RISE IONBIKE

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Deliverable D1.1 / D1

Title: Synthesis of precursors

Author (Lead beneficiary, country): UBx, France

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1 Objective

This deliverable describes synthetic routes and protocols for the reproducible synthesis of precursor compounds for iongels, including biocompatible protic ionic liquids, deep eutectic solvents, and biodegradable poly(ionic liquids) and/or new functional biopolymers.

2 Description of tasks

In this deliverable the main activities carried out during the first year of the project in the Task 1.1, Task 1.2 and Task 1.3. All the activities are related to the preparation of chemical precursors such as ionic liquids and polymers for the future preparation of iongels in WP2.

2.1 Task 1.1 Synthesis of biocompatible protic ionic liquids and biocompatible deep eutectic solvents

First, biobased ionic liquids, bearing the cholinium cation and different amino acids and carboxylated anions, were prepared by slow dropwise addition of the corresponding acid or amino acid (1:1) to aqueous cholinium bicarbonate solution, as shown in Figure 1. The mixtures were stirred at ambient temperature and pressure for 12 h. The resulting products were washed with diethyl ether or ethyl acetate to remove unreacted acid or amino acid, respectively. Excess of water and traces of other volatile substances were then removed by rotary evaporation under reduced pressure. The chemical structures and purities of synthesized cholinium-based ILs were confirmed by ^{1}H- and ^{13}C-NMR. Figures 2 and 3 show some examples.

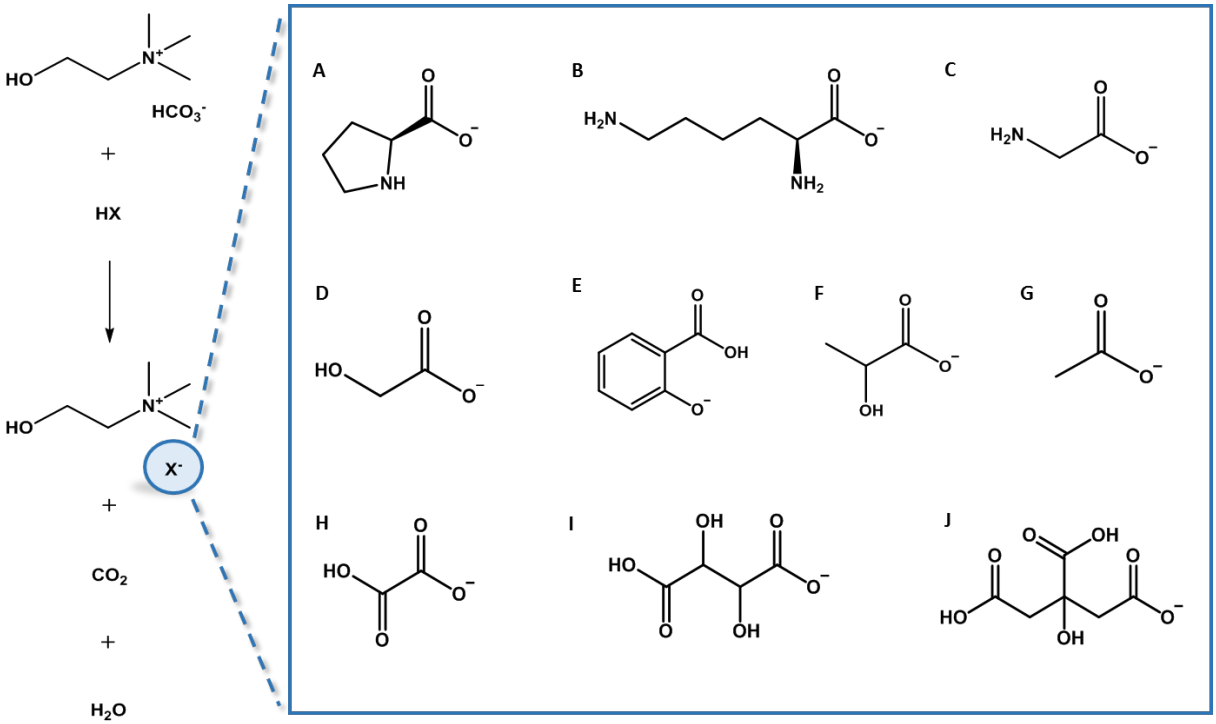

Figure 1. Synthetic pathway and chemical structures of the prepared cholinium-based ionic liquids with amino acids and carboxylated anions: (A) prolinate, (B) lysinate, (C) glycinate, (D) glycolate, (E) salicylate, (F) lactate, (G) acetate, (H) oxalate, (I) tartarate and (J) citrate.

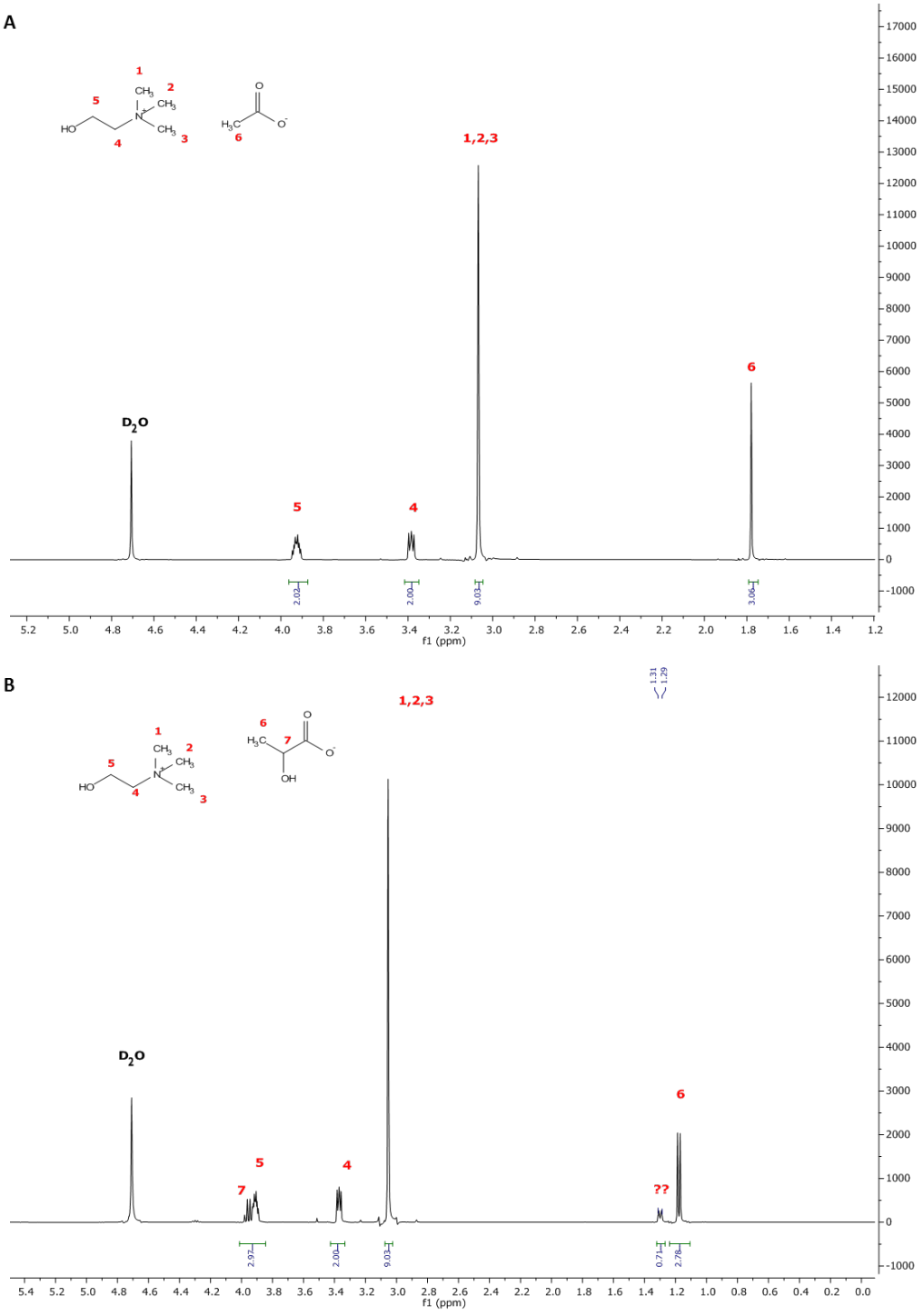

Figure 2: 1H-RMN spectra of (A) cholinium acetate and (B) cholinium lactate.

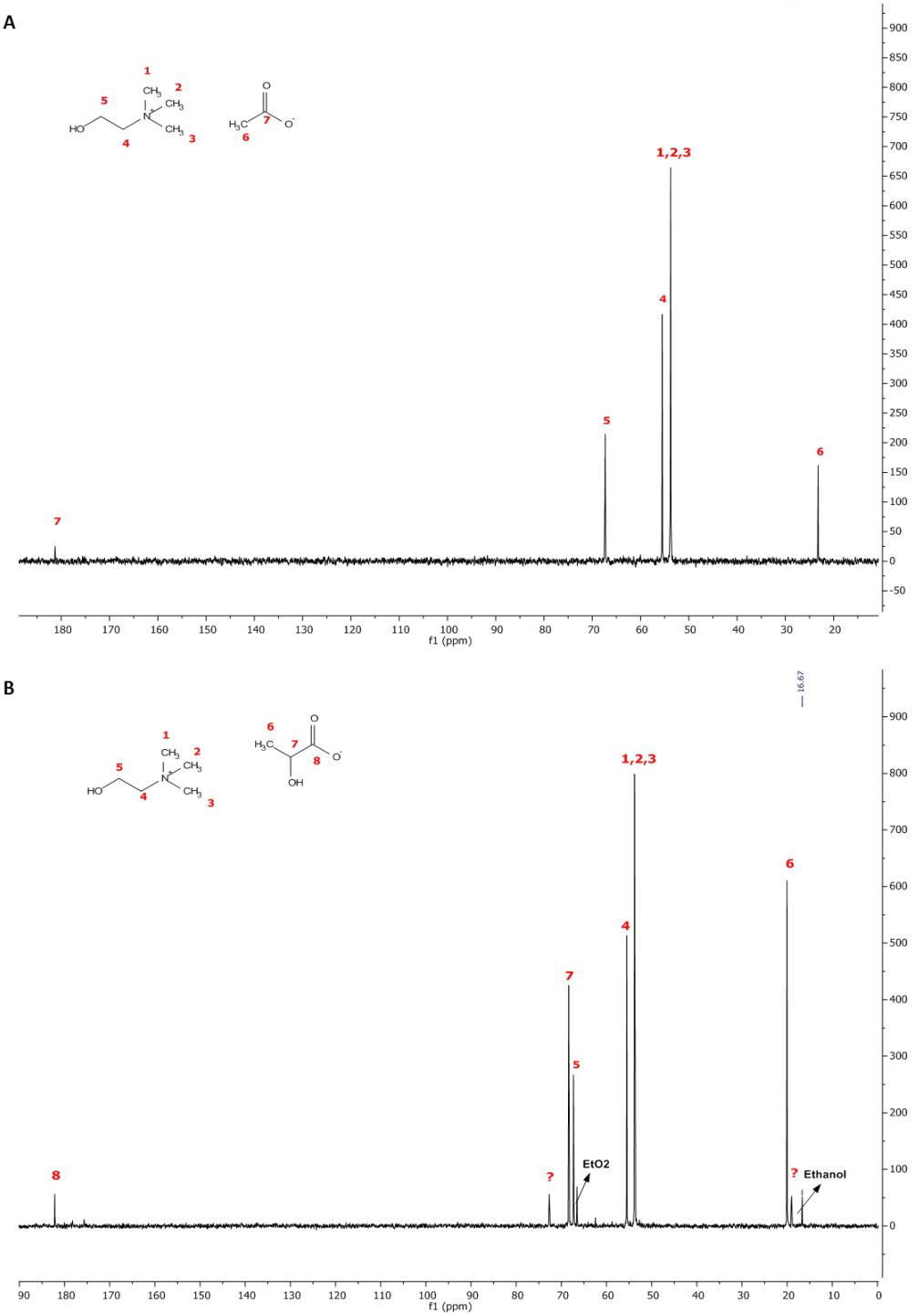

Figure 3: ^{13}C-RMN spectra of (A) cholinium acetate and (B) cholinium lactate.

As a second family of biobased ionic liquids, Acetyl cholininum carboxylated ionic liquids (Figure 4) were prepared. In this period we synthesized three different ionic liquids by keeping the same cation and varying the length of the carboxylate. The following procedure was used:

Potassium hydroxide (0.95 mol) was dissolved in a minimum amount of MiliQ water. The desired acid (1 mol) was dropwise added to the potassium hydroxide aqueous solution. The water was removed by using a rotatory evaporator and the synthesized solid was washed with excess diethyl ether and filtrated. The formed precipitate (1 mol) and the acetyl choline chloride (1 mol) were separately dissolved in a minimum amount of ethanol and then mixed. The desired acetyl cholinium carboxylate was obtained by filtration of precipitated KCl and evaporation of EtOH. The biobased ionic liquids were again characterized by FTIR and NMR spectroscopies.

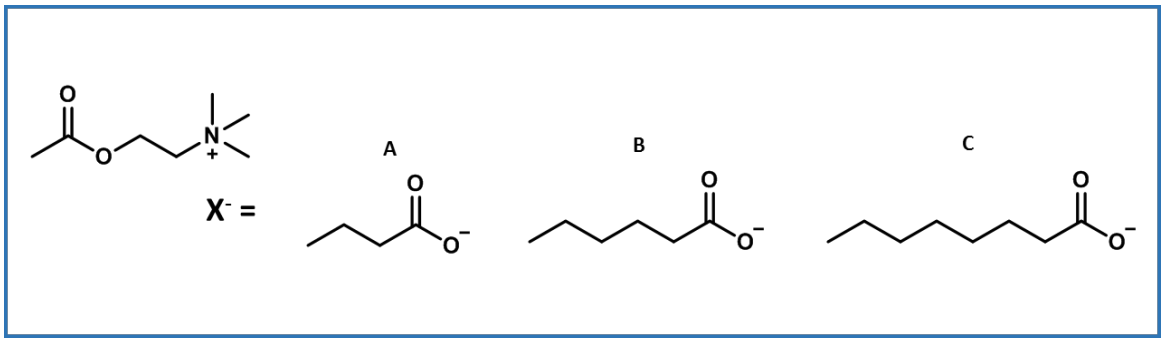

Figure 4: Chemical structures of the prepared acetyl cholinium-based ionic liquids with carboxylated anions: (A) butyrate, (B) hexanoate and (C) octanoate.

2.2 Task 1.2 Synthesis of biodegradable poly(ionic liquids)

In this tasks, new poly(ionic liquid)s based on the polycation diallyldimethylammonium and two neurotransmitters as counter-anions, namely gamma aminobutyric acid (GABA) and valproate (VALP), were synthesized via a two-step anion exchange reaction as shown in Figure 3. First, an aqueous solution of poly(diallyldimethylammonium hydroxide) was prepared by passing an aqueous solution of the commercially available poly(diallyldimethylammonium) chloride through a column filled with anion exchange resin (SUPELCO Amberlite IRN-78) in the hydroxide form. Subsequently, the prepared basic polymer solution was neutralized by slowly dropwise addition of a slight excess of the corresponding neurotransmitters, with cooling. The mixtures were stirred at ambient temperature and pressure for 12 h. Excess of water was then removed by rotary evaporation under reduced pressure and dried under vacuum at 45 ºC.The chemical structures of the prepared poly(ionic liquid)s were confirmed by NMR analysis.

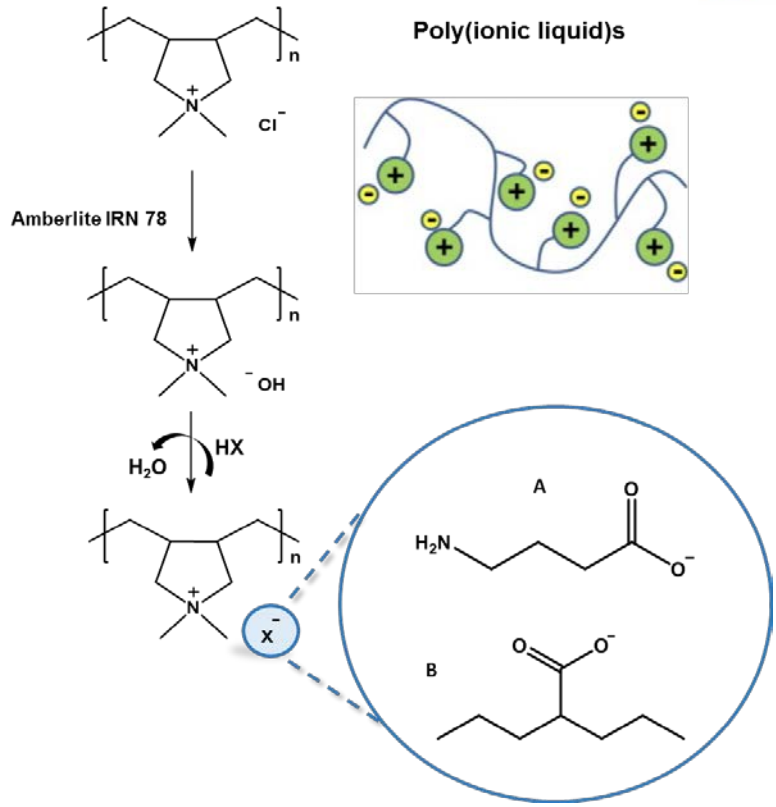

Figure 5: Chemical structures of the prepared poly(diallyldimethylammonium) with neutransmitters as counter-anions: (A) gamma aminobutyrate and (B) valproate.

2.3 Task 1.3 Synthesis of new functional biopolymers

Within this tasks, tannic acid and other phenolic compound and biopolymers were used in order to modify the structure of poly(vinyl alcohol) (PVA) through the formation of hydrogen bonds in order to prepare semi-solid iongels with cholinium carboxylate ionic liquids. In a typical experiment, PVA (0.05 g) was dissolved in water (0.5 g) under vigorous stirring at 90 °C. Then, the phenolic compounds (gallic acid: 0.0239 g, pyrogallol: 0.0270 g and tannic acid: 0.0386 g) were added to the mixture. A molar ratio of 0.5 (phenolic compounds' functional group/PVA hydroxyl groups) was used.

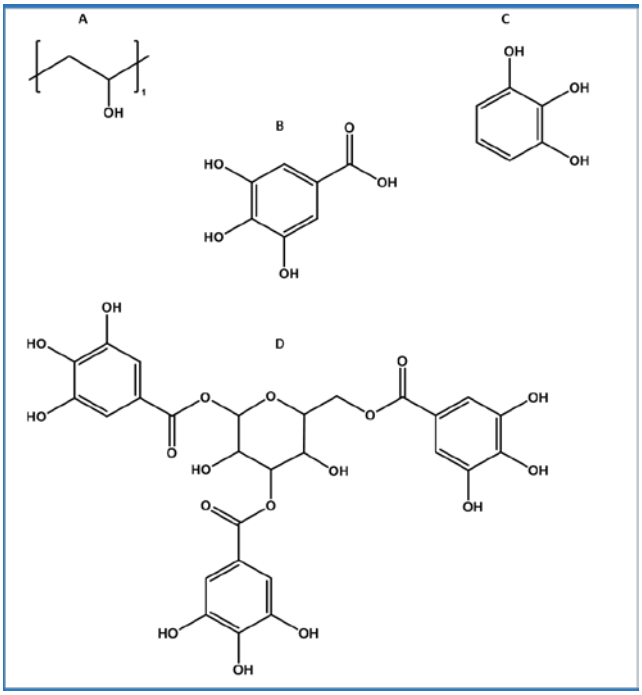

Figure 6: Chemical structures of (A) poly(vinyl alcohol), (B) gallic acid, (C) pyrogallol and (D) tannic acid.

Moreover, the biopolymer hyaluronic acid (polyanion) was also modified by adding two neurotransmitters as counter-cations (Figure 4), namely dopamine and acetyl choline, were also synthesized via a two steps anion exchange resin (Dow Amberlyst A26) in the hydroxide form.

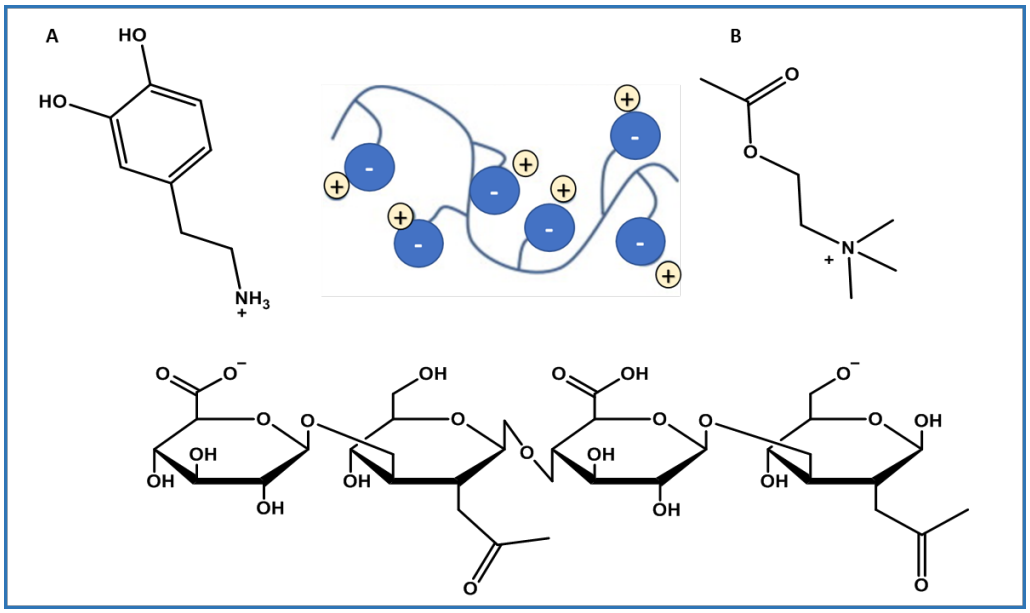

Figure 7: Chemical structures of biodegradable poly(ionic liquid)s based on the hyaluronic acid as polyanion and two neurotransmitter as counter-cations: (A) dopamine and (B(acetyl choline).

3 Description of work & main achievements

Within this first year of the project, we established the synthetic routes and protocols for the reproducible synthesis of precursor compounds for iongels, including biocompatible protic ionic liquids, deep eutectic solvents, and biodegradable poly(ionic liquids) and/or new functional biopolymers. These activities produced new materials to be tested in the development of iongels and the further use in bioelectronics in WP2, WP3 and WP4. The main achievements were:

- Reproducible synthesis up to 10 grams of a new family of cholinium based biocompatible and bioactive ionic liquids.
- Synthesis of bioactive poly(ionic liquid)s having neurotransmitters as counter-anions.
- Synthesis of new functional biopolymers such as modified tannic acids and bioactive hyaluronic acids.

4 Deviations from the workplan

The work was carried out without deviations from the workplan.

5 Performance of the partners

The development of precursors shown whithin this deliverable was carried out at partner UPV/EHU, during the secondments visit from/to Deakin University, Universidad de Rio Cuarto and Universidad Nacional de Litoral.

6 Conclusions

The activitities and results carried out during the first year of the project showed that this deliverable was fulfilled in a very satisfactory manner.