Fatty acid approach for the synthesis of individual LCCP reference standards

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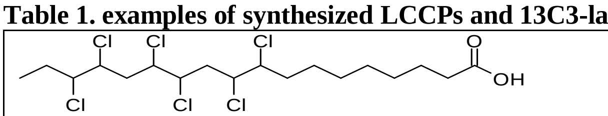
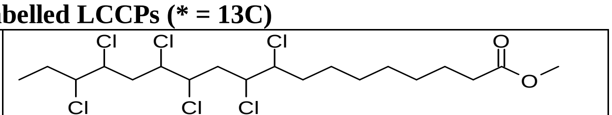
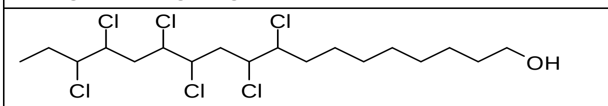
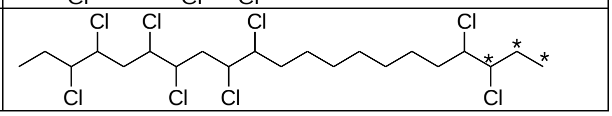
Introduction: Chlorinated paraffins (CPs) are a class of polychlorinated industrial chemicals and the technical products are grouped in three classes: short-chain (SCCPs, C10-13), medium-chain (C14-17), and long-chain CPs (LCCPs, C>17). Short Chain CPs (SCCPs) were classified as persistent organic pollutants (POPs) by the Stockholm Convention in 2007, followed by restrictions and bans. But production and use of Medium Chain CPs (MCCPs) and Long Chain CPs (LCCPs) is currently not regulated. Technical CP produced consists of a complex mixture of thousands of different congeners. The validation of analytical methods for the identification and quantification of CPs in various matrices is being hindered due to a lack of certified reference materials (CRM). In 2019 Chiron launched the Eurostars project entitled CHLOFFIN and later the REVAMP and the GreenREF projects. In the REVAMP EU Framework H2020-MSCA-ITN-2020 Programme, one of the goals is to develop reference standards with defined composition and response factors, which can be used to mimic the industrial mixtures and to be used for the certification of individual LCCPs in environmental and food samples and used in degradation and toxicity studies. Another goal is to develop ^{13}C-labelled LCCPs as internal standards. These new generation standards are useful in the quantification of CPs as well as helping in distinguishing the various congener groups according to carbon chain length and chlorine content. The synthesis of individual SCCPs and MCCPS has been achieved by chlorination of alkenes with multiple double bonds. Synthesis routes for LCCPs have then been designed by using commercially available unsaturated fatty acids, esters and alcohols as building blocks, considering the carbon chain length of fatty acids which can be as long as LCCPs.

Materials and Methods: Unsaturated fatty acid or fatty esters or fatty alcohols with carbon number of C_{18}-C_{22} were chosen as building blocks for the synthesis of LCCPs. The chemical synthesis includes following steps:
1) chlorination of double bonds with chlorine gas or other selected chlorination reagents
2) subsequently convert the acid, ester or hydroxy group to hydrocarbyl (methyl group mostly).

Decarboxylation of fatty acids, dehydration of fatty acids can also be done first to give an extra double bond and chlorination of all double bonds after. The synthesis routes were designed for the individual LCCPs with defined chlorines position and number. The optimized synthesis methods were applied for the synthesis of ^{13}C-labelled LCCPs. All the compounds synthesized have been purified to remove impurities and CP isomers due to under or over chlorination. The chemical purity is analysed by one or several of the following GC-methods: GC-FID/MS, GC-, high resolution GC-MS and HPLC. NMR techniques are used for structure characterization.

Results: We have produced different individual LCCPs with chain length of C18-C26 and ^{13}C-labelled LCCPs (examples shown in Table 1), CRMs are produced by a combination of purity determination by GC-FID, identity by NMR and excess water, solvent and ash by TGA in addition to stability and homogeneity assessment.

Table 1. examples of synthesized LCCPs and 13C3-labelled LCCPs (* = 13C)

Conclusions: Both individual LCCPs, and ^{13}C-labelled individual CPs are synthesized by using unsaturated fatty acids as stating materials. These compounds can be used as reference materials and internal standards for the analysis of LCCPs, and the synthesized standards will give more accurate measurements and are more suitable reference materials compared to the technical mixtures which are used as reference materials today.

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