ii) inventory analysis, iii) impacts assessment and iv) interpretation of the results (ISO, 2006).

The goal of this LCA was to estimate the potential environmental impacts associated with producing 1 L of drinking water for each municipal water supply area in Barcelona and for bottled water (mineral water in PET bottles). For the case of tap water, the treatment processes of each drinking water treatment plant are described in Section 2.2. Environmental impacts associated with the production of drinking water in each drinking water treatment plant were calculated and then combined considering the water flow supplied by each plant in each area. The additional environmental impacts of domestic filtration using a carbon filter were not included, since they are likely to be small (<1% of the overall impact) (Garfí et al., 2016; ILCD, 2010; SO, 2009). For the case of bottled mineral water, the production includes: i) pumping from aquifers; ii) washing the PET bottles using detergents (i.e. potassium hydroxide, hydrochloric acid) and disinfectants (i.e. foaming agent, potassium hydroxide); and iii) filling the bottles with drinking water.

Environmental impacts referred to the production of 1 L of water (the functional unit). System boundaries accounted for input and output flows of material (mainly chemicals and materials for packaging) and energy resources (electricity). The phases of construction, maintenance and decommissioning of the facilities were not included, since they account for minor environmental impacts (<1% of the overall impact) (Foley et al., 2010; ILCD, 2010; Lorenzo-Toja et al., 2016).

We report inventory data in Table A1 per 1 L of drinking water for each drinking water treatment plant and bottled water. Inventory data were provided by the local authorities and companies involved in the production and distribution of both tap water and bottled mineral water. Data consist of the annual average (2019) levels of required materials and energy, and waste generated through the production of both tap water and bottled mineral water. All environmental data regarding inputs and emissions of each material and waste analysed were obtained from *Ecoinvent 3.5* databases (Weidema et al., 2013). Environmental impacts were evaluated using the software SimaPro® (PRé Consultants, 2019) and the Recipe2016 endpoint (H) method (Huijbregts et al., 2016). The goal of the ReCiPe method is to transform the long list of life cycle inventory data into a limited number of indicator scores. These indicator scores express the relative severity on an environmental impact category. Indicators in ReCiPe are organised at two levels: 17 mid-point and 3 end-point impact categories. The former focus on the environmental impacts, while the latter take into account the damage on the 3 areas of protection (human health, ecosystem quality and resource scarcity). In this study, the primary end-point impact categories were considered:

1) damage to ecosystems, expressed in species per year, which refers to the number of species lost integrated over time;
2) damage to resource availability, expressed in dollars, which refers to the cost of raw materials extraction.

We also considered the following end-point category:

3) damage to human health, from environmental factors linked to drinking water production (e.g. particulate matter emissions), expressed as DALYs in the global population.

These indicators quantify the global damage to ecosystems, contribution to resource scarcity, and human health impacts caused by the production of 1 L of water. They are obtained by combining the mid-point impact categories using standard characterisation factors (Huijbregts et al., 2016). For instance, damage to human health is obtained by considering the diseases caused by particulate matter emissions, ionizing radiation, ozone depletion and toxicity due to materials and energy used, as well as waste and emissions generated through the whole life cycle of the product, process or activity considered.

In order to integrate the LCA with the HIA results, we estimated the annual environmental impacts of meeting drinking water needs under S1–S4 by combining estimates of impact per L of water with population data in each water supply area, assuming each individual consumes 2 L/d of drinking water. Health impacts of ingestion were estimated for the Barcelona population as explained in the HIA section, while the environmental and health impacts of production derived from LCA were estimated at a global scale (Huijbregts et al., 2016). Integrating both tools can provide a more comprehensive view of the health and environmental impacts associated with the consumption and production of drinking water.

Fig. 2 presents the conceptual model showing how we integrated data on water supply area, population exposure to THMs, and water treatment technologies in a combined health impact and life cycle assessment to estimate the health burden of consumption and environmental impacts of production of meeting drinking water needs of the Barcelona population.

3. Results

Drinking water source share in S1 varied across water supply areas, with 71% of participants in the BHS residing in the Llobregat water supply area drinking bottled water compared to approximately 58% of the population in Barcelona as a whole (Table 1). Total THM exposure levels were lowest in the Llobregat water supply area, with a median concentration in 2016 of 31.1 μg/L in Llobregat water supply area and 40.1 μg/L in Ter water supply area (Table 2). Total THM exposure was highest in the scenario where all drinking water was supplied by tap without domestic filtration (S2) and lowest in the scenario with all drinking bottled water (S3) (Table 3).

The environmental and global health impacts associated with drinking water in each water supply area are shown in Tables 4 and A2. Bottled water production showed the highest environmental impacts, from 500 to 50,000 times higher than tap water depending on the water supply area and impact categories. Considering only tap water, the production of drinking water in the Llobregat area showed the highest environmental impacts: impacts in Llobregat area were 2 times higher than in Llobregat + Ter area, and 30 times higher than the Ter water supply area. As expected, the environmental impacts were highest for the scenario in which all drinking water was bottled (S3) (Table 4). We estimated 1.43 species per year would be lost due to the production of bottled water to meet the drinking water needs of the Barcelona population, whereas the damage to ecosystems would be negligible if all drinking water was from the tap. We estimated considerable costs of raw materials extraction for the current drinking water source share in Barcelona (S1). The cost of raw material extraction would be nearly eliminated through a complete shift to tap water (around $24,000 per year, which means that each resident would be responsible for $0.02 per year), but it would increase by $83.9 million through a complete shift to bottled water (which means that each resident would be responsible for around $60 per year). The production of bottled water to meet the drinking water needs of Barcelona population was estimated to result in 625 DALYs per year in the global population (Table A2). This burden would be reduced to 0.5 DALYs if only tap water, or filtered tap water were consumed.

Our results indicate that under the current drinking water source share, 3% of new (incident) bladder cancer cases annually are attributable to THM exposure from drinking water, resulting in 94 years of life lost in the Barcelona population (Table 6). A complete shift to tap water without domestic filtration would increase the number of life years lost to 309 (on average approximately 2 h of lost life expectancy if borne equally by all residents of Barcelona). Adding domestic filtration would reduce the number of life years lost to 36. A complete shift to drinking bottled water would essentially remove the health burden to THM exposure through drinking water. Most of the attributable health burden due to THM exposure from drinking water was from years of life lost rather than lived in disability.