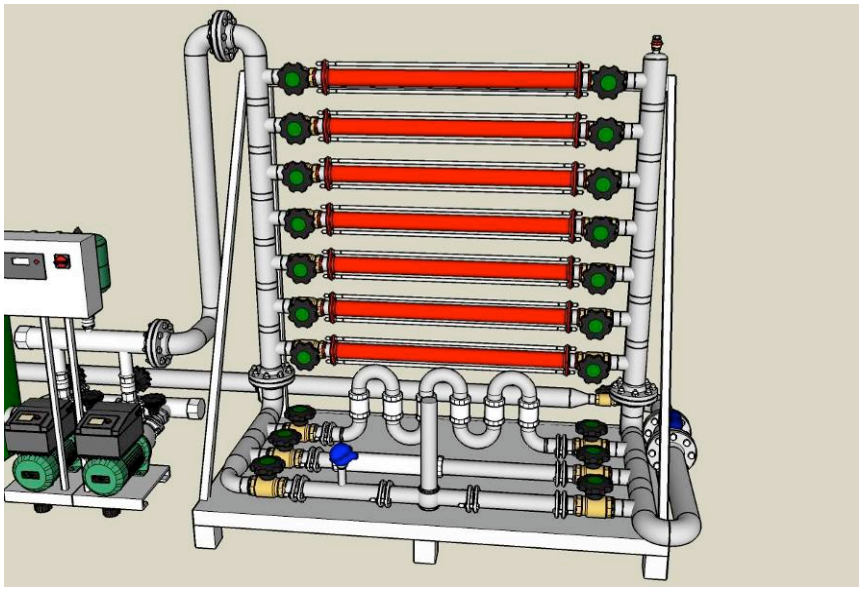
Figure 3: Schematic depiction of the laboratory piping test system designed in Task 6.1 by IWW

3.2 Technical description

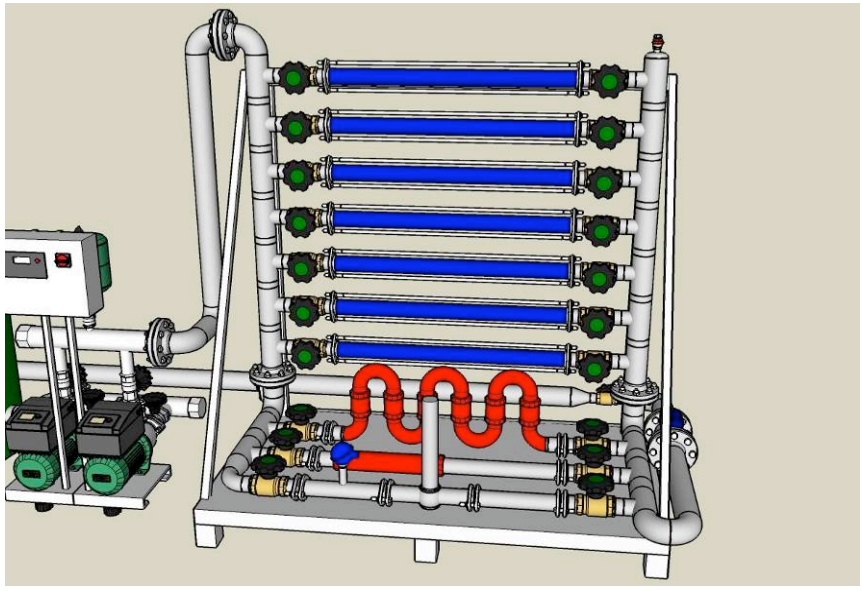
The laboratory piping test system designed in task 6.1 is shown in figure 4 and equals the schematics shown in figure 3. For clarification, (i) the multiple parallel pipes for generation of deposits in pipes, (ii) the parallel lines for the implementation of coupon devices as well as (iii) the parallel line for the installation of the deposit sensors are colour shaded in figures 5 a-c.

Figure 4: Photograph of the laboratory piping test system installed at the site of partner 4 (IWW)

(a)



(b)



(c)

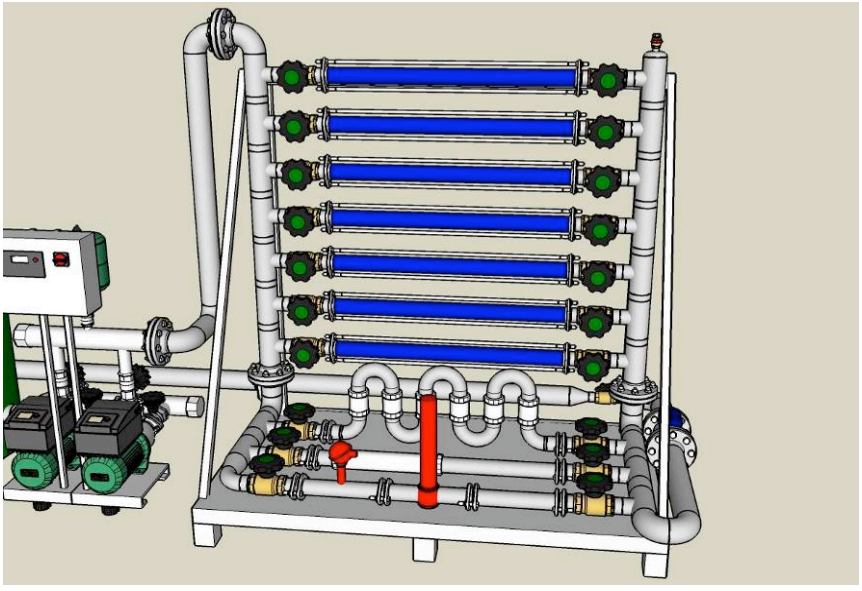


Figure 5: Localization of the multiple parallel pipes (a), the parallel lines for the implementation of coupon devices (b) and the parallel line for the installation of the deposit sensors (c) shaded in red colour in each case.

The main technical parts are listed in table 1. These parts have been used for the construction of the laboratory piping test system at the site of partner 4 (IWW) but similar or comparable parts can be used to build such a pipe test system.

Table 1: Main technical parts of the laboratory piping test system installed at the site of partner 4 (IWW)

Part	Manufacturer / type	Description
Circulation pump	WILO Booster station Comfort-Vario COR-2MHIE1602-2G/VRWMS.-EB	Drinking water booster station with 2 pumps, max. 66 m³/h, PN 10 bar
Flow meter	Krohne Optiflux 2100 W	Magnetic inductive flow meter, DN 80, PN 40
Pipes of the test rig	Stainless steel pipes, flanges and weld fittings	1.4571 stainless steel, DN 80 (88.9 mm outer diameter) for circulation system and DN 50 (57.0 mm outer diameter) for connections to sample pipes
Valves	Watts, KWD 50 ball valves	Ball valves certified for drinking water use, DN 50, full bore
Connections to sample pipes	Distance regulation fittings	Custom made brass fittings, 2 " connection to ball vales and flat sealing to sample pipes
Storage tank	Rain barrel	400 l rain barrel
Dosing pump	Ismatec IPC-N	Peristaltic pump
Dosing pump	Heidolph PD 5201	Peristaltic pump

At present, polyethylene pipes (PW-HD 100) which are normally used for house connection lines in drinking water distribution systems are used as sample pipes for the generation of deposits. The sample pipes have a length of 100 cm and a inner and outer diameter of 51.6 and 63.0 mm respectively. These sample pipes can be installed to and samples from the test rig system during operation of the remaining system.

3.3 Generation of deposits

3.3.1 Generation of biofilm

To generate biofilms on the sample pipe surfaces, the continuous circulation of drinking water is possible.

The inoculum will be the natural drinking water microbial population. To maintain a sufficient nutrient concentration a constant dosing of R2A medium by a dosing pump is necessary. The amount of nutrient added is dependent on the acceleration of biofilm growth which should be achieved. Furthermore, the number of sampling pipes operated at the time and the water volume circulated through the system has to

be taken into account. Thus, a general concentration and amount to be added can not be given. For example, the addition of R2A solution (see appendix) over 24 h resulting in a 1:1000 dilution is appropriate for first test (Example: water volume for circulation = 100 l; dosing of R2A solution should be 100 ml per day. Thus, continuous addition of 4.17 ml/h R2A solution is necessary. Further acceleration (faster and more) of biofilm growth can be achieved e.g. by adding R2A medium resulting in 1:100 dilution (= 41.67 ml/h R2A solution addition) is possible.

3.3.2 Generation of inorganic deposits

The generation of inorganic deposits can be achieved e.g. with calcium carbonates to simulate scaling, clay particles or iron oxide particles to simulate corrosion deposits.

The most simple way is the batch addition of the respective materials to the storage tank of the piping test system. Sedimentation of the particles in the tank must be prevented by stirring if necessary. During the circulation of the water through the system, the particles may also form deposits on the sample pipe surfaces. To ensure a fast deposit formation, sufficient particle concentrations have to be used which are not realistic to the natural concentrations in drinking water systems. For example, iron oxide particles at 10 g/l may be used to generate such deposits on the sample pipe surfaces.

3.3.3 Experimental procedure

Multiple sample pipes made of PE-HD 100 as mentioned above or other pipe materials with comparable dimensions will be installed to the test rig. The generation of deposits according to 3.3.1 and 3.3.2. is done by continuous circulation of drinking water with the addition of nutrients and/or inorganics as described above. In addition, coupon monitoring devices and sensors will be installed at the same time to follow deposit formation on the coupons and to get the respective sensor signals. Results regarding the coupon monitoring devices and the sensors will be given in the future deliverable D 6.4.

The flow in the system is adjusted in the range of 0.1 m/s to 1 m/s in each sample pipe by means of the flow meter and a regulation valve. The pressure will be held constant to e.g. 2 bars by use of the booster station.

3.3.4 Sampling and analyses

To analyze the development of the desired deposit on the sample pipes, single sample pipes will be taken from the system after e.g. each two days or each week. After disassembling a sample pipe, either a new pipe has to be installed or the flow in the total system has to be readjusted to keep the flow velocity in the remaining sample pipes constant.

The deposit in the sampled pipe can be quantified by scraping the deposit from a known surface area. Depending on the kind of deposit total cell counts by DAPI staining or quantification of inorganic elements by ICP is performed. For comparison, the same analyses should be done on coupons exposed under the same conditions (see future D6.4). Additionally, direct microscopy will be possible on the coupon surfaces.

As soon as the “kinetic” of the deposit formation has been evaluated by the time dependent sampling of single pipes the generation of a defined deposit is possible in multiple sample pipes in one experimental run. Such pipes can be used to study the incorporation of CBRN surrogates or to evaluate cleaning strategies. In addition, the pipes with deposit can be send to the consortium partners for further experiments. To do so, the pipes are taken from the test rig, drained and closed in wet condition by use of end caps.

4 Appendix

Composition of R2A solution

R2A medium is commercially available only in the form of agar. The R2A solution has to be prepared using the following composition:

0.5 g Yeast Extract
0.5 g Proteose Peptone No. 3
0.5 g Casamino Acids
0.5 g Dextrose
0.5 g Soluble Starch
0.3 g Sodium Pyruvate
0.3 g Dipotassium Phosphate
0.05 g Magnesium Sulfate
per 100 ml deionized water

The medium should be autoclaved at 121 °C for 15 min.