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Challenges of the green supply chain management in the pharmaceutical industry

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Green supply chain management has gained significant interest in recent years; however, we still have limited understanding of specific characteristics of different industries. The aim of this paper is to characterize the pharmaceutical supply chains from an environmental perspective. Our methodology provides a novel contribution to the literature describing green supply chain management, since no detailed analysis of the environmental aspects of the pharmaceutical industry has been carried out this way. Our results can inform pharmaceutical businesses and policymakers about the limiting factors of green supply chain management in the pharmaceutical sector and provide insights to overcome hindrances and to design new tools. By looking at the supply chains of the pharmaceutical sector, we demonstrate that the potentials of green supply chain management may be limited by several factors. First, the relationship between pharmaceutical substance suppliers and medicinal product manufacturers is characterized by long-term partnerships and strong interdependence. Second, interviews suggest that consumers neither have environmental expectations towards medicinal products, nor act in an environmentally conscious manner regarding the disposal of medicinal products. Third, our findings on actual environmental measures implemented by companies suggests that the specific characteristics of pharmaceutical supply chains, such as strict quality and health requirements, impose severe limitations on the greening of supply chains. This study builds on the analysis of the international literature, through which it presents the issues of green supply chains in the pharmaceutical industry. Our research can be useful to national and international readers as well.

Keywords: corporate sustainability, green supply chain management, pharmaceutical industry, green chemistry.

Introduction

Supply chains are networks of organizations that incorporate both internal and external connections, and processes and actions which create added value to the product or service delivered to the final consumer (Christopher, 1992). Although the definition and goal of supply chain management have not changed fundamentally in the past 30 years, members of supply chains must constantly employ new and innovative solutions to create value for their customers in changing market environments.

The sustainability challenge presented by local, regional, and global environmental and social issues poses a threat to the operation of supply chains. Companies have responded to this challenge by developing and implementing green and sustainable supply chain practices, which are becoming increasingly widespread in many industrial sectors.

Since supply chains of various industries show distinct characteristics, it is important to understand how these characteristics effect green supply chain management practices. The pharmaceutical industry is a specialized sector in several respects. On the one hand, its placing on the market of medicinal products is preceded by a long process of research and development and authorization, which indirectly and significantly affects the functioning of their supply chains. If there is a change in any of the ingredients of the medicine, the product must be re-authorized, and the new medicine cannot be marketed until it has been authorized. For these reasons, pharmaceutical supply chains are characterized by stable, long-standing partnerships. On the other hand, the pharmaceutical industry is constantly evolving industries, and its environmental activities are still disputed to this day. At the same time, a continuous and even supply of medicines to people can be considered as a sustainability issue as well.

We started our research with a summary of the characteristics of green supply chains and proceed step by step to formulate our research questions by continuously narrowing the topic. First, we summarized the literature review of the green supply chains, which was followed by the related motivating and barrier factors. We then focused on presenting specific characteristics of the selected industry, the pharmaceutical industry along the literature. We wanted to supplement the brief literature analysis of specific characteristics of the pharmaceutical industry with current, practical perspectives, and so we visited the three largest and most significant companies in the Hungarian pharmaceutical industry that operate in the international pharma market, where we had several occasions of discussions with the colleagues responsible for supply chains and environmental protection.

We then summarized results of the literature review with the experience of our visits to pharmaceutical companies and identified four main research questions, which are the following: What are the most important characteristics of pharmaceutical supply chains and how do these influence the potentials of GSCM practices along the supply chains? What is the role of final consumers in greening the pharmaceutical supply chains? What are the most important environmental measures undertaken by the companies of the pharmaceutical sector and what factors limit the implementation of these? What environmental management practices are used by pharmaceutical companies and what are their limitations. We divided our four main research questions into interview questions, which were used during our visits at the Hungarian pharmaceutical companies.

1. Literature Review

1.1. Greening the supply chain: an historical overview

With the spread of Sustainable Development[1], companies started to integrate environmental protection aspects into various areas of company operations including the management of their suppliers. As early as 1994, Murphy and Daley published a paper regarding the potentials of green logistics, while Drumwright addressed green purchasing (Murphy and Daley, 1994; Drumwright, 1994). Sarkis examined the connections between supply chains and environmentally conscious production strategies in 1995 (Sarkis, 1995). Due to the rise of environmental issues, the ISO 14000 family of standards, introduced in 1996, also included provisions on the environmental performance of suppliers to streamline companies' environmental performance.

Since the early 2000s, companies have placed increasing emphasis on environmental issues, and the green supply chain has become a separate definition in the literature, with several publications on the subject over the past twenty years. The main goal of green supply chain management (GSCM) is defined in the literature as all members of the supply chain should take environmental aspects into account in their activities and, where possible, use environmentally friendly solutions while remaining economically profitable (Hervani, Helms and Sarkis, 2005; Srivastava, 2007; Sezen and Çankaya, 2018).

Green supply chain management by now may involve a number of activities, such as: green purchasing, environmental auditing of suppliers, environmentally conscious production and material management, environmental performance evaluation, green distribution, environmentally sound packaging, green marketing, publication of sustainability-related performance data, reverse logistics, waste management, life cycle assessment, environmental education, and environmental management spanning over the whole supply chain (Kazancoglu et al., 2020).

Reading the definition of green supply chains, it is important to highlight the last economic factor that has the greatest impact on the spread of GSCM in practice. A green supply chain can be successful in the life of a company if that company can gain a competitive advantage from it. These benefits include cost savings (energy, waste savings, or avoidance of various penalties), a higher level of customer satisfaction (more positive social perception, serving environmentally conscious consumers directly or indirectly). All these simplified findings are well supported by detailed analysis of the motivational and barriers to the spread of GSCM, which are briefly described below.

Simultaneously with the definition of GSCM, several researchers have made efforts to identify the motivations and barriers to the spread of GSCM in detail. In 2001, Min and Galle found that the most prominent hindrance to the spread of GSCM is the lack of relevant information (Min and Galle, 2001). Five years later Zhu and Sarkis concluded that the main incentive for the spread of GSCM among export-oriented companies is the need to comply with government regulations regarding national and international markets (Zhu and Sarkis, 2006).

In 2008, Walker et al. came to a similar conclusion, stating that the main barrier to the spread of GSCM is still a lack of information and concerns regarding the publication of sensitive data regarding environmental performance (Walker, Di Sisto and McBain, 2008).

[1] Our Common Future. (1987) *Brundtland report*. Oxford University.

Wang et al. identified the lack of information as the primary barrier as well, but also added the lack of strategic planning, high investment risks, and the lack of external funding to the factors, which influence GSCM activities (Wang, Wang and Zhao, 2008). Albino et al. reported that the improvement of energy efficiency is the most recognized GSCM strategy (Albino, Balice and Dangelico, 2009). Del Rio et al. identified the lack of public pressure as the most prominent hindrance for the spread of GSCM (Del Río, Carrillo Hermosilla and Könnölä, 2010). A study about the German automobile industry concluded that the main drivers of ecological initiatives are the competition and the need to meet the demands of clients, while compliance with legislation plays only a secondary role (Thun and Müller, 2010). One of the external barriers to implementing GSCM referred to by Dashore and Sohani (Dashore and Sohani, 2013) is concern regarding the publication of commercially confidential information, as well as the lack of qualified workforce (Dashore and Sohani, 2013).

Facilities certified according to the ISO 14001 standard are more likely to implement green supply chain management practices and assess suppliers' environmental performance when making their purchasing decisions. Certified facilities are more likely to attempt to green their supply chains by requiring that their suppliers undertake environmental measures (Arimura, Darnall and Katayama, 2011, p. 171).

Based on a comprehensive review of the literature Dhull and Narwal (Dhull and Narwal, 2016) identified decreasing costs, savings related to the disposal of harmful substances and the pressure exerted by the investors as internal incentives, while identifying high investment costs as the most important barrier. According to Dhull and Narwal (Dhull and Narwal, 2016) organizations often do not recognize or understand the concept of greening the supply chain and as a result the implementation of GSCM practices poses difficulties. Small and medium enterprises are often reluctant to adapt technological developments, and they believe that supply chain greening is an investment with low, or even zero returns. The survey of manufacturing companies confirmed that high market uncertainty combined with international market competition creates a difficult position for industries, as they need to keep their costs low while applying GSCM. Nevertheless, if the demand for environmentally friendly products is high, competition can present itself as an incentive, enabling the company to create a green image or improve the standing of the corporation and undertaking GSCM activities (Dhull and Narwal, 2016).

Laari et al. (Laari, Töyli and Ojala, 2018) divided the studied companies into two main groups: "leaders" and "laggards." Based on their survey, leaders are more developed in their application of GSCM strategies. The group comprised of the lagging companies, however, seemed to be less proactive regarding environmental protection, for which one of the main reasons is that they mostly meet the demands of price-sensitive customers, and aim to achieve the bare minimum when it comes to sustainability-related measures. Pishchulov and colleagues examined the circular economy perspective in sustainable supply chain management as a possible solution to supply chain greening. Their study also highlighted the environmental and sustainability pillars of how these can bring economic benefits to a given company (Pishchulov et al., 2018). Balon defined government regulations, the importance of corporate social responsibility, the possibility of new investments, and the environmentally friendly product market as the four cardinal incentives to the introduction of green supply chains in his 2020 study (Balon, 2020).

After a brief review of the literature, we can see that our research colleagues have come to a similar conclusion to our view, that the activities of green supply chains can

only take place in the life of any company to the extent that it can bring economic benefits to that company either directly or indirectly. The aim of the present study is to examine the functioning of green supply chains in the pharmaceutical industry, which is a rarely researched, but very important industry. However, before presenting how pharmaceutical companies feel about the questions of the green supply chain, we would like to describe specific characteristics of the international pharmaceutical industry, and challenges of environment management in the pharmaceutical industry briefly based on the international literature.

1.2. The special case of the pharmaceutical supply chain

The raw materials of the pharmaceutical industry — pharmaceutical substances — are produced by substance producers, who supply them to medicinal product manufacturers. They, in turn, produce active ingredients using the purchased substances as well as the final medicinal products utilising the active ingredients. Medicinal product manufacturers are either originator or generic manufacturers, depending on whether they develop active ingredients themselves or produce active ingredients previously authorized by other manufacturers.

Originator medicinal products contain newly developed active ingredients, which are expensive to develop and take a long time to market. The regular development route, spanning over 10–17 years, covers the discovery phase (2–5 years), preclinical development phase (1–2 years), clinical research phase (6–8 years), authorisation and registration (1 year), and the safety monitoring phase during which the manufacturer collects data regarding the effectiveness of the product. The active ingredient developed this way is protected by a 20 (in some cases 25) yearlong product patent, during which period no other manufacturer can market a product with the same active ingredient. When the patent expires, other manufacturers may use the active ingredient to produce generic medicinal products. For the manufacturers of the innovative (originator) medicinal products competitiveness derives from the knowledge created during the expensive research and development process as well as the marketing of the new product, while generic producers compete with their low production costs and the effectiveness of their management (Holland, Bátiz-Lazo, 2004). Customers often play a passive role in pharmaceutical supply chains as the demand is mostly shaped by physicians and pharmacists. The pharmaceutical company or pharmacy can freely promote non-prescription medicines to their customers; however, prescription-only medicines can only be advertised of physicians and pharmacists, and these advertisements are subject to strict regulations. Direct sales are performed by medical sales representatives, who are professionally trained specialists employed by the manufacturers.

Unused and expired medicines, which are not safe for consumption, must be treated as hazardous waste. The manufacturers and the pharmacies are obliged to ensure that unmarketable medicines are destroyed in a manner corresponding to environmental protection legislations. Furthermore, they are supposed to participate in the disposal of residential pharmaceutical waste as well. Some of the by-products generated by the suppliers and the manufacturers, which are considered hazardous waste, are purified using various technological processes, and fed back into the production processes. Both hazardous materials that cannot be utilized and unused medicinal products are dealt with in specialised

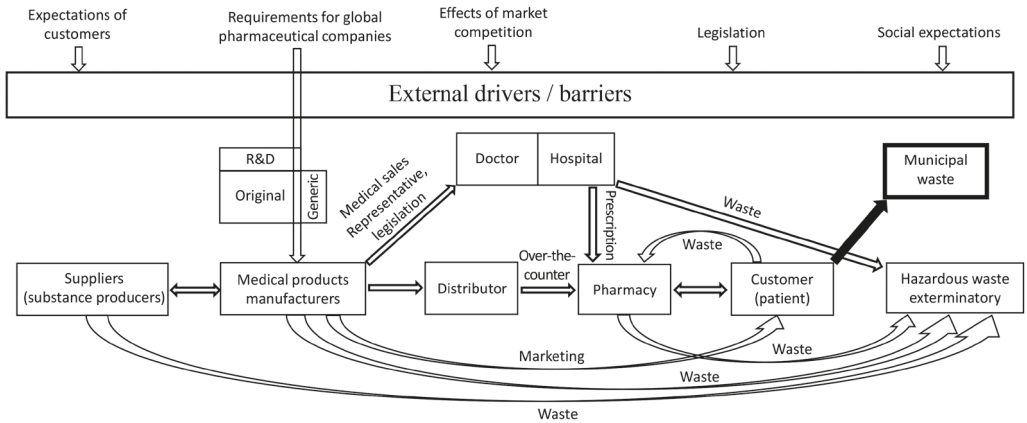

Fig. The structure of pharmaceutical supply chains

hazardous treatment facilities. Figure outlines the supply chains of the pharmaceutical industry.

The extensive use of chemicals along the pharmaceutical supply chain poses significant challenges to the companies involved in the production and distribution of medicinal products in all parts of the world. Both the scale of production and the high toxicity of chemical substances in both humans and the eco-systems require a careful management of processes.

Green chemistry guidelines may provide guidance on the development, manufacture, distribution, and disposal of medicines at the design stage. According to Anastas and Warner, green chemistry should pay considerable attention to the design of safer chemicals and their degradation, as well as the prevention of pollution (Anastas and Warner, 1998)[2].

The US Environment Protection Agency defines green chemistry as an effort "to promote innovative chemical technologies that reduce or eliminate the generation of hazardous substances in the design, manufacture, and use of chemical products"[3]. According to Iles (Iles, 2008), one of the most serious challenges of green chemistry is to find ways to make it more attractive commercially in the current regulatory system. In his view, companies should generate not only more internal information and exchange information with other companies, but also find ways to forge "sustainability" into a market advantage in chemistry, and to help with this through appropriate marketing tools. Iles (Iles, 2008) also notes that the pharmaceutical industry is a notoriously "wasteful" industry, therefore it is worth exploring possibilities of green chemistry for pharmaceutical companies.

To improve the environmental performance of the supply chain, medicinal product manufacturers should select their suppliers so that they conform to environmental and social responsibility commitments (Low et al., 2016). Xie and Breen (Xie and Breen, 2012) recommend four GSCM practices: top management commitment, supplier certification

[2] The 12 principles of green chemistry are as follows: 1) prevention; 2) atom economy; 3) less hazardous chemical synthesis; 4) design safer chemicals; 5) safety solvents, and auxiliaries; 6) design for energy efficiency; 7) use renewable feedstocks; 8) reduce derivatives; 9) catalysis; 10) design for degradation; 11) real time analysis; 12) inherently safer chemistry (Anastas and Warner, 1998).

[3] EPA. (2005) *Basics of Green Chemistry.* URL: https://www.epa.gov/greenchemistry/basics-green-chemistry (accessed: 03.03.2021).

and cooperation, customer cooperation, and eco-design, which are to be carried out by the relevant members of pharmaceutical supply chains.

Apart from selecting the right suppliers and production equipment, it is essential that pharmaceutical companies regularly check the production processes and the environmental compliance of their suppliers. According to Rossetti et al. (Rossetti, Handfield and Dooley, 2011), and Mahapatra et al. (Mahapatra, Das and Narasimhan, 2012), it is of utmost importance to the medicinal product manufacturers to set an example of proper operation to their suppliers, thus guaranteeing that their activities are compliant with ethical and sustainability-related norms. They recommend holding planned and random checks to monitor the activities and regulatory compliance of the suppliers, the results of which may help identify needed adjustment measures. Blum-Kusterer and Hussain (Blum-Kusterer and Hussain, 2001) show that while the pharmaceutical industry actively participates in environmental protection measures, the main driver of sustainability-related and environmental protection measures will continue to be the need of compliance with legislation. Villamil and Hallstedt (Villamil and Hallstedt, 2020) concluded that the integration of life cycle-based thinking into operations and the inclusion of social sustainability aspects are key for pharmaceutical companies, however, in practice companies do not handle sustainability at the strategic level.

According to Gernaey et al. (Gernaey, Cervera-Padrell and Woodley, 2012) the regeneration and reuse of by-products created during the production processes of pharmaceutical companies (e. g., solvents) is marginal. The main reason for this is the high investment cost related to technologies involved in by-product regeneration, which increases the costs of manufacturing processes and thus the costs of the product itself. Without the integration of innovative processes, the manufacturing of sustainable and environmentally friendly medicines will not result in an effective and environmentally sound production for the manufacturer.

The greening of pharmaceutical supply chains has the potential to reduce downtime in pharmaceutical industry processes. The technologies of Industry 4.0 (big data, Internet of things) may help harmonize the manufacturing processes and the current demand for medicinal products, thus decreasing the amount of hazardous waste created by excess products and additional emissions created during production, minimizing substance usage, optimizing energy- and water-consumption, thereupon mitigating potential environmental impact (Schaber et al., 2011; Gernaey, Cervera-Padrell and Woodley, 2012; Stegemann, 2016). The need for integration of Industry 4.0-related technological innovations into the manufacturing process may also burden pharmaceutical companies with a significant amount of expenses. Pharmaceutical companies in a monopolistic market position, which have available capital to invest are expected to pioneer the integration of these technological innovations, while smaller players will have difficulties in following them. Beside the sustainability-related questions of medicinal product manufacturing, emphasis should also be given to the recycled material based- and recyclable, lightweight secondary product packaging of medicinal products (Raju et al., 2016; Xie and Breen, 2014; De Soete et al., 2014). According to Xie and Breen (Xie and Breen, 2014), a portion of medicinal waste generated can be attributed to disproportionate or unsuitable packaging. De Soete et al. (De Soete et al., 2014) draw attention to the fact that while most medicinal product units have 28, 30 or 31 daily doses, prescriptions given by physicians generally pertain to 28 daily doses. The packaging of medicinal products must encourage clients to

consume the product fully, thus decreasing the amount of household generated hazardous waste (Xie and Breen, 2014). Kongar et al. (Kongar et al., 2015) reviewed the social sustainability of pharmaceutical supply chains, more specifically the questions related to the redistribution of medicines. They suggest distributing unused medicines still under warranty through a donation system to individuals in need, who cannot afford them due to their original high price. Currently, the large number of fraud cases related to medicinal products complicates the redistribution of medicines, however, security measures related to the decreasing of medicinal product falsification may aid the recalling and traceability of products. One such measure is the medicine serialisation system announced by the European Union Intellectual Property Office mandatory since 2019[4].

As we have seen in the international literature on the pharmaceutical industry, one of the most specific features of the pharmaceutical industry, is the long lead time of the research development and the prescription licensing. From an environmental point of view, the pharmaceutical industry does not show significant differences compared to other chemical sectors (e. g. pesticides, insecticides, etc.). However, the international literature has made several proposals for greening the pharmaceutical supply chains and making the pharmaceutical industry more environmentally conscious.

Before defining our research questions that we would like to ask all Hungarian pharmaceutical companies, we visited the three largest and most significant companies in the Hungarian pharmaceutical industry to discuss their supply chain and environmental challenges and their views on the international literature. The purpose of our visit to the three large pharmaceutical companies was to prepare even more accurate questionnaire questions based on the experience of the conversations with them, with which we later visited all the pharmaceutical companies operating in Hungary. At the three major pharmaceutical companies, we spoke separately to our colleagues responsible for supply chains and our colleagues responsible for environmental protection. We talked to all colleagues in each company on the order of three to four hours. We did not prepare for these discussions with specific questions, but with groups of questions that we had an informal conversation with our interviewees to learn as much as possible about the practical challenges in the pharmaceutical industry. The experiences of the conversations are summarized in the next subsection.

2. Preliminarily research with large multinational pharmaceutical companies

In preliminary surveys with large multinational pharmaceutical companies, we had asked them about the current state of the pharmaceutical industry a first. According to the surveyed companies, the pharmaceutical market is constantly growing because of aging societies and rising living standards. Both over the counter and prescription therapies are growing; the engines of growth are typically innovative, new formulations and biological and central nervous system therapies. The growth of companies with a strong, innovative portfolio is above the market average. Manufacturers with a mature portfolio are also growing, although their growth rate is lower than the market average. In 2020, the phar-

[4] ADENTS. (2018) *The Essential Guide to Serialization in Europe.* URL: https://adents.com/wp-content/uploads/2018/11/The-Essential-Guide-to-Serialization-in-the-EU-Adents.pdf (accessed: 16.03.2021).

maceutical market grew significantly because of the first wave of the COVID pandemic, returning to pre-COVID levels during the last quarter. According to the pharmaceutical companies surveyed, the most significant changes in the coming years will be as follows. In the field of promotional activities, centralization will become more common. It is expected that the strategic focus will shift from quantitative objectives to higher quality products. The development of digitization of the sector is a key area, which, however, can only be pursued at a modest speed due to the strict regulatory environment.

COVID-19 has completely overturned both production planning and sales processes — a phenomenon that has had a major impact on all market participants (substance suppliers, packaging material suppliers, manufacturers, wholesalers, pharmacies, hospitals, consumers, and patients) in terms of optimal inventory and financing activities. Adaptation to new market conditions and to the competitors gains importance. Due to uncertain market situations (e. g., because of the COVID pandemic), the determination of optimal inventory levels will become an important challenge, and all this will shift the focus even more towards economic issues rather than environmental protection. According to the surveyed pharmaceutical companies, the pharmaceutical supply chains are differed from the supply chains of other industries, mainly due to the long process of research and development and licensing. Medicinal product manufacturers cannot deviate from the formulation created due to the R&D and authorisation process unless going through the stages of the development phase again. While such a re-authorization process is in progress, the medicinal product is not marketable and the manufacturer risks losing its profit. During this time, consumers may also switch to another substitute product. Thus, changing any of the substances used in a pharmaceutical product poses a significant market risk to pharmaceutical companies. The quality (chemical composition and purity) of the components delivered by the suppliers is key for the development of the formulation therefore, in their view, all pharmaceutical companies are heavily dependent on their suppliers. For them, the failure and replacement of a supplier poses a much greater economic risk than in any other industry. In addition, it was pointed out that the pharmaceutical industry differs from other industries in that they consider the regulatory system to be the strictest for them (sometimes too strict), but that these regulations are primarily aimed at protecting product quality. In terms of environmental protection, they do not perceive difference compared to other chemical industries. The preliminarily survey large pharmaceutical companies believe that they are aware of the factors and opportunities of the green supply chain, so the lack of information in the adaptations of these is not a barrier. They are not afraid of disclosing data on environmental performance, as their emissions are compiled in accordance with legal regulations, and their hazardous waste is treated as intended. During their strategic planning, environmental issues appear less likely, they prefer to comply with the necessary legal requirements, in addition they undertake corporate social responsibility activities (mainly for self-marketing purposes) or invest in investments whose primary goal is cost savings. Their environmental aspects are only additional inherent. In their opinion, their consumers do not have environmental but rather quality expectations of them. Therefore, the surveyed pharmaceutical companies also have quality expectations of their suppliers, and the environmental activities of their suppliers are of secondary importance. They know the principles of green chemistry, but they cannot replace the active ingredients of their medicines with other, less environmentally harmful components. The redesign of the drug formulation causes re-authorization

process, and the new environmental-friendly components could reduce the active ingredients of medicines. In the case of secondary packaging of medicines (paper box), the aim is to use recycled paper boxes, but at the primary packaging of medicines (with the medicine itself comes into contact) the goal is to store the medicines properly and not to use environmentally friendly packaging. In their view, the biggest environmental challenge for the pharmaceutical industry is drug distribution in pharmaceutical logistics. The drug suppliers often visit a pharmacy more than once a day due to the delivery of emergency drugs which means a significant environmental burden.

As we can see from the summary of preliminary research with large multinational pharmaceutical companies, we have already received answers to some of the statements in the literature in these informal conversations. However, for our research to be valid, we must also ask other companies in the Hungarian pharmaceutical industry. We will use four main research questions for our research, along which we will prepare specific interview questions later. Our main research questions are described in the next section.

3. Research questions

Medicinal product manufacturers cannot deviate from the formulation created because of the R&D and authorisation process unless going through the stages of the development phase again. While such a re-authorization process is in progress, the medicinal product is not marketable and the manufacturer risks losing its profit. During this time, consumers may also switch to another substitute product. Thus, changing any of the substances used in a pharmaceutical product poses a significant market risk to pharmaceutical companies. The quality (chemical composition and purity) of the components delivered by the suppliers is the key for the development of the formulation. These characteristics can affect relationships between members of the pharmaceutical supply chain creating a high level of interdependency between the companies. Pharmaceutical companies may be reluctant to experiment with new substance suppliers since testing of substances from a new supplier and its further development (modification, purification) takes a long process. As the quality of the medicinal product is exposed to the quality of the substances used, and since the pharmaceutical industry is characterised by a limited number of suppliers, the special relationships between supply chain members may create an obstacle to the spread of GSCM practices in the industry.

Based on these assumptions, we formulate our first research question as follows: *what are the most important characteristics of pharmaceutical supply chains and how do these influence the potentials of GSCM practices along the supply chains?*

An important incentive for the spread of GSCM is the ability to meet customer demand and market competition. In contrast, the members of the pharmaceutical supply chain cannot rely on gaining a market advantage by manufacturing environmentally friendly pharmaceutical products (Thun and Müller, 2010; Dhull and Narwal, 2016; Balon, 2020). Prescription medicinal products must not be advertised to the end consumer but are prescribed to patients by doctors. Over-the-counter medicines are freely advertised by the pharmaceutical company, however, advertisements that offer environmentally friendly pharmaceutical products are rare.

We assume that those with an impact on the purchasing decision (doctors, pharmacists, and patients) have expectations primarily regarding the quality (effectiveness) of

the active substance, while the environmental impacts related to the product take only a secondary role. Hence our second research question: *what is the role of final consumers in greening the pharmaceutical supply chains?*

The pharmaceutical industry is one of the most significant sectors of the chemical industry and has a significant impact on the environment. Medicine is considered a special commodity; therefore, international, and country-specific regulations determine processes along the supply chain from the production of raw materials to the consumer. Legislation aims at promoting the high quality of the production processes, transport, storage, and sales to identify the journey of the medicinal product to the patient and, where appropriate, to prevent counterfeiting medicinal products. Companies along the supply chain have abundant opportunities to mitigate the environmental effects of their production processes including the application of environmentally friendly technologies, the reduction of energy consumption, the regeneration of by-products created during manufacturing, appropriate waste management, the usage of environmentally friendly logistics and packaging materials, as well as the use of life cycle assessment. Our third research questions address these opportunities taking the strict regulatory environment into account: *what are the most important environmental measures undertaken by the companies of the pharmaceutical sector and what factors limit the implementation of these?*

Green chemistry, along with other initiatives such as the Responsible Care programme, provides not only guidance to companies of the chemical industry but it may be also useful for the members of pharmaceutical supply chains. To promote the greening of their supply chains and to comply with environmental regulations pharmaceutical companies may directly monitor, audit, and evaluate the environmental performance of their suppliers and use environmental management systems certified according to the international ISO 14001 standard or implemented in line with the European EMAS regulation promote compliance with environmental regulations. The strict regulatory environment suggests that the use of these tools is widespread in the pharmaceutical industry. We address this issue by posing our fourth research question: *what environmental management practices are used by pharmaceutical companies and what are their limitations?*

4. Methods

While research regarding the greening of supply chains is abundant, the specific case of the pharmaceutical industry has not been addressed in detail yet. First, we visited the three largest multinational pharmaceutical companies operational in the country, where we conducted in-depth interviews with colleagues responsible for environmental protection and supply chains. Typically, two to three interviews were conducted in each company. These in-depth interviews provided us with a comprehensive picture of the international environmental challenges of the pharmaceutical industry and the specifics of their supply chains.

Based on the experience of the discussions, we prepared a questionnaire for Hungarian pharmaceutical companies, which we reviewed and supplemented. Subsequently, the obtained questionnaire was specialized for the three types of pharmaceutical companies. We prepared one questionnaire for the pharmaceutical medicinal product manufacturers, one questionnaire for pharmaceutical substance suppliers, and one questionnaire for the pharmaceutical logistics companies and all actors of the Hungarian pharmaceutical

industry were contacted with the questionnaires (both substance suppliers, medicinal product manufacturers and the pharmaceutical logistics companies) during the autumn of 2020. To compile our sample, we used Hungarian company databases, and due to its help, we compiled a list of all pharmaceutical companies operating in Hungary. As the pharmaceutical industry is a typically closed industry with many sensitive information, so we did not involve "query companies" in our research. We visited pharmaceutical companies one by one (103 companies) and, demonstrating the importance of our research, asked them to participate in the research. The progress of research and the availability of pharmaceutical companies have been hampered by the current pandemic situation, which had put even more strain on pharmaceutical companies, but we did not want to suspend our research for this reason. (We also asked the three major pharmaceutical companies involved in the preliminary research to answer our list of specific questions, so they were part of our sample.)

As of November 2020, there were 55 pharmaceutical substance suppliers listed in the official company registry of Hungarian enterprises. By removing those, which do not actually operate (9 companies), which are under liquidation (13 companies) and which are registered several-fold, but operate as one single entity (8 companies), we narrowed the population to 25 companies: 12 micro, 6 small and 7 medium sized. Out of these, 1 micro, 2 small and 3 medium sized suppliers agreed to participate in the research. 6 pharmaceutical substance manufacturers companies (pharmaceutical raw material companies). All the 6 pharmaceutical substance supplier companies which were participating in our research, although Hungarian-owned companies, they sell the 100 % of their pharmaceutical substances on the foreign market (Europe, Asia, Africa). In this viewpoint, their responses can be relevant internationally.

The registry of Hungarian enterprises also lists 73 pharmaceutical manufacturers. 17 of these did not have employees and sales, so we excluded them from the sample. Out of the 56 companies surveyed, 13 companies indicated having their profile on production of food supplements and vitamins and being on the list of pharmaceutical companies aims to maintain the possibility in case they would later add pharmaceuticals products to their portfolio. Because the producing of food supplements and vitamins are not needed to apply pharmaceutical requirements, we considered them irrelevant to our research and excluded them from the sample. Thus, with our questionnaire, we visited a total of 43 pharmaceutical medicinal manufacturers, of which 15 were micro-enterprises, 7 small enterprises, 13 medium-sized enterprises and 8 large enterprises. Most micro-enterprises indicated having limited activities of the production of 1 special medicine, which are mainly manufactured for 1 partner company, so they do not have a relevant view of the pharmaceutical supply chains and therefore do not want to participate in interviews. Among the pharmaceutical medicine manufacturers companies 2 small companies, 5 medium-sized companies and 4 large companies participated in our research. The surveyed 11 pharmaceutical medicines manufacturers companies which, except of 3 companies, are all foreign owned. 80 % of the raw materials needed to produce pharmaceutical products are imported from foreign markets (mainly Asia) and more than 70 % of the manufactured pharmaceutical products are sold on foreign markets (Europe, Asia, Africa). In this viewpoint, their responses can be also relevant internationally. In order to get an even more comprehensive picture of the sustainability issues of pharmaceutical supply chains in our research, we also addressed 5 pharmaceutical logistics companies with an own question-

naire, and we could interview the largest pharmaceutical logistics company in Hungary. The surveyed pharmaceutical logistics company is a 100 % foreign-owned company, but it operates mainly in the Hungarian market.

Finally, a total of 17 pharmaceutical companies and one large pharmaceutical logistics company participated in the research. While the first interviews were held in person, later interviews were conducted on-line because of the coronavirus pandemic. Interviews aimed at professionals responsible for environmental protection measures and supply chains in the case of large companies and the general manager in the case of SMEs.

We used three types of questionnaires during the research: questionnaire for the pharmaceutical substance suppliers (contains 70 questions); questionnaire for the pharmaceutical medicinal product manufacturers (contains 88 questions); questionnaire for the pharmaceutical logistics companies (contains 41 questions).

The semi-structured interviews contained open and closed questions regarding the activities and structure of the companies; the challenges facing the industry and their effects on operations; the supply chains and relationships with members of the supply chains as well as the environmental protection measures implemented by the companies.

5. Results and discussion

5.1. Interdependency between pharmaceutical suppliers and manufacturers

Hungarian pharmaceutical companies are tightly linked to the international market. Respondent manufacturers (4 large pharmaceutical manufacturers and 7 SMEs) import 80 % of the substances used for their products from foreign markets while the 6 surveyed suppliers sell 100 % of the substances for foreign customers. Pharmaceutical manufacturers surveyed typically use one substance to produce 5–10 medicinal products and purchase the feedstock from suppliers who specialize in the production of only a few (often only one or two) substances. Large pharmaceutical companies in the sample typically work with 30–50 substance suppliers, medium and small pharmaceutical companies have much fewer, typically 5–10 suppliers. The supplier relationships of the 18 pharmaceutical companies (including the packaging company) involved in the research date back to more than 20 years and most manufacturers often have been ordering substances from the same suppliers since their inception.

All the surveyed manufacturers and substance suppliers believed the risk and reward sharing between the members of the pharmaceutical supply chain is the primary requirement of market success and can only be realized through long-term partnerships. 8 companies out of the surveyed 11 manufacturers have not changed their supply chain in the last 3 years while 2 companies added only one new supplier to their supply chains. The quality of the manufacturing processes and products of the product manufacturers are entirely dependent on the quality of the components they purchase or produce. In interviews, manufacturers believed that if their suppliers could not provide the necessary volume of substances, it would be difficult to substitute the supplier. The tendering of new suppliers, the inspection of the substances they distribute, the business agreement and the contract negotiations are all time-consuming processes. The quality of the delivered substance presents a risk for the product manufacturer, since if it does not have the needed

purity, it must go through further laboratory processes. According to the large manufacturers, they can facilitate this using their own infrastructure, but the time-consuming nature of the process presents a significant vulnerability for them since the continuous satiation of the medicinal product demand forms the basis of their competitiveness. Interviewed manufacturing SMEs have no means of improving/purifying the components, as they do not possess the required technology, and as a result, the pharmaceutical products manufactured by them are even more dependent on the quality of the components used.

The long process may cause a loss of production during the manufacturing of the pharmaceutical product. The changing of any element of the registered medicine formulation can lead to significant business risks for the pharmaceutical product manufacturing company.

5.2. Motivations along the pharmaceutical supply chain

Of the surveyed manufacturers, only one large company indicated that environmental protection is important to its customers and that their customers have environmental expectations. The other 17 interviewed pharmaceutical companies unanimously stated that the final consumers of the pharmaceutical products have no demands for environmentally friendly pharmaceutical products. All interviewees agreed that consumers would not pay a higher price for medicines produced in an environmentally conscious way. The four large manufacturers, one SME manufacturer and the pharmaceutical logistics company, apply sustainability measures, but these measures cover corporate social responsibility activities in a general sense and are primarily aimed at enhancing the company's reputation. The other six manufacturer SMEs and six substance suppliers do not apply sustainability measures at all. The interviewed large enterprises and SMEs agreed that the manufacturing of environmentally friendly pharmaceutical products has higher production costs, which customers are not willing to pay.

Pharmaceutical companies primarily compete with the quality of their products, timely development of the substances to match market demand, and product prices. The environmental load of the pharmaceutical industry can be mitigated by using environmentally sound materials and production processes and by reducing the environmental risks posed by pharmaceutical products to the ecosystems. Interviewees stressed that the production of suitable active substances often requires chemical components and processes, which should be replaced by environmentally friendly ones, but it might lead to the deterioration of the quality of these active substances. The use of a new, environmentally sound components would require the adjustment of the formulation of already existing products on the market, which in turn requires a new authorisation process. The high expense and lead time of the repeated research and development-, and authorisation processes could pose a market risk, even if there was adequate demand for environmentally friendly products and if the necessary environmentally sound components were available. The opinion of the medicinal product manufacturers coincides with those of the substance producers that if their customers do not show interest towards environmentally friendly components, they will not start long and expensive R&D processes to develop them. Overall, therefore, in the absence of environmental expectations from consumers, pharmaceutical manufacturers will not invest in environmentally friendly manufacturing, as consumers are not willing to pay a higher price. With little or no environmental

expectations on behalf of manufacturers, this effect spills over to pharmaceutical suppliers whose market strategies only centre around meeting the quality and quantity expectations of their customers including steady supply at affordable prices.

The 11 pharmaceutical manufacturers interviewed agreed that at present, the disposal of household-stored unused or expired medicine is the most important environmental issue of the pharmaceutical industry, as only a small percent of the consumers return them to pharmacies as intended. In their opinion, the consumers could be motivated with an incentive system (for example, pharmacies could offer a discount for the next purchase, based on the returned medicine). The solution to this problem requires government intervention. Most of the pharmaceutical companies (both the manufacturers and the substance suppliers) have cited good practice in disposing of household waste (refrigerators, batteries) as an example adding that wasted pharmaceutical products are less "spectacular". While substance suppliers are further removed from this issue, they also agreed that end consumers are not only reluctant to pay more for environmentally friendly medicines but are also unwilling to dispose of pharmaceutical waste appropriately.

5.3. Actual environmental measures

Green chemistry suggests the use of less polluting compounds, the use of safer solvents and additives, the design of the degradation, and the use of renewable substances. Of the surveyed 17 pharmaceutical companies, all the substance suppliers and the medicinal product manufacturers carry out significant R&D activities. Pharmaceutical companies agreed that the principle of "designing safer chemicals and products" cannot be applied in the pharmaceutical industry, as many medicinal products require an artificially produced synthetic molecule, which cannot be substituted and thus limits the possibilities of designing for the environment. "Design of the degradation" is also a challenge for the pharmaceutical industry, as medicines must be stable from manufacturing through storage to end use. None of the companies surveyed design the degradation of their pharmaceuticals. In their view, the only environmentally sound way to dispose of medicinal products is to incinerate waste by specialized hazardous waste incinerators. Medicinal products that end up in the ecosystems (for example medicinal waste of the households) pose risks to animals as they are often created to treat viral, bacterial or cancerous diseases. The design of the degradation of pharmaceutical products is limited due to the special active ingredient composition of the products. For similar reasons, renewable substances are also difficult to use in the manufacturing of pharmaceuticals.

According to the interviews three of the large pharmaceutical companies interviewed would be willing to experiment with new, environmentally friendly substances, while the fourth large pharmaceutical company and pharmaceutical SMEs prefer substances already in use, because of the high cost and length of R&D and re-authorization processes.

Emissions of volatile organic compounds, generation of hazardous waste and medicine residues entering the ecosystem are the most important problems identified by the companies. Another significant environmental challenge is the packaging of final products, but due to quality requirements of medicinal products, as well as special packaging requirements (e. g. dosage), the use of environmentally friendly options has serious limitations (e. g. the use of recycled materials). Regeneration and recycling of by-products (such as solvents) that are hazardous substances in manufacturing processes is particular-

ly common in large manufacturers and larger SMEs. Large manufacturing companies can recycle nearly 30–40 % of the solvents generated during their manufacturing processes, while smaller manufacturing SMEs and substance suppliers usually recycle less than 10 %.

Large manufacturers agreed that the manufacturing of the active substances is the most polluting of the pharmaceutical manufacturing process. The by-products created during the manufacturing of the active substance, such as different solvents, aqueous solutions containing hazardous materials, or even paper and packaging contaminated by medicine remnants present a significant environmental load. The other important substantial environmental load along the pharmaceutical supply chains is the transportation of the components, as most of the interviewed large manufacturers import a considerable part of their components from Asia. Large manufacturers aim to regenerate waste created during their activities. On the other hand, however, the costs of quality assurance and the required advanced technology of on-site regeneration of by-products has a prohibitive cost for SMEs. Pharmaceutical large enterprises see further opportunities in the regeneration of glass waste, as at present, glass waste is destroyed, however, in their opinion, they could be reused after being subjected to heat treatment. One large manufacturer also indicated that to protect the environment, they hand over some of the waste generated during the production to other industries (e. g., to factories producing paint) for further usage. We discovered no such examples at the manufacturing SMEs, although upon discussing the issue, some of the SMEs indicated that they would consider the feasibility of such measures.

Pharmaceutical companies keep full accounts of waste generated during their manufacturing processes, which is constantly monitored by the authorities. Manufacturers stressed that there are still countless opportunities for improvement in wastewater treatment. The four large manufacturers manage wastewater treatment on-site. Treatments include cyanide decontamination of wastewater containing toxic materials and cyanide, pre-treatment of wastewater with high salinity or containing intermediates and final products, and evaporation of wastewater. Manufacturing SMEs have no means to regenerate wastewater on-site, thus after collection they hand it over to companies specialized in the elimination of hazardous waste, while creating an additional environmental load through the transportation process. During the interviews, the four large manufacturing companies also pointed out that the incineration of expired medicines also poses significant environmental risks. Pharmaceutical SMEs reported that they are mainly motivated by legal obligations, while large producers mentioned other objectives as well, such as improvements in energy efficiency and transparent operations.

Although medicinal product manufacturing SMEs can compete with the price and quality of the products of the large enterprises, they still consider voluntary environmental protection measures (e. g., the application of new environmentally sound technologies) as a significant additional cost item, which can threaten their market positions. For this reason, they call for government assistance.

SMEs supplying substances aim at the required minimum during their environmental protection measures. They believe that the greening of the supply chain is an investment with low, or even zero returns, and compliance with environmental demands exceeding the legislation is not a precondition to their market success.

The interviewed substance suppliers unanimously stated that the companies with more capital are more likely to be able to react to the changes of the regulatory system. The

micro enterprises can only meet the tightening environmental protection regulations with help from the government or their customer partnerships. The two large manufacturers stated that would in fact offer financial aid to the component manufacturer for them to further provide the delivered components. The medicinal product manufacturing SMEs, which have a smaller amount of capital at their disposal, would not be able to afford supporting their component manufacturers, thus they would have to involve a new component manufacturer in their supply chains.

According to the pharmaceutical logistics company the biggest challenge during the delivery of a medicinal products is the controlled mode of delivery (proper temperature, humidity) and the frequency of deliveries while the continued satisfaction of increased demand also poses a challenge. The delivery of the medicinal products is continuous, in some cases two or more times a day, which has a significant impact on the environment. The use of electric vehicles is planned, however, due to the time required to charge them (and due to their continuous use), this would require the maintenance of a car fleet much larger than the current one. The company believes that the use of electric vehicles is only a "symptomatic treatment" of the problem. The solution is seen in matching the inventory of pharmacies with the current demand for pharmaceutical products, which can be achieved with the technological innovations of Industry 4.0. The Internet of Things would make it possible to connect pharmacies and pharmaceutical logistics companies into a single cloud. By analysing big data, pharmaceutical logistics companies could instantly get accurate information about the daily turnover of the pharmacy. Moreover, in the case of emergency medicine delivery, the use of drones is seen as an environmentally friendly solution. The pharmaceutical logistics company also highlighted the environmental potentials of automated warehousing as an additional energy-efficient, environmentally friendly solution. Thanks to the technological innovations of Industry 4.0, pharmaceutical logistics may undergo significant developments in the coming years. However, since companies will be motivated primarily to save energy and costs, the protection of the environment is only seen as an additional positive factor.

5.4. Environmental audits and management systems

Of the surveyed four large manufacturers, two companies are ISO 14001 certified. In their view, the certificate, like any other management system, manages the site's environmental efforts in an integrated structure and approach. The structure, operation and development of the system is consciously planned and transparent. However, the two ISO 14001-certified large manufacturers also indicated that their customers do not require certification, nor do they require certification from their suppliers. The other two large manufacturers do not have ISO 14001 certification. While they claim that they operate as if they had a certificate, they also believe that the actual certification imposes a significant administrative burden on companies, so they do not intend to acquire the certificate in the future. One company out of the 7 surveyed manufacturing SMEs indicated that it does not currently have ISO 14001 certification but plans to acquire it in the future to increase the company's reputation. The other 6 pharmaceutical SMEs are not and have not been ISO 14001 certified before. Like the large manufacturers, they had the opinion that by complying with environmental regulations, they already operate as if they had ISO 14001 certification and the extra work invested in the administration does not pay off.

Five of six surveyed substance suppliers do not currently have ISO 14001 certification and do not intend to obtain certification. The 6th substance supplier indicated that due to having been ISO 14001 certified earlier, they do not have a certification anymore, because of the extra time and effort demanded by them and that they must comply with regulations anyway. The large pharmaceutical logistics company participating in the research is ISO 14001 certified. In their opinion, with the help of the certificate, the control of the processes was integrated into their daily activities, therefore the operation has become more efficient, and they have managed to mitigate environmental pollution.

All surveyed pharmaceutical companies, regardless of whether they have/currently have/plan to have ISO 14001 certification, stated that their customers/partners do not require any environmental certificate, therefore, having one provides no advantage on the market. At the same time, however, the surveyed companies reported that they are continuously audited by their partners. These audits cover both the manufacturing process and product quality, but do not address environmental issues. Interviewees stated that the main reason for this is that if companies did not comply with regulations, they would not be able to operate, and any further environmental aspects of operations are their own internal issues.

6. Green supply chains in the pharmaceutical industry (motivations and barriers): Comparison of the research results with the international literature

After an in-depth analysis of the relevant literature, we have come to the following conclusions: Among the findings in the literature, it is true for the pharmaceutical industry that the main driver of GSCM is the compliance with government regulations on national and international markets and improving energy efficiency in the pharmaceutical industry are the most recognized GSCM strategy (Zhu and Sarkis, 2006; Albino, Balice and Dangelico, 2009). Dhull and Narwal's claims can also be applied to the pharmaceutical industry, in which declining costs, savings related to the disposal of harmful substances and pressure from investors were identified as internal incentives, while high investment costs were identified as the main obstacles. It is also true that small and medium-sized enterprises are often reluctant to adapt to technological developments and believe that greening the supply chain is a low, even zero-return investment (Dhull and Narwal, 2016).

The claim of Blum-Kusterer and Hussain is also true, as the pharmaceutical industry is actively involved in environmental measures (mainly by enforcing environmental legislation) and for this reason, compliance with the legislation will continue to be the main driver of environmental measures (Blum-Kusterer and Hussain, 2001). The claim of Gernaey et al. i. e. that the recovery and reuse of by-products (e. g., solvents) generated during the manufacturing processes of pharmaceutical companies is marginal has also been confirmed. The main reason for this is the high investment cost associated with the technologies involved in by-product regeneration, which increases the cost of the manufacturing processes and the cost of the product itself. Without the integration of innovative processes, the production of sustainable and environmentally friendly medicines will not result in efficient and environmentally friendly production for the manufacturer (Gernaey, Cervera-Padrell and Woodley, 2012). Industry 4.0 technologies (big data, Internet of things) can help align manufacturing processes with current drug needs, thereby

reducing the amount of hazardous waste from surplus products and additional emissions during manufacturing, minimizing drug use, optimizing energy and energy efficiency. water consumption, thereby mitigating potential environmental impacts (Schaber et al., 2011; Gernaey, Cervera-Padrell and Woodley, 2012; Stegemann, 2016).

The need to integrate technological innovations related to Industry 4.0 into the manufacturing process can also impose significant costs on pharmaceutical companies. Pharmaceutical manufacturers in a monopolistic market position with the capital available to invest are expected to play a pioneering role in integrating these technological innovations, while smaller players will have difficulty following them. In addition to the sustainability issues of pharmaceutical manufacturing, emphasis should also be placed on recycled material-based and reusable, light secondary packaging of pharmaceuticals (Raju et al., 2016; Xie and Breen, 2014; De Soete et al., 2014).

Contrary to the literature, our research shows that the spread of green supply chains is not hindered by a lack of information, fear of publishing sensitive data on environmental performance, or a lack of strategic planning in the pharmaceutical industry (Min and Galle, 2001; Walker, Di Sisto and McBain, 2008; Wang, Wang and Zhao, 2008). For the pharmaceutical industry, it is not true that the pharmaceutical industry that the main driver of ecological initiatives is the need to compete and meet customer needs (Thun and Müller, 2010). Nor can the findings of Arimura et al. be validated in the pharmaceutical industry that certified facilities are more likely to try to green their supply chains by requiring environmental measures from their suppliers (Arimura, Darnall and Katayama, 2011, p. 171). Balon identified government regulation, the importance of social responsibility, the possibility of new investments and the green product market as the four key drivers for the introduction of green supply chains in his 2020 study, of which we only see compliance with environmental regulations as true. (Balon, 2020).

Iles's study sees the potential of green chemistry in the pharmaceutical industry, however, our research has shown that there are several barriers to this in the pharmaceutical industry (e. g., long lead times for drug re-authorization and loss of profit) (Iles, 2008). The findings of Low et al. and Rossetti and Mahapatra on the selection of suppliers could not be supported by our research in the pharmaceutical industry, as the selection of suppliers is not based on their environmental adequacy or subsequent verification based on our results (Low et al., 2016; Rossetti, Handfield and Dooley, 2011; Mahapatra, Das and Narasimhan, 2012).

Villamil and Hallstedt (Villamil and Hallstedt, 2020) concluded that integrating life cycle thinking into operations and incorporating social sustainability considerations is key for pharmaceutical companies, but in practice, companies do not address sustainability at a strategic level. Although Pishchulov and his colleagues have outlined a few solutions to the potential of the circular economy and its environmental impact, such as unused drugs can be collected in pharmacies in the pharmaceutical industry, they cannot be reused, or used of by-products for other industries (Pishchulov et al., 2018).

Conclusions

The purpose of this article was to analyse pharmaceutical supply chains from an environmental perspective. In the first chapter of the article, we briefly summarized the characteristics of green supply chains, as well as their motivating and hindering factors

along the literature, and then discussed the specific characteristics of the pharmaceutical industry in a separate subchapter. Following the findings in the literature, we conducted preliminary in-depth interviews with the three largest Hungarian pharmaceutical companies to supplement our literature approaches with practical perspectives. Based on this information, we identified four main research topics to examine the extent to which the motivating and hindering factors of green supply chains in the literature are true for pharmaceutical supply chains. Along the four main research areas, we formulated interview questions with which we approached all pharmaceutical companies in Hungary (103 companies in total) to get answers to our questions. Our research was hampered by the fact that several of the 103 companies collected according to the Hungarian company information databases are no longer active, or that one company is listed as more than one company (for example, plasma centres with 8–9 companies belonging to the same organization) and several companies that currently do not engage in pharmaceutical activities are only registered as a pharmaceutical company as a possible future profile of their company. This information was already revealed during our research when we contacted the companies and significantly decreased our sample size. Another setback was the current pandemic situation, which has put a significant strain on pharmaceutical companies, making the industry, which is already difficult to reach, even less accessible to participate in research in the last 1.5 years.

Based on our research, it can be concluded that the practices of green supply chain management are gaining importance in many industrial sectors around the world. Sectors characterised by high environmental risks and ever-increasing regulatory and social expectations are the most active in this field as seen by the growing literature. The distinct characteristics of supply chains, however, warrant a sectorial approach when studying green practices along supply chains. By looking at the supply chains of the pharmaceutical sector, we demonstrated that even in industries, which deal with significant quantities of dangerous substances and toxic wastes, the potentials of green supply chain management may be limited by several factors. First, the relationship between pharmaceutical substance suppliers and medicinal product manufacturers is characterised by long term partnerships and strong interdependence, which constrain the choice of suppliers and raw materials. Medicinal product manufacturers prioritise the reliability of delivery over the environmental features of raw materials, which also limits the motivation to search for environmental options. Second, the interviews suggested that consumers neither have environmental expectations towards medicinal products, nor act in an environmentally conscious manner regarding the disposal of medicinal products. Accordingly, pharmaceutical manufacturers do not require their suppliers to use environmentally sound processes. Thus, compared to supply chains in other industrial sectors, the spread of GSCM in the pharmaceutical industry is not motivated by consumer demand for environmentally safe products.

Third, our findings related to the actual environmental measures implemented by the companies suggests that the specific characteristics of pharmaceutical supply chains, such as strict quality and health requirements, impose severe limitations on the greening of supply chains. Finally, we found that environmental auditing and certification in the pharmaceutical industry is not a universal practice at all. Audits focus on the quality of substances and processes rather than environmental issues, and certification, if implemented at all, serves the narrower objectives of communication and transparency. These

factors result in a low motivation to improve corporate environmental performance along the pharmaceutical supply chain beyond regulatory requirements. While strict regulations mainly benefit product quality and safety, they may also block the development of environmentally sound solutions. Coupled with a long R&D process and a low uptake of environmental management systems as well as environmental audits, this results in supply chains which puts a low priority on environmental issues. Our findings imply that voluntary measures along pharmaceutical supply chains may not be sufficient to deal with the significant environmental risks characteristic to the industry and thus the role of regulatory intervention is higher than in other industrial sectors. Moreover, since both production processes and medicinal products carry high environmental risks, not only the activities of suppliers and producers, but the disposal of medicinal products should also be strictly regulated to minimise environmental impact.

It is clear from our research that it is not enough to examine the motivators and barriers to green supply chains in general, as different characteristics of different industries may have different opportunities and barriers.

Despite these difficulties, we have been able to contact most pharmaceutical companies and find answers about how the motivating and hindering factors of supply chain greening differ from those defined in the literature. The pharmaceutical companies participating in our research operate in the international market, so our research can also serve as a useful basis for future research. As future research opportunities, we can identify the analyses of the motivating and hindering factors of green supply chain greening in each industry separately, and then perform comparative analyses based on them. The positive and negative effects of Industry 4.0 on supply chains and their environmental performance can also be identified as an open research question. Several theoretical studies have been conducted on the latter, but it would be worthwhile to conduct case studies as well as further quantitative research based on industry-specific (even manufacturing) data.

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Проблемы управления зелеными цепочками поставок в фармацевтической промышленности

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В последние годы управление зелеными цепочками поставок часто вызывает исследовательский интерес, однако все еще встречается ограниченное представление об отраслях с конкретными характеристиками. Цель данной работы — охарактеризовать фармацевтические цепочки поставок с экологической точки зрения. Методология исследования вносит новый вклад в литературу, описывающую зеленое управление цепочками поставок, так как подробный анализ экологических аспектов фармацевтической промышленности до сих пор не был проведен. Полученные результаты дают представление фармацевтическому бизнесу и политикам об ограничивающих факторах управления зелеными цепочками поставок в фармацевтическом секторе и о способах преодоления существующих в отрасли препятствий. Рассмотрев цепочки поставок фармацевтического сектора, мы убедились, что потенциал зеленого управления ограничен несколькими факторами. Во-первых, отношения между поставщиками лекарственных препаратов и их производителями характеризуются как долгосрочные, партнерские и взаимозависимые. Во-вторых, проведенные в ходе исследования ин-

тервью показали, что потребители не имеют экологических ожиданий по отношению к лекарственным препаратам и не ведут себя экологически сознательно в отношении их утилизации. В-третьих, наши выводы, касающиеся экологических мер, реализуемых компаниями, свидетельствуют о том, что специфические характеристики фармацевтических цепей поставок, такие как строгие санитарные требования, накладывают серьезные ограничения на экологизацию цепей поставок. Исследование основано на анализе интернациональной литературы, в которой представлены проблемы экологически чистых цепочек поставок в фармацевтической промышленности.

Ключевые слова: корпоративная устойчивость, зеленое управление цепочками поставок, фармацевтическая промышленность, зеленая химия.

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