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Report
Description of Deliverable D.3 – WP1

Less-Water Bev.Tech
Contract ECO/13/630314

Reporting Date
31.03.2015

Project coordinator: **A DUE DI SQUERI DONATO & C. S.p.A.**

Project website: **lesswaterbevtech.com (online from March 31st, 2015)**

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European Commission | Executive Agency for Small and Medium-sized Enterprises

Description of the Deliverable n. 3 of Work Package 1.

The Deliverable D.3 of Work Package 1 (WP1) included in the Annex I of the Grant Agreement for the Project Less-Water Bev. Tech (ECO/13/630314) regards the “Project coordination meeting #2”.

Such meeting has taken place on March 16th 2015, at A DUE S.p.A. premises in Riccò di Fornovo Taro (PR) – Italy.

The meeting has been postponed with respect to the date it was initially planned (February 25th 2015) because of organizational issues.

- **<u>Meeting Participants:</u>**

Participants:

- Ing. Simone Squeri, A DUE S.p.A., CEO;
- Dott. Federico Cappa, A DUE S.p.A., in-house consultant;
- Craig Clayton, CVAR Ltd, Owner, connected in teleconference;
- Ing. Marco Bortolini, Università di Bologna, senior researcher;
- Ing. Alberto Dilda, A DUE S.p.A., COO and R&D director;
- Ing. Micaela Guerzoni, A DUE S.p.A., subcontractor;
- Prof. Mauro Gamberi, Università di Bologna, associate professor;
- Ing. Alessandro Graziani, Università di Bologna, PhD researcher, connected in teleconference;
- Ing. Marco Iasoni, A DUE S.p.A., project engineer;
- Ing. Guido Marossa, A DUE S.p.A., project engineer;
- Ing. Maurizio Violi, subcontractor;
- Ing. Paolo Caselli, A DUE S.p.A., project designer automation;
- Ing. David Delmonte, A DUE S.p.A., Automation engineering Dept. Director;
- Ing. Gian Paolo Pescini, A DUE S.p.A., Mechanical engineering Dept. Director.

- **<u>Meeting Agenda:</u>**

The agenda for the meeting, as fixed during the previous meeting on Dec. 3rd 2014, is the following:

- Discussion about the definition of the main technical specification of the pilot plant (ADUE, UNIBO, Guerzoni Micaela and Ing. Violi Maurizio as subcontractors): due by end of February 2015.

- Discussion about the definition of main characteristics of water to be treated by the new water treatment plant (ADUE, UNIBO, Guerzoni Micaela and Ing. Violi Maurizio as subcontractors), due by end of January 2015.
- Conclusion of the state of the art regarding water treatment technologies coming to light during ADUE analysis (UNIBO) due by end of January 2015.
- Preparation of summary report and training in ADUE especially focused on the ultrafiltration technology (ADUE and UNIBO), due by end of February 2015.
- Schedule of the next Meeting.

- **<u>Report of partners' activities implemented from December 3rd, 2014.</u>**

  - **Main technical specification of the pilot plant.**

Starting from the initial scheme reported in Annex I, the project's participants have deepened the analysis and the study of technical specification for the following realization of the pilot plant, introducing some important improvements.

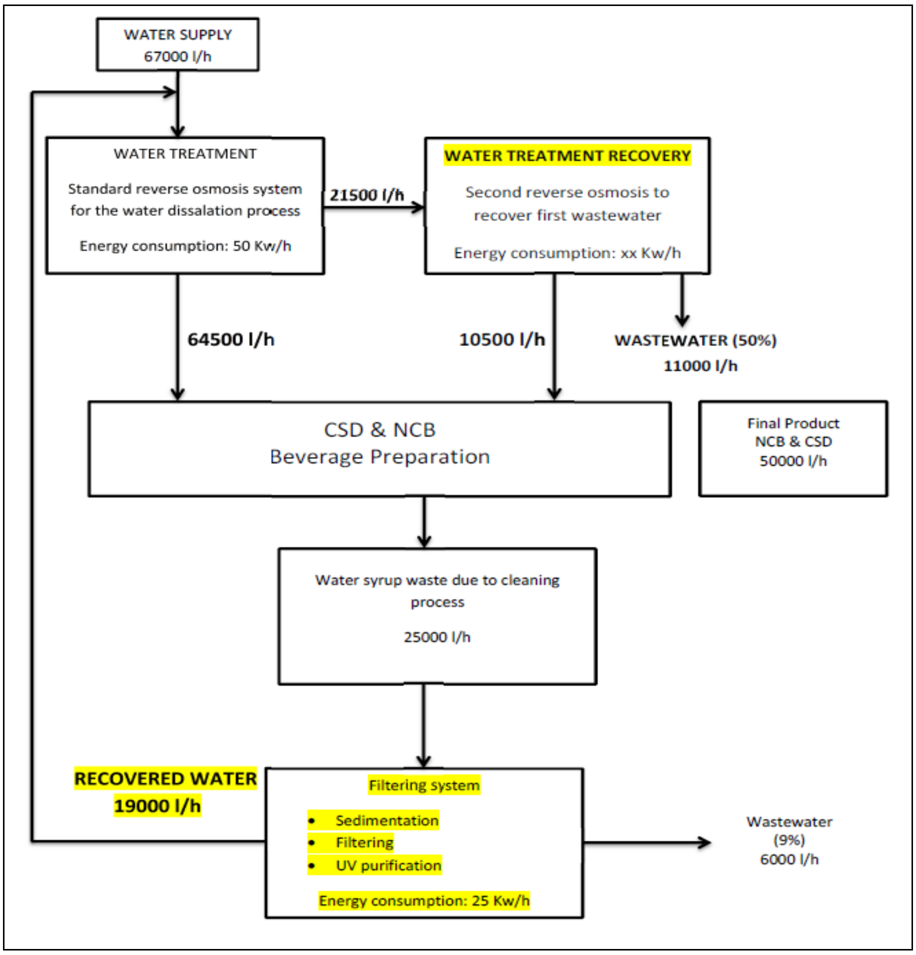

Fig.1: original scheme regarding the *proposed NCD and CSD process.*

The original scheme had the following characteristics:

- Achieve a final production of 50.000 l/h;
- Waste water of 25.000 l/h due to production process;
- Waste water estimated at 40.000 l/day for the CIP cleaning phases (this is not in continuum, and is implemented in batches influenced by format changes, taste changes, etc.).

Starting from these milestones, the functional scheme has been simplified, maintaining the characteristics included in the original scheme but adding some important improvements, as illustrated in the following figure (the CIP phase has not been illustrated in such figure for simplicity, but it is considered in the process).

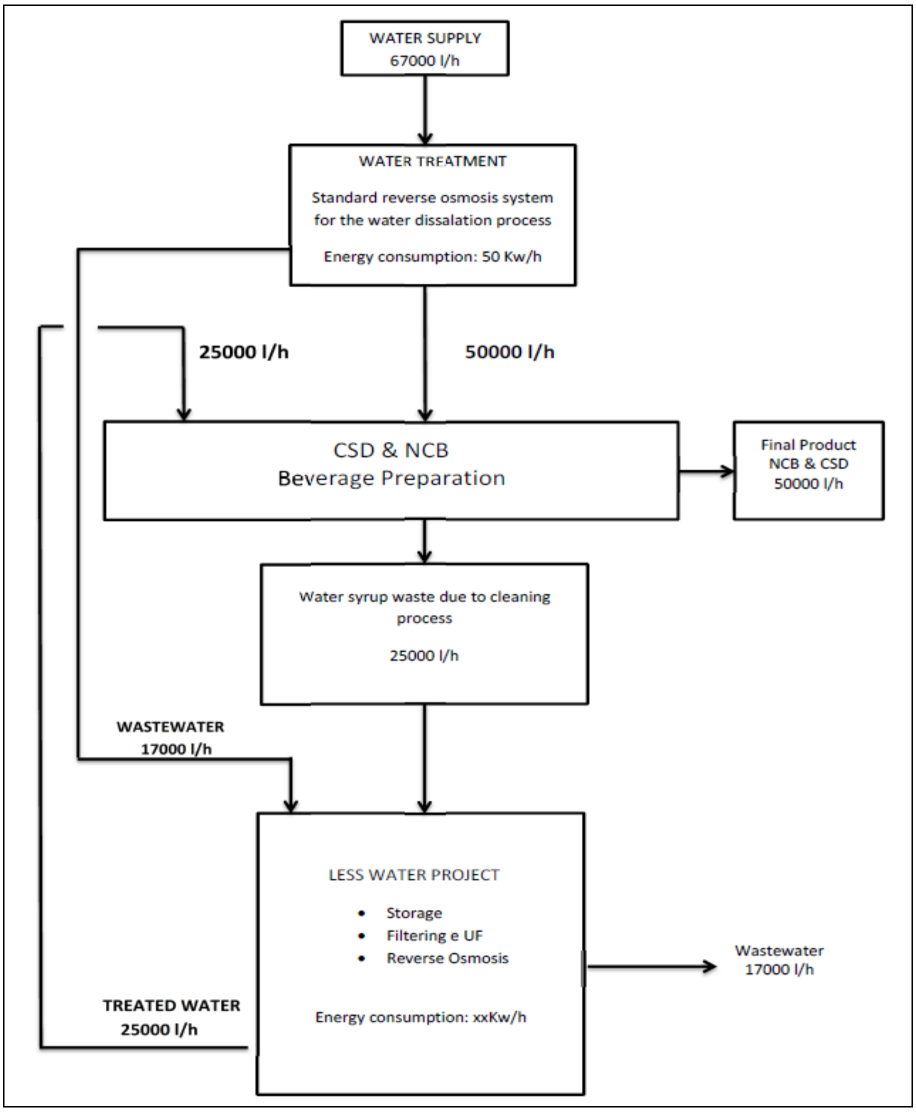

Fig.2: updated scheme regarding the *proposed NCD and CSD process.*

The new scheme has, at the end of the production process, a storage tank, a first ultra-filtering device and a UV treatment like the original solution, but added a Reverse Osmosis device (which was already present in the project but it is now moved at the end of the process.

This will permit not to send the recycled water to the Reverse Osmosis already present at the beginning of the process, but to send it directly to the Beverage Preparation phase.

This new solution will achieve the same results of the original solution, and will add the following improvements:

- Given that the water after the production process, collected after the Ultra-Filtering and UV treatments is very rich in salts, avoid saturating the membranes of the Reverse Osmosis already present, which will have to treat water with higher salt content then the water from the grid or from the well;
- Avoid saturating the production capacity of the Reverse Osmosis already present at the beginning of the process, which usually is designed to respond to the plant production needs;
- The new water treatment system becomes more easily replicable, because it becomes a stand-alone system easily installable beside the original production plant, not asking for changes in the water treatment solutions already present (and maybe not easily modifiable);
- The water recovered by the new water treatment system could then be used to send the water to the existing production plant, or also to supply a new production plant. With the new solution, the CSD bottler has the two option open. This will make the innovation more easily acceptable from the market, with more advantages in terms of environmental sustainability.

From the scheme illustrated above, the project's participant have developed a first project of the prototypal plant, on the basis of the beverage production plant where the water samples were taken from in the previous preparatory activities.

From the production process, the new water treatment needs to collect water from the points where water is actually discharged and wasted. From some of these discharging points (the ones where water is under pressure), water could be automatically collected adding simple pipes bringing to the Storage Tank at the beginning of the water treatment system.

The other discharging points (where water is not under pressure), need the further installation of a system of pumps and storage tank, from where the water is then sent to the Storage Tank at the beginning of the water treatment system.

This Storage Tank at the beginning of the water treatment system serves as a balancing buffer between the production process (and its capacity and its production batches) and the water treatment system (with its own capacity and production in continuum).

The capacity of this Storage Tank in terms of litres has not been defined yet.

From the Storage Tank, waste water will be filtered and treated with UV, and then with the Reverse Osmosis.

Then, the recycled water could be sent back to the production process, or to a new production plant.

Finally, the project will study and design a set of solutions to be applied directly on the machines used for the production of CSD, in order to optimize their own water consumption.

- **Main characteristics of water to be treated by the new water treatment plant.**

The water samples collected from CLIENT1, CLIENT2, CLIENT 3 in the previous activities were analysed.

In particular, CLIENT2 has been chosen for the prototypal water treatment system, because is the more difficult to be treated among the three clients originally selected and sampled.

The technical parameters and specifications of the prototype were reviewed on the basis of the results from the analysis on water samples.

The strategic points for the project are the ones highlighted in green in the following Figur

From CUSTOMER 2 - 05/11/2014															
Laboratory code	14SA24302	14SA24303	14SA24306	14SA24304	14SA24301	14SA24305	14SA24300	14SA24309	14SA24314	14SA24310	14SA24311	14SA24312	14SA24313	14SA24307	14SA24308
ADUE code	5	7	6	10	4	2	1	9	9	9	9	9	9	8	3
Sample description / analyzed parameter	FILTER (INPUT)	OSMOSIS PERMEATE	BIOLOGICAL FILTER (OUTPUT)	WELL WATER AFTER PLANT COOLING *	COOLING TOWER	DEGASER	HOMOGEN EIZER	PUSHING (500)	PUSHING (600)	PUSHING (650)	PUSHING (700)	PUSHING (750)	PUSHING (800)	CIP WASHINGS **	BOTTLES RINSES
Conductivity (at 25°C) (µS/cm)	1060	28,7	1064	1056	841	1007	25,6	675	668					36900	53,6
pH (pH unit)	7,6	5,4	7,4	7,4	7,8	8,3	5,2	7,2	7,1					12,8	3,9
Flourine (Flourides) (mg/l)	0,38	< 0.15	0,38	0,38	0,28	0,32	< 0.15	0,22						3,53	< 0.15
Chlorine (Chloride) (mg/l)	150	4,7	159	143	134	130	5,2	124						116	4,4
nitric nitrogen (Nitrates) (mg/l)	< 3.0	< 3.0	< 3.0	< 3.0	128	5,4	< 3.0	6,7						338	< 3.0
Sulphates (SO4) (mg/l)	47,5	< 4.0	48,5	48,8	23,9	42,9	< 4.0	59,8						29,8	< 4.0
Sodium (Na) (mg/l)	75,2	4,7	77,4	71	116,6	131,8	3,8	59,1						4460	4,37
Barium (Ba) (µg/l)	218,9	< 50.0	166,9	209,2	57	74,9	< 50.0	130						135,2	< 50.0
Calcium (Ca) (mg/l)	121,3	0,2	120	117,1	39,9	62,5	0,399	34						86,8	0,478
Iron (Fe) (µg/l)	333	< 20.0	22,4	398	< 20.0	< 20.0	< 20.0	< 20.0						276	< 20.0
Magnesium (Mg) (mg/l)	41,4	0,2	42	39,9	11,61	30,9	0,2	38,1						27,7	0,2
Manganese (Mn) (µg/l)	372	< 5.00	< 5.00	382	< 5.00	< 5.00	< 5.00	< 5.00						33,6	< 5.00
Potassium (K) (mg/l)	3,06	< 0.200	3,1	2,91	4,71	4,45	< 0.200	2,87						20,1	< 0.200
Ammonia (NH4) (mg/l)	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050						0,95	< 0.050
Silica (SiO2) (mg/l)	22,38	0,94	25,45	21,3	15,81	24,26	0,3	19,28						< 0.02	0,6
Sedimentable Solids (2 ore) (ml/l)	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10						4	< 0.10
Total suspended solids (mg/l)	< 1.0	1	< 1.0	< 1.0	< 1.0	< 1.0	1,67	1						418	< 1.0
Turbidity (NTU)	2	1	< 0.40	1	1	1	2	1						314	< 0.40
Alkalinity P (CaCO3) (mg/l)	27,9	< 5.0	43,8	42,8	6	55,7	< 5.0	24,8						9035	15,8
Alkalinity T (CaCO3) (mg/l)	332,3	13,9	328,4	337,3	81,6	334,3	12,9	126,7						9393	63,4
Alkalinity (HCO3) (mg/l)	337,5	17	293,8	307,1	85	271,9	15,8	94,2						< 2.0	38,6
Alkalinity (CO3) (mg/l)	33,4	< 2.0	52,5	51,3	7,2	66,9	< 2.0	29,7						429,8	19
Alkalinity (OH) (mg/l)	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0						2950	< 2.0
total hardness (come CaCO3) (mg/l)	472,99	1,32	472,2	456,34	147,351	282,94	1,8175	241,21						330,57	2,015
Oxidisability (Kubel's method) (mg/l O2)	< 0.50	< 0.50	< 0.50	0,51	< 0.50	< 0.50	< 0.50	< 0.50						49,6	48,6
BOD5 (O2) (mg/l)			< 5			< 5		< 5						164,5	
COD (mg/l O2)			< 25			< 25		< 25						359,45	
Total Organic Carbon TOC (mg/l)			1,57			5,98		< 1.0						124,4	
redox potential (mV)															298
optical refractometric residue(°Brix)								0	0,2	1,7	3,1	5,2	7,5		
Hourly flow rate (m3/h)		90		70	3	2,4	2								35
Total annual average amount (m3)		561.600													
potentially recoverable waste from a qualitative point of view															
* recoverable after checking the temperature															
** recoverable only by separating the washing steps															
utilities consumption															
not recovered wastess from customer plant															

Fig.4: results from the analysis on water samples from CLIENT2

On the base of such data, the capacities of the water treatment plant have been defined.

The functional parameters for the Ultrafiltration will then be set.

The functional parameters for the UV treatment will then be set.

The functional parameters for the Reverse Osmosis will then be set.

Such parameters will then be merged to define the functional parameters of the entire system.

- **Conclusion of the state of the art regarding water treatment technologies.**

Concerning the analysis of the state of the art about solutions and methods for water treatment the University of Bologna refined the review of the scientific literature on this topic highlighting the following key aspects, evidences and trends:

- The food and beverage sector is the reference industrial context for the water treatment technologies;
- Reverse osmosis technology already reached industrial and commercial consolidated standard levels so that the most of the research is on membranes and energy/environmental analyses to reduce its impacts;
- Filtration technologies based on the mechanical sieve theory are successfully applied in multiple food and beverage application, while ultra-filtration is an emerging and interesting field to be further investigated;
- The combination, in series, of filtration and reverse osmosis represents a privileged way of facing the issue of water purification for industrial uses in the food and beverage sector.

Furthermore, the analysis points out a set of reference scientific journals for both data collection and the project result scientific spread. Among them Desalination, Trends in Food Science & Technology, Innovative Food Science & Emerging Technologies, Food and Bioproducts Processing, Water Science & Technology, Water Supply and Food Bioprocess Technology.

From this analysis the interest in the following focus on ultra-filtration technology is of strong interest and its inclusion among the project plant functional modules appears very appropriate.

- **Summary report and training on Ultra-Filtration technology.**

The University of Bologna illustrated an analysis on the Ultra-Filtration Technology (overview & drivers for applications) which will serve as basis for the following choice of the Ultra-Filtration technology to be applied in the prototype of the new water treatment system.

The report was focused on:

- **Fundamentals of Ultra-Filtration**

Definition: UF is recognized as a low-pressure membrane filtration process; it is usually defined to be limited to membranes with pore diameters from 0.005μm to 0.1μm. When the source water is passing through the filter under a trans-membrane pressure provided by the gravity or a pump, the bacteria and most viruses can be removed, […] the drinking water quality can be satisfied for consumers, and the use of chemicals, capital, and operating cost can be reduced (Gao et al., 2011).

Operating principle: mechanical sieve theory

Range of working: (see graph).

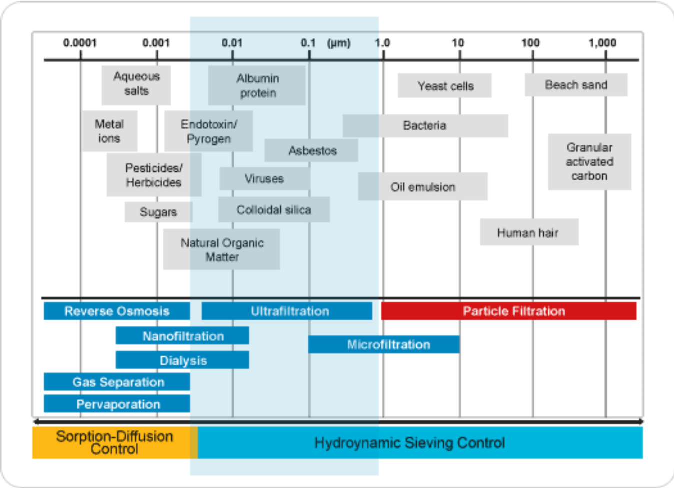

Fig.5: Food & Beverage UF industrial applications

Industrial applications: Dairy industry (Daufin et al., 2001) Beverage industry: (Cheryan, 1998; Cassano et al., 2008) Fish & poultry industry (Afonso et al., 2002, 2004; Chabeaud et al., 2009).

Overall Operating Conditions: pressures 0.03 ÷ 3 bar, pore diameter 0.005 ÷ 0.1 µm, withholding molecular amount 1 ÷ 500 kDalton, membrane structure: porous anisotropic structure (Cieszko, 2009), flow rate 40 ÷ 90 l/m^{2}h depending on the treated water.

Distinctive features vs. (micro)-filtration: low pressure, no high temperature required, smallest pore diameter, high dynamics of the process with flux decrease due to *fouling*.

- **Structures and materials of the membranes**

Basic structures: hollow fibre, tubular, spiral (see pictures).

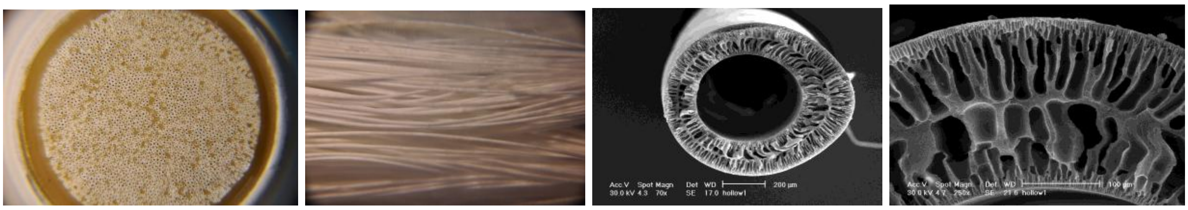

Fig.6: basic structures of membranes for UF

Membrane materials: Polyvinylidiene fluoride (PVDF), Polyether sulfone (PES), Polysulfone (PS), Polyacrylonitrile (PAN), Polyethylene (PE), Polypropylene (PP), Polyvinyl chloride (PVC). PVDF and PES are the most frequently adopted materials best matching the following properties: mechanical strength, hydrophilicity, durability, chemical stability, low polymer cost.

- **Working methods**

Two basic methods are feasible:

- Dead-end filtration: The complete feed flow is forced through the membrane and the filtered matter is accumulated on the surface of the membrane. The dead-end filtration is a batch process as accumulated matter on the filter decreases the filtration capacity, due to clogging. A next process step to remove the accumulated matter is required;
- Cross-flow filtration: A constant turbulent flow along the membrane surface prevents the accumulation of matter on the membrane surface. The feed flow through the membrane tube has a higher pressure as driving force for the filtration process and a high flow speed to create turbulent conditions. The process is referred to as "cross-flow", because the feed flow and filtration flow direction have a 90 degrees angle.

- **Operating and maintenance conditions, parameters and methods.**

Fouling: the UF membrane is prone to losing permeability because of the accumulation of impurities (physic-, chemic-, and bio-substances) on or inside the membrane matrices. The membrane fouling is responsible for the permeability yields with low/no effect on the water quality (permeate).

Types of foulant: particles' fouling on membrane surface and inside the pores, organic fouling caused by natural organic matter from the source water and interactions, bio-fouling from aquatic organisms, such as algae, forming colonies.

O&M actions: pre-treatment, operation condition, cleaning (rinsing, air scrub, chemical cleaning).

The report concluded that, as originally supposed by the project, ultra-filtration is not enough as a stand-alone system for water recycling, but reaches optimal results and maximum effectiveness in series to other complementary water treatment technologies (reverse osmosis, particularly).

- **Website preview.**

During the meeting, the beta version of the project's website has been reviewed and approved by the participants. (http://niagara.gaflimbo.it)

Please refer to Deliverable D6.10 for a complete description.

- **Next steps.**

  - Next meeting will be on **11th May 2015**.
    - Confirmation from the Client.
    - All the information available in order to start with the design and engineering phase.
  - The agenda for the next meeting will be:
    - **Confirmation from CLIENT2 for the installation of the prototype.**
    - Overview of the information for the design and engineering;
    - Definition of installation costs;
    - Definition of a schematic solution for CLIENT2;
    - Design of the Reverse Osmosis system;
    - Design of all the functional groups;
    - Design of the water treatment system;
    - Technical Group will meet once again on May 11th, 2015 at A DUE S.p.A. premises in Riccò di Fornovo (PR), Italy.
    - Then next meeting will be in July 2015.

1.1 Results achieved as compared to what was planned in the project proposal

Results in line with the plan in the project proposal, with improvement decided on the prototypal water treatment system to be realized.

1.2 Deviations, problems and corrective actions taken in the whole project period

No deviations, problems or corrective actions have emerged so far.

2 Other issues (max 1 page)

No other issues have emerged so far.

3 Overview on hours spent

Will be regularly submitted with the Progress Report #1 on month 12 (September 2015).