A Life Cycle Assessment (LCA) of Antibacterial Gel Production

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Abstract. During the COVID-19 pandemic the antibacterial gel become an important prevention measures to stop the spread of the virus. In Mexico, the demand for preventive hygiene products and health supplies increased more than 50% at the beginning of the pandemic. With the concern of knowing the negative impacts that the high demands of this product can cause to the environment, we took on the task of looking for life cycle assessment (LCA) studies related to the production of antibacterial gel, it was unexpected not to find any scientific information reported about the subject. This paper takes as one of its main motivation the lack of information to accomplish an LCA which is used to evaluate the negative environmental impacts associated with the products or services. The aim of this paper is elaborate an LCA study of the antibacterial gel, a substance widely used during the COVID-19 pandemic, to assess the environmental impacts from its production. We focus on a case study involving the antibacterial gel from a company in Mexico. We completed the inventory analysis in collaboration with the company and compiled the impact assessments using the GaBi software and the ReCiPe method. The results shows that the principal impact categories of the antibacterial gel production are the Climate Change, Ozone Depletion, Fossil Depletion and Human Toxicity.

Keywords: Life cycle assessment · LCA · Antibacterial gel · COVID-19

1 Introduction

The Life Cycle Assessment (LCA) is a powerful tool to provide information to researchers in terms to "translate the sustainability into useful knowledge to support commercial and regulatory decision making" [1]. The begin of LCA concept start during the SETAC congress in 1990. LCA was defined as "An objective procedure for assessing the energy and environmental loads related to a process or an activity, carried out through the identification of energy and the materials used and the waste released into the environment" [2]. From this perspective, LCA was established as a methodology to evaluate the potential negative environmental impacts and the resources used all over a product life cycle (raw material extraction, design, and production process, use phases,

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and waste management); is a deep assessment which considers the natural ecosistems, human health, and resources [3].

The process was set up by the International Standards ISO 14040 and in specific ISO 14044. ISO 14040 and 14044 provided key principles, frameworks, and it's mandatory to develop an LCA study. The main phases which define all the steps for LCA studies are: Goal and Scope Definition, Life Cycle Inventory Analysis (LCI), Life Cycle Impact Assessment (LCIA), and Interpretation [4]. In the first phase, the main cause to perform the study, the functional unit and the limitations are included [4]. The LCI phase collect the inputs (resources) and the outputs (emissions) through the product life cycle in relation with the chosen functional unit [4]. For the LCIA phase the data from the inventory is evaluated to understand the importance of the potential environmental impacts of the studied product [4]. And to finish the LCA, in the Interpretation phase the previous values from the LCIA have a correlation with the goal and scope to reach recommendations [4].

LCA studies help to recognize the way in which products influence the environment and society, making them a real tool for companies. That is the main reason of these kinds of studies have been carried out on products of widely use such as shampoo, soaps, sunscreen, and detergents. Sanchez et al. (2018) carried out a study for the company Natura in Brazil where they make soap their product of analysis, only considering the materials for soap, packaging, and distribution [5]. Lucchetti et al. (2019) elaborated the study for the company Tea Natura in Italy analyzing the production process of a detergent, to contrast the environmental impacts with similar products [6]. Golsteijn et al. (2018) assesses the feasibility and relevance of improve Product Environmental Footprint Category Rules (PEFCR) for shampoos obviously using an LCA in European countries [7]. Thakur (2014) made a comparative study of the life cycle of sunscreen with chemical and organic products for a company in the United States [8]. The previously studies are some good examples of the great opportunity that exists within the industry and over time they will be more used to implement preventive measures and help the environment.

1.1 Alcohol-Based Hand Sanitizer

The studies of Semmelweis and Wendell established that the diseases get into the hospital were transmitted via the hands [9]. Semmelweis is considered the father of hand hygiene, and the first provider of evidence that cleansing heavily contaminated hands with an antiseptic agent can reduce the transmission of virus and germs more efficaciously than handwashing with soap and water. This statement includes the essential elements for an infection control [9].

The 80s defined a landmark in the concepts of hand hygiene in health care. The first national hand hygiene guideline was published in the starts of this years, followed by different countries over the years [10]. In 1995 the Health Infection Control Practices Advisory Committee (HICPAC) and the Center for Disease Control and Prevention (CDC) in USA, recommended the used of a waterless antiseptic agent before and after leaving the rooms of the patients [11]. In 2002, the HICPAC guidelines defined alcohol-based hand rubbing as a basic practice for hand hygiene in healthcare settings and establish that handwashing is reserved for particular situations [12].

The hand hygiene products (liquid, gel, or foam) are alcohol based. The alcohol preparation is designed for hand application to inactivate microorganisms and suppress their growth. The preparations must contain alcohol, active ingredients with excipients, and humectants [13].

The alcohol-based gel hand sanitizer varies in the amount of alcohol in its composition between 60% and 85%, the most common amount being 70% [14]. Alcohol kills between 99.99% and 99.999% of bacteria, although it does not act against spores of anaerobic bacteria, hence hydrogen peroxide is added to the gel, which it does. It is also an effective viricide and fungicide. It is characterized by the rapidity of the onset of its action (about 15 s) [14].

More recently in 2010, the Wealth Health Organization (WHO) published a Guidelines on Hand Hygiene in Health Care, this one has two sections to making alcohol-based gel hand sanitizer, a practical guide for the preparation of the formulation and the technical information. Now the people have access to important safety information, and they know the material relating to distribution [15].

Using an antibacterial hand gel has many benefits when soap and water are not available. In addition to being a simple, cheap, effective measure and within the reach of most of the population, it not only reduces the risk of infection, but also decrease the transmission of germs to other people. Nowadays, disinfection with alcohol-based products is the most quickly and effectively way to deactivating a variety of potentially harmful germs and virus in hands [15]. WHO recommends antibacterial hand gel planted the next factors [15]:

- Its microbicidal, fast and broad-spectrum activity.
- It is appropriate in remote or resource-limited locations that do not have sinks or other hand hygiene facilities (clean water, towels, etc.).
- Encourages more frequent hand hygiene, as it is faster and immediately accessible.
- Minimizes the risk of adverse effects, as it is safer, more acceptable, and better tolerated than other products.
- It reports economic benefits, since it reduces the annual cost of hand hygiene, which represents approximately 1% of the additional cost generated by infections associated with health care.

On the market there are different products that serve to eliminate bacteria and virus, for example wipes, sprays, soaps, and gels that use alcohol as an active ingredient to break the cell membrane of the microorganism or damage its structure, which tends to produce his death [16]. When purchasing antibacterial or disinfectant products, it is important to know the difference between them, the disinfectant are chemical agents used mainly on objects, in order to destroy or inhibit the growth of microbes. The antibacterial products also prevent the proliferation and development of bacteria and microorganisms harmful to health, but the term is more used in specific products for personal use [16].

The disinfectant sprays are applied with the containers in an upright position; it is sprayed on clean surfaces for 3–4 s from 15–20 cm distance. Let it rest until the surface dries. Although they are in aerosol, it is important to note that they should be used on surfaces and areas of constant contact [16]. Different from sprays or gels, disinfectant wipes are made of absorbent cellulose-based materials that are impregnated with one or more active agents. Although towels and sprays are effective, they are not recommended for the use on living tissues (such as skin), it is better to use them on surfaces such as floors, furniture, or objects because they are disinfectant products [16]. The soap should normally be applied and rubbed for a period of approximately 15 to 20 s, when washing hands, which requires the use of water to be able to use it, instead the antibacterial gel can be used immediately by putting a portion and rubbing both hands to distribute the product on the hand [16].

The antibacterial gel is the best option among the products mentioned when the hand washing is difficult, and for these advantages the demand grows little by little occupying a moderate space on pharmacy shelves. In 2020 received renewed interest due to its shortage during the COVID-19 (SARS-CoV-2) pandemic, for be one of the measures to avoid the transmission of harmful germs and virus and avoid infections [17].

1.2 COVID-19 Pandemic

COVID-19 is the disease caused by the new coronavirus known as SARS-CoV-2. The WHO know the existence of this new virus on December 31, 2019, when it was informed of a group of cases of "viral pneumonia" that had been declared in Wuhan (People's Republic of China) [18]. After it spread to all the continents of the world, it was characterized as a pandemic on March 11, 2020.

As of May 4, 2021, 153,187,889 confirmed cases (644,685 new cases) and 3,209,109 deaths (10,501 new deaths) have been reported worldwide. The overall fatality rate is 2.1% [19]. Currently America and Europe are the most affected, the first with 62,589,322 cases and the second with 52,099,114 cases [19]. This disease was registered for the first time in Mexican territory on January 14, 2020. As of May 4, 2021, 2, 352,964 total cases and 217,740 total deaths from COVID-19 have been confirmed [19].

According to the Pan American Health Organization (PAHO), informing the population about the health risks that COVID-19 may pose, as well as the measures that can be taken to protect themselves, is a key to reducing the chances that people become infected and thus mitigate further spread [20]. With the first deaths from COVID-19, the WHO disseminated health safety protocols with new hygiene and care practices that people adopted to prevent the spread of COVID-19 [20]:

- Wash your hands with soap and water.
- Use alcohol-based antibacterial gel.
- Maintain a safe distance from people.
- Use mask and face shield.
- Do not touch your face (specifically eyes, nose, and mouth).
- When you sneeze or cough, cover your mouth with a tissue or bent elbow.

This pandemic has caused an increase of more than 50% in the demand for preventive hygiene and health supplies, such as face masks, alcohol, wipes, and antibacterial gel at the beginning of the pandemic in Mexico [21]. Despite the difficulties of the health contingency, Mexico managed to position itself as an exporting country of medical products, during the first half of 2020. The exports that Mexico made to the US in 2020 are of an estimated sales value of 6 thousand 259 millions of dollars, which represented an increase of 8.4% compared to last year 2019 [22]. This represents 3.3% of exports of critical products against COVID-19 worldwide. Which establishes the country as the fifth country with the most exports of this type in the world [22].

In the list of countries that also participate in the export of products are China (54 thousand 643 million dollars), the United States (23 thousand 182 dollars), Germany (16 thousand 961 dollars) and the Netherlands (10 thousand 771 dollars). And after Mexico came Japan (5.8 billion dollars), followed by Belgium (5 thousand 596 dollars), France (5 thousand 276 dollars), Malaysia (4 thousand 440 dollars) and Ireland (4 thousand 204 of dollars) [22]. Exports from these countries represent 72.5% of global exports of medical products to face the coronavirus. Which makes them head the importance of them before the world. With the above, one has an idea of the great production that is taking place globally, and that the production, transportation, purchase, and waste will bring problems in the future if they are not conducted in the correct way [22].

1.3 Research Objective and Hypothesis

Currently, more consumers are concerned about the negative impacts that products may have, and with the help of media they have the information at their fingertips, thereby increasing a demand for products which are not harmful. The companies feel economic pressure, because people stop buying their product, and social pressure, for the change and the message they give to society.

The antibacterial gel became a product of massive use during the COVID-19 pandemic, as mentioned, according to the WHO is a crucial measure to avoid the transmission of harmful virus and avoid infections is the antibacterial gel, because is effective for destroying viruses in the hands, due to its wide capacity as a virucidal and bactericidal.

The potential environmental impacts related with its production and distribution are amplified. Later in the related work chapter it will be shown that there was no scientific information reported on the impacts that the production of the antibacterial gel generates.

The aim of this paper is elaborate an LCA study of the antibacterial gel, a substance widely used during the COVID-19 pandemic, to assess the environmental impacts from its production. It starts from the hypothesis that studying the environmental performance of antibacterial gel will allow an approximation of the environmental impact generated by its production. The limitations of the research are in accordance with the limitations of the life cycle study that will be considered in the phase one of the LCA and will be shown in the methodology chapter.

2 Related Work

The review of articles related to the LCA of the antibacterial gel production did not give the expected results, there was no scientific information reported related to this subject;

it was considered that an exhaustive review of LCA of alcohol production in general broadened the research. The production of ethyl and ethanol from another process is the most common in the papers reviewed and for research purposes they serve to know the methods and especially the environmental impacts they cause. Figure 1 shows the main articles that were considered as the state of art for this paper, this is a practical way to identify the important parts for each study, when its necessary we do not have to return to the full text and is easier to understand the LCA methodology.

Author, year	Subject and geographical context	LCA remarks and energy	Main results
Caffrey, K.R., Veal, M.W., Chinn, M.S. (2014)	Ethanol production from sweet sorghum juice in the United States.	Comparison of scenarios for a quantitative assessment of environmental issues, using the raw material for cellulosic fuel and animal feed as energy input.	A major source of cost, energy use, and environmental impacts is associated with transportation. The biomass material proposed for use in bioenergy production generally is high in moisture content and low in bulk density, reducing load capacity on a weight basis. This study showed that transportation was a major contributor to the climate change metrics, eutrophication, and solid waste landfill.
Caldeira-Pires, A., Benoist, A., Da Luz, S.M., Chaves,V., Silveira, C. M., Machado, F. (2018)	Ethanol production with sugar cane biomass in the Petrobras agro-industrial unit, in Brasilia, Brazil.	Evaluate the environmental impacts of the removal of sugarcane straw from the soil throughout the life cycle of bioethanol production, with raw material for cellulosic fuel and fossil fuel and the electrical network as energy input.	Two scenarios were studied considering the effect of the straw on the amount of sugar in the sugarcane juice and considering the use of a second-generation ethanol unit based on the hydrolysis of both bagasse and straw. In the study the main impact category was the global warming, that comes from the global climate change metrics.
Bessou, C., Lehuger, S., Gabrielle, B., Mary, B. (2013).	Ethanol production with sugar beet biomass in the Picardy region, France.	Compare ethanol from sugar beet with its fossil-based equivalent, gasoline, to examine the benefits of substituting the latter for bioethanol, albeit strictly within an attributional framework.	The sugar beet ethanol had lower impacts than gasoline for the global warming, ozone layer depletion and photochemical oxidation categories. Conversely, sugar beet ethanol had higher impacts than gasoline for acidification and eutrophication due to losses of reactive nitrogen in the arable field.
Canter, C. E., Dunn, J.B., Han, J., Wang, Z., Wang, M. (2016).	Integrated production of corn ethanol and corn stubble in the United States.	Evaluate the integrated production of ethanol from corn grains and corn stubble, using fossil fuel and the electrical network as energy input.	This analysis examines different LCA scenarios that could influence the volume of high-GHG reduction fuels that integrated corn grain-corn stover ethanol facilities produce. The main impact category in the study was global warming.
Alves, R., Guimarães, R. (2017).	Ethyl biodiesel production from soybean oil and beef tallow in a region of Brazil.	Identify the environmental impacts caused during the biodiesel production process from two different raw materials: soybean oil and bovine tallow, using fossil fuel and the electrical network as energy input.	The results show that the ethyl biodiesel production from the two different scenarios presents major environmental damage in the categories of global warming pollution, solid waste landfill, destruction of abiotic resources, destruction of the ozone layer, human toxicity, freshwater ecotoxicity, terrestrial ecotoxicity, acidification and eutrophication.

Fig. 1. Remarkable information of the papers related to the subject.

Caffrey et al. (2014) describe the ethanol production from soluble sugars recovered from sweet sorghum, implementing a comparative analysis with different process configurations. In the comparison of environmental impacts, all scenarios presented higher levels of Climate Change, Ozone Depletion and Eutrophication values for the high amount of diesel required for operations [23].

Caldeira-Pires et al. (2018) use straw together with bagasse for the production of bioethanol in two different scenarios. The evaluation is focused on the Global Warming Potential (GWP) as the main environmental impact, characterizing biotic and fossil carbon fluxes, they evaluate other impact categories such as Eutrophication and Abiotic Depletion for elements and fossil fuels [24].

Bessou et al. (2012) realize a case study involving the ethanol production from sugar beet using six different combinations of climate types and crop rotations to estimate yields and environmental emissions. Sugar beet ethanol had a lesser impact than gasoline in the Abiotic Depletion, Global Warming, Ozone Depletion, and Photochemical Oxidation categories. However, it had greater Acidification and Eutrophication impacts than gasoline. Therefore, the LCA values were sensitive to changes in management factors [25].

Canter et al. (2015) tested the difference between corn grain and stubble ethanol production considering different approaches for combined heat and power treatment. They focused on the greenhouse gas emissions (GHG) from grain ethanol. They conclude that although they have that environmental impact, there is a reduction compared to the GHG emissions from the gasoline [26].

Alves et al. (2017) compared the production of biodiesel extracted from soybean oil and bovine tallow, through the ethyl transesterification process. The data used were calculated based on similar scientific articles and nine categories of environmental impacts were analyzed for both processes, highlighting that the final evaluation shows a big damage in the categories of Destruction of Abiotic Resources, Ozone Depletion, Human Toxicity, Freshwater Ecotoxicity, Terrestrial Ecotoxicity, Acidification and Eutrophication). The biodiesel production from tallow presents a major damage in two impact categories (Land Use and Global Warming) [27].

With the previous investigation of the LCA papers related to ethanol and ethyl production, and with those mentioned within this work, the conclusion is reached that even though the studies are carried out in different places and dates, the impact categories that are the most frequently presented are Climate Change, Global Warming, Ozone Depletion, Eutrophication, and Abiotic Depletion. Based on the research, we can affirm that there is no LCA specifically focused on the antibacterial gel production.

3 Methodology

This is an LCA study of the chain production of the antibacterial gel of a Company in Mexico with national and international presence, this study follows the ISO 14044 standard. The transportation of raw material, production of the substance, pack and distribution are considered.

3.1 First Phase: Goal and Scope Definition

The goal of this study is to identify the environmental impacts caused during the production process of antibacterial gel. It starts with the transportation of raw materials from the vendor warehouse to the factory, continues with the manufacturing process of the product. After production, the antibacterial gel is packed and stored inside the factory. When the product is sold, is taken to the distribution center, when the product arrives there the study is concluded. It is considered from the perspective of the chain production of the Mexican company that we do not include the resources and emissions associated with the raw materials extraction, use, and final disposal of the product, to focus just on the environmental impacts of the antibacterial gel production is decided to skip the impact of these stages. The scope is shown in Fig. 2 that includes the process of the raw materials in the factory.

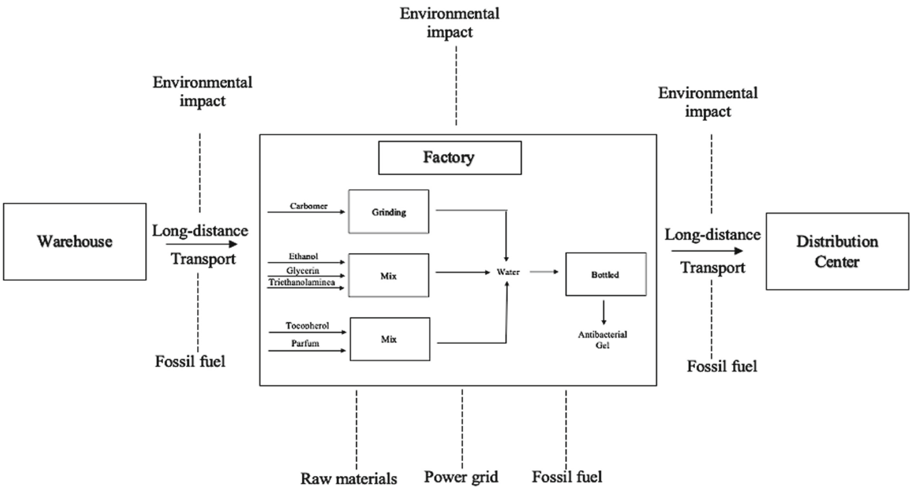


Fig. 2. Flow diagram of the LCA process model.

The reference flow is 450, 000 bottles in one day of production and the chosen functional unit is 1 bottle of 120 ml of antibacterial gel manufactured and packaged in Mexico. The company has 3 different bottle sizes for the antibacterial gel: 60 ml, 120 ml, and 450 ml. For this specific study, the 120 ml presentation was used because it is the one with the highest sales in the market.

The LCA software GaBi was used for modeling the environmental performance of the production, based on the primary data from the Mexican company along with supplementary background data from the GaBi database. GaBi is a software that models from a life cycle perspective the elements of a system to take the best decisions during the life cycle of any product [28]. GaBi combines the LCA modelling software, databases, and reporting tools [28].

The value that came from this software estimates the environmental impact categories as stated in the ReCiPe 2016 method, it was developed through a cooperation between the Dutch National Institute for Public Health and the Environment (RIVM), Radboud University Nijmegen, Norwegian University of Science and Technology, and PRé Sustainability [29]. This method is an improvement of CML 2000 and Eco-indicator 99, the principal object is transforming the life cycle inventory into indicator scores, these express the environmental impact in the corresponding impact categories [29].

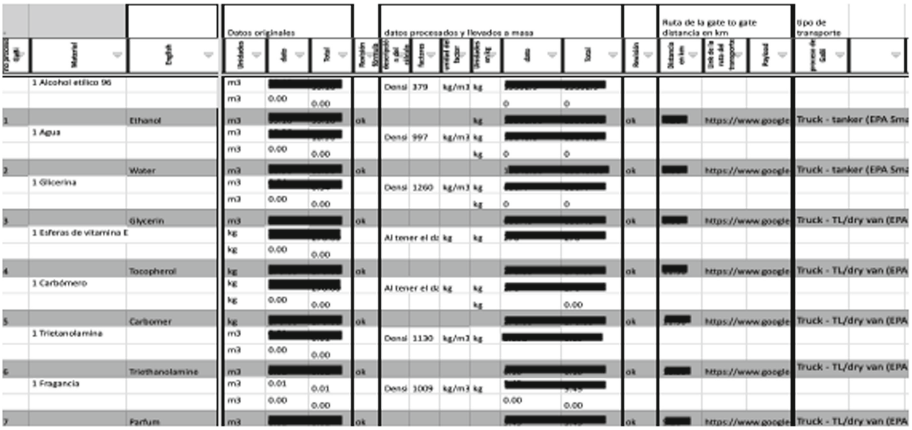
3.2 Second Phase: Life Cycle Inventory Analysis (LCI)

The data given for the process managers in the factory for the inventory are identified and quantified. Antibacterial gel process data, as well as antibacterial-related information, should be meticulously collected to develop the best inventory. Is very important to have a good relationship with the concerned parties for the best data collection.

It starts defining the process stages and given them a name into the LCI, then the materials that are used in the production of the antibacterial gel, the information of each raw materials used in the process (data sheet, amount and units), the manufacturer's process, the energy consumption for each process (energy consumption pear year, origin of energy consumed and units) and the water consumption (water consumption pear year, origin of water consumed and units) must be given by the company. It must be considered if water is from storm water, treated or from the local water distribution system; the same with the energy if is from local electricity grid, solar panels, biomass, diesel. The logistic that was followed to collect the data is shows in Fig. 3, without the amount of materials for a company request. Everything collected will be used later to model the information with GaBi software to obtain life cycle impact category results.

The bottle where the substance is deposited is also part of the inventory, and the transport used to move the raw material from the vendor warehouse to the factory as well as the distances traveled, are also a vital part of the study.

When the antibacterial gel is packed and stored the final product is shipped to the distribution center.



			Datos originales				datos procesados y llevados a masa							Ruta de la gate to gate distancia en km			tipo de transporte	
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	1 Alcohol etílico 96		m3	[redacted]			Densi	379	kg/m3	kg	[redacted]							
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1		Ethanol	m3	[redacted]		ok				kg	[redacted]		ok	[redacted]	https://www.google		Truck - tanker (EPA Sma	
	1 Agua		m3	[redacted]			Densi	997	kg/m3	kg	[redacted]							
			m3	0.00	0.00					kg	0	0						
2		Water	m3	[redacted]		ok					[redacted]		ok	[redacted]	https://www.google		Truck - tanker (EPA Sma	
	1 Glicerina		m3	[redacted]			Densi	1260	kg/m3	kg	[redacted]							
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Fig. 3. The logistic of LCI used for the LCA of the antibacterial gel production.

The Fig. 4 shows the model of the process created in GaBi, the result of this will be the indicator scores express the impact categories of ReCiPe: Climate Change, Default, Excl Biogenic Carbon [kg CO2 eq.]; Climate Change, Incl Biogenic Carbon [kg CO2 eq.]; Fine Particulate Matter Formation [kg PM2.5 eq.]; Fossil Depletion [kg oil eq.]; FreshWater Consumption [m3]; Freshwater Ecotoxicity [kg 1,4 DB eq.]; Freshwater Eutrophication [kg P eq.]; Human Toxicity, Cancer [kg 1,4-DB eq.]; Human Toxicity, Non-cancer [kg 1,4-DB eq.]; Ionizing Radiation [Bq C-60 eq. to air]; Land use [Annual crop eq.·y]; Marine ecotoxicity [kg 1,4-DB eq.]; Marine Eutrophication [kg N eq.]; Metal Depletion [kg Cu eq.]; Photochemical Ozone Formation, Ecosystems [kg NOx eq.]; Photochemical Ozone Formation, Human Health [kg NOx eq.]; Stratospheric Ozone Depletion [kg CFC-11 eq.]; Terrestrial Acidification [kg SO2 eq.]; Terrestrial Ecotoxicity [kg 1,4-DB eq.] [29].

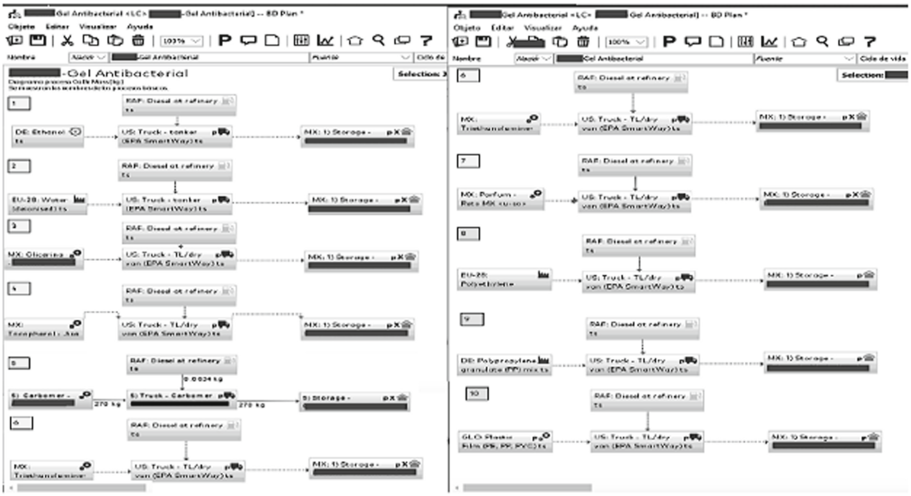

Fig. 4. Model of the antibacterial gel production in GaBi.

3.3 Third Phase: Life Cycle Impact Assessment (LCIA)

After modeling the LCI, the software rates the impacts of the second Phase in the LCA impacts categories. The data have the best approximation to the environmental impact (See Fig. 5) and the results highlight the stages that contribute the most.

Fig. 5. Impact categories by ReCiPe in GaBi.

3.4 Fourth Phase: Interpretation

In this last phase, the impacts of the process were broken down and the interpretations obtained were verified by a critical review with the work team, this information will be developed in Sect. 4. Different improvements were proposed for the company, with the aim to reduce the environmental impacts caused by the production of its antibacterial gel. In the meeting with the process managers, they showed acceptance from the proposed changes.

4 Results and Discussion

In Fig. 6, the results of the environmental impacts in the LCA are represented in the graph.

The following table gives a better visualization of the impact categories that are consider relevant for this study, as it's prerogative in the ISO standard (Table 1).

Owing to an impact category bundle different emission into a single effect on the environment, with the program only one result can be obtained for each category, even

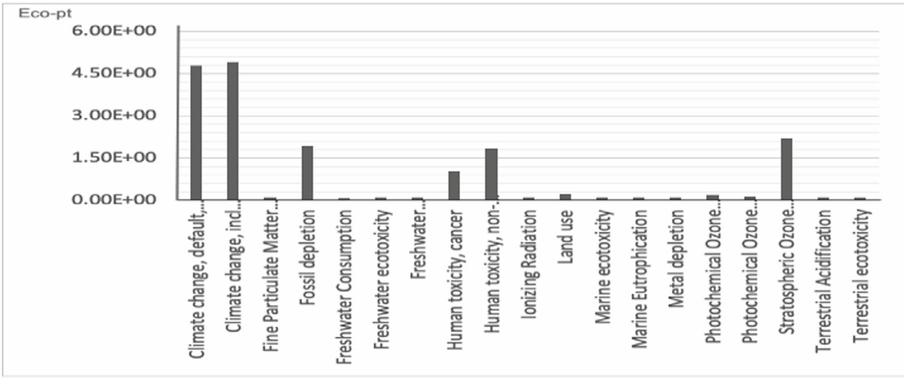

Fig. 6. Impact categories with original units.

Table 1. Impact categories.

No	Impact category		Value
1	Climate change, incl biogenic carbon	[kg CO2 eq.]	4.9E+00
2	Fine Particulate Matter Formation	[kg PM2.5 eq.]	4.26E−3
3	Fossil depletion	[kg oil eq.]	1.94E+00
4	Freshwater ecotoxicity	[kg 1,4 DB eq.]	1.69E−4
5	Freshwater Eutrophication	[kg P eq.]	1.42E−2
6	Human toxicity, cancer	[kg 1,4-DB eq.]	1.0425E +00
7	Human toxicity, non-cancer	[kg 1,4-DB eq.]	1.83E+00
8	Land use	[Annual crop eq.y]	1.7E−01
9	Marine ecotoxicity	[kg 1,4-DB eq.]	3.95E−4
10	Marine Eutrophication	[kg N eq.]	3.86E−3
11	Photochemical Ozone Formation, Ecosystems	[kg NOx eq.]	1.30E−01
12	Photochemical Ozone Formation, Human Health	[kg NOx eq.]	1.15E−01
13	Stratospheric Ozone Depletion	[kg CFC-11 eq.]	2.2E +00
14	Terrestrial Acidification	[kg SO2 eq.]	8.52E−3
15	Terrestrial ecotoxicity	[kg 1,4-DB eq.]	1.11E−3

if you have many processes. After the results, it was observed that climate change is one of the categories with the highest values in the process. This is mainly due to the data on the amount of energy consumed directly by the trucks and the machines in the chain production.

The carbon dioxide emissions emitted are caused for the transportation of the raw material from the warehouses to the factory and the final product (antibacterial gel) from the factory to the distribution centers. A fact that is worth highlighting is that although the machines are part of this negative impact, they are not the main cause of contamination, the trucks and routes of transport are the stages that polluted the most. These periodic operations and the consumption of fossil fuels are the cause of these high values.

Climate change affects the increase in radiative forcing, changing the balance of radiation and temperature control on the earth's surface, this is directly related to the depletion of the ozone layer, which would be another category that has elevated values in the study. When we have this kind of impact, it has an immediate negative effect on human health and the environment, because the emissions that are thrown into the atmosphere promote the formation of photochemical oxidants, which are gases with a powerful oxidizing effect that cause diseases and damages the ecosystem.

With the sum of the average of Climate Change, Default, Excl Biogenic Carbon and the Climate Change, Incl Biogenic Carbon, is obtained the Global Warming impact, which comes out as the main impact in the papers that were reviewed to get an idea of how the results could give to us.

As already mention, a considerable cost source and environmental impacts is associated with transportation. The category of Fossil depletion is a clear example of this, since its high values are expected due to the use of fossil fuels in freight transport, added to the fact that the distances traveled between the factory and the distribution centers can be considered relatively high in some regions. These routes contribute to the increase of particles harmful to the environment, is recommended that the routes and time in the distribution centers be optimized to improve its performance.

Although the other categories are smaller compared to the others within the same production process, they are not disposable, because even if their impact is less, it does not mean that they do not cause any damage to the environment. Each point must be considered to improve the process and lower the levels of contamination generated by the product.

The impacts of freshwater, and terrestrial ecotoxicity cause the loss of ecosystems, changing the area, bringing sudden changes in temperature, floods or, on the contrary, droughts in the area. Another impact category that has a negative contribution on the environment is eutrophication, the increase of phosphorus in the water will lead a depletion of water; even though the data does not reflect a considerable demand of water during the process and the impact category is not as representative in comparison to those already mentioned, water continues to be a vital liquid for life and must be treated with relevance.

Some actions to improve the antibacterial gel production process are the change of old truck transports and the optimization of transport routes. The implementation of new technological components that will eliminate waste and make the process more efficient are consider. In the same way, some work times were corrected in the stages within the process to improve the delivery time of the final product.

5 Conclusion

The COVID-19 pandemic caused the radical increase sales of antibacterial gel, as it became one of the measures to prevent the spread of the virus, people use it daily and several times a day. With the large amount of demand for this product, it is important to know the repercussions that its manufacture can bring to the environment. When conducting a search on this topic to inform us about the negative impacts that its production has, we realized that there were no reported results. The lack of scientific information became one of the main motivations for conducting the study.

The LCA elaborated for this work evaluated the environmental impacts of the production of antibacterial gel of a Mexican company, by documenting the experience we had with them, it is hoped that the information may be of use to other people.

The limitations for this study were that only the stages of raw material transportation, product production and transportation the final product to the distribution center were considered, to focus only on the production chain. The LCI phase was complicated, because the data collection was slow due to the confinement of the pandemic, in the same way knowing the complete production process will always be better with a visit to the factory to verify everything in depth, not only in a virtual tour like was our case.

As already mentioned, the study did not consider the part of the extraction of materials and neither was it extended to use, nor to disposal, but the importance is not ruled out. For future works it is expected to expand the work to these stages, to have the best approximation of the environmental impact of the complete life cycle of an antibacterial gel. This would be of vital importance, because the alcohol that evaporates and goes into the atmosphere must be considered, in addition to the part that goes into the water after washing hands or even knowing where the waste ends up.

We believe that conducting this kind of study is important nowadays, society's thinking is changing, more and more people are taking responsibility for their consumption, wondering which product does not pollute the environment. Finally, it is not too much to say that LCA studies have a future not only in products of widely use but also in all those that seek to improve their environmental performance.

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