European Research Studies Journal
Volume XXIV, Special Issue 3, 2021

pp. 894-904

The COVID-19 Pandemic and the Problem of Plastic Waste in the EU

Submitted 22/07/21, 1st revision 02/08/21, 2nd revision 21/08/21, accepted 10/09/21

Bernadeta Baran[1]

Abstract:

Purpose: *This article aims to compile and analyze initial data on the impact of the pandemic on the amount of plastic waste generated and the plastic waste management system in the EU.*
Design/Methodology/Approach: *Methods used in this study are statistical and intuitive. To a great extent, the considerations are based on recent literature (the time of pandemic) and secondary data. Statistics are delivered from reports and databases: Eurostat, PlasticsEurope (associations representing plastics producers), The Ellen MacArthur Foundation (a charity working with business, government & academia to build a framework for a CE), Research and Markets Reports.*
Findings: *One of the EU's most important objectives is closing the circular economy, i.a., for plastic waste. The COVID pandemic has posed new challenges to achieve it (1) extra pressure: more plastic waste, mainly single-use which are mostly not recyclable (leading to inappropriate management strategies, including mobile incineration, direct landfills, and local burnings); (2) the implications of the lockdowns for the recycling industry: loss of valuable secondary raw material due to shutting down/temporarily cease operating in many converting plants and the record low prices of virgin plastics resulting from the falling oil prices on world markets.*
Practical Implementation: *This article is a compilation and an analysis of preliminary data on the impact of the pandemic on the amount of plastic waste generated and on the recycling industry in the EU. This issue is important both because of the magnitude of the plastic waste problem by itself (in the pre-pandemic time) and the ongoing implementation of the circular economy in the EU (despite the pandemic).*
Originality/Value: *The plastic waste surge's economic and environmental impacts due to pandemic have not yet been thoroughly analyzed, as the COVID-19 pandemic is ongoing (its implications are sure to be felt for a long time to come).*

Keywords: *Plastic waste, circular economy, COVID pandemic.*

JEL classification: *Q53, Q57, Q5.*

Research Tyrpe: *Research article.*

Acknowlegdement: *"The project is financed by the Ministry of Science and Higher Education in Poland under the programme "Regional Initiative of Excellence" 2019 - 2022 project number 015/RID/2018/19 total funding amount 10 721 040,00 PLN"*

[1]*Ph.D., Wroclaw University of Economics and Business, Poland, bernadeta.baran@ue.wroc.pl;*

1. Introduction

The beginning of the 21st century brought a rising awareness of the impending environmental catastrophe caused by the increasing prevalence of plastics in the environment. Governments, international institutions, organizations, companies, and even citizen groups put forth many regulatory initiatives and actions targeting plastic pollution. However, the 2020 COVID19 pandemic has disrupted this momentum - many plastic pollution reduction policies have been suspended, canceled, or postponed (Grima *et al.*, 2020). What started as a health crisis promptly evolved into an economic, social, and environmental threat. Public health has become an utmost priority, along with close monitoring of economic and social impacts. At this time, the implications of COVID-19 in the environment remains largely undervalued.

There is a legitimate fear that plastic pollution has increased, primarily due to the higher consumption of single-use plastic items and personal protective equipment (the proper handling of hazardous medical plastic is a separate issue). New challenges have also arrived from the implications of the lockdowns for the recycling industry (loss of valuable secondary raw material due to shutting down/temporarily cease operating in many converting plants and the record low prices of virgin plastics resulting from the falling oil prices on world markets).

2. Literature Review

The modern economy is synonymous with industrial expansion, urban concentration, and socio-cultural changes. Unfortunately, human economic activity has been based on a linear model in which an increase in production entails an increase in resources obtained from the environment and leaves behind waste with disregard of the sustainability of the process. The symbol of the economic changes of the last half-century, and at the same time a cause for great concern, is plastic - one of the world's most-used materials. The concept of plastics (polymers) is a comprehensive one. This name refers to materials whose primary components are polymers, i.e., multimolecular chemical compounds obtained in industrial polymerization processes (from so-called mers) and auxiliary components (additives).

These additives make it possible to improve the mechanical and thermal properties of plastic products, increase their aesthetic value and at the same time reduce the price and give them unique functional properties, e.g., durability, mechanical and chemical resistance (also for corrosion), low electrical and thermal conductivity, low specific gravity, and recyclability (Ambrogi *et al.*, 2017). They make the use of plastics versatile (e.g., in the household goods and packaging industry, electrical, electronic, automotive, medical, clothing, construction, aerospace, agriculture, and sports sectors) and have led to a dynamic increase in demand for it. Unfortunately, the estimates show that from the 1950s (the beginning of the plastics industry's development) until 2015, 70% of plastics waste has been accumulated in landfills or the environment, especially in the oceans (Geyer *et al.*, 2017).

This phenomenon leads to irreversible environmental changes. Fragments into which plastics are broken down, both larger and smaller (so-called microplastics), are found in all parts of the oceans. They have a significant impact on the whole ecosystem - entering the food chain, they get back to the human being, affecting his health (Watkins and Brink, 2017). Another cause for concern is chemical additives - the main components of plastics. These additives pose an ecotoxicological risk to marine organisms during plastic fragmentation (mainly in the seas). There are also uncertainties about the potential consequences of their long-term exposure to other substances, their combined effects, and the products of leakage into the biosphere (Ludovic *et al.*, 2017). Moreover, both the plastic production process and plastic waste incineration entail carbon dioxide emissions, affecting the environment and human health (CIEL, 2019).

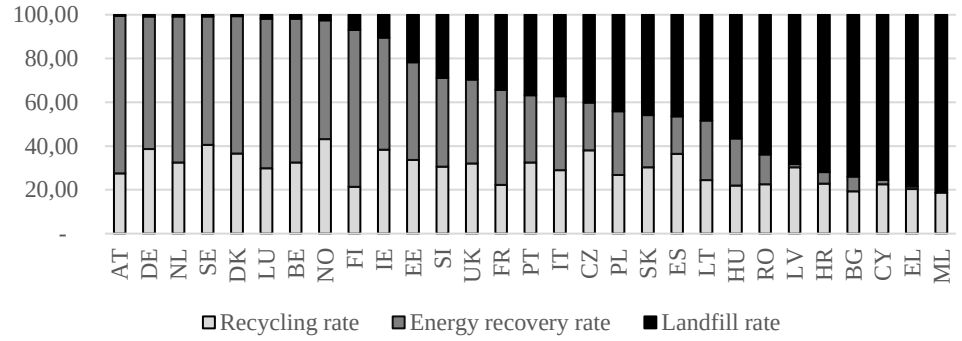
In response to the increasing pressure of human activities on ecosystems, scientists began to undermine growth concepts based on continuous growth in production, consumption, and the unlimited exploitation of resources (Meadows *et al.*, 1972; Rockström *et al.*, 2009). It was argued that the growth must be sustainable and not disturb ecosystems. Attempts have been made to address these challenges, but the results have not been satisfactory for a long time (MA, 2005). The following years brought conceptual development of the idea of circularity. It has attracted an expanding body of research and literature from different fields and geographical areas (Ghisellini *et al.*, 2016). The concept of circular economy emerged as a political and economic aim of many states and organizations.

The European Commission launched a first Circular Economy Action Plan in 2015 (COM/2015/614), identifying five priority sectors to speed up the transition along their value chain. To deal with the enormous plastic waste problem, the EU has adopted a different strategy (COM/2018/028). It aims at reducing the amount of plastic waste by creating the conditions under which the production of plastic products will be adapted to reuse needs, and recycling will be a cost-effective solution for businesses. EU goals in the CE area are reducing the amount of waste generated, maximizing recycling and reuse, limiting incineration to non-recyclable materials, and phasing out landfilling to non-recyclable and non-recoverable destruction.

In December 2019, European Commission announced the European Green Deal (COM/2019/640) - Europe's new plan for sustainable growth by turning climate and environmental challenges into opportunities and making the transition just and inclusive for all. It aims to boost the efficient use of resources by moving to a clean, circular economy, stopping climate change, revert biodiversity loss, and cutting pollution. One of the main building blocks of EDP is a new Circular Economy Action Plan (COM/2020/98) adopted in March 2020. It focuses on designing and producing a circular economy to ensure that the resources used are kept in the EU economy for as long as possible. Its priority is to reduce overpackaging and packaging waste, drive design for reusable and recyclable packaging and reduce the complexity of packaging materials.

A circular economy has become a strategic goal at the EU level both in environmental restrictions and because of its economic profits. However, some EU countries have previously recognized the needs and benefits of creating their national CE strategies. Consequently, leading plastic waste management indicators show a great diversity in implementing the CE model among the EU member states (chart 1). The leaders in plastics reuse (for recycling or energy recovery) are Austria, Germany, and the Netherlands. On the other side, some countries mainly landfill their plastic waste: Malta, Greece, or Cyprus (PEMRG, 2020).

Figure 1. *Dispose of plastic waste in EU countries (% of collected plastic waste, 2018)*



Source: *Own, based on PEMRG statistics (2020).*

The plastic waste recycling rate in the EU is improving every year and currently stands at 32,5%. However, it should be emphasized that this indicator refers only to the plastic waste collected for recycling and registered (the rest is not recyclable due to contamination, mixing, inability, or unprofitability of the recycling process).

Moreover, a significant volume of plastic waste is exported or hidden in untracked trade flows and illegal landfills. It has been estimated that less than 10% of the new plastic demands end up being recycled. As a result, only 6% of new plastic materials produced in the EU are derived from recycled plastics (the rest are losses in the recycling process, Material Economics, 2018; Plastics Europe, 2018). The pre-covid period can be summarised as follows: although positive trends are evident, the EU has been only at the beginning of the road to a circular economy in the field of plastics.

2.1 The Pandemic of Single-use Plastic Waste and Challanges for Recycling Industry

The COVID pandemic has brought new challenges (Khan *et al.*, 2020). They are related to (1) extra pressure, more plastic waste, mainly single-use which are mostly not recyclable (leading to inappropriate management strategies, including mobile incineration, direct landfills, and local burnings); (2) the implications of the lockdowns for the recycling industry: loss of valuable secondary raw material due to

shutting down/temporarily cease operating in many converting plants and the record low prices of virgin plastics resulting from the falling oil prices on world markets.

Extra pressure – more (the least desirable) plastic waste: The importance of plastic as a protector during the current pandemic is crucial. Devices used in hospitals are made (totally or partially) of plastic: respirators, thermometers, COVID-19 tests, personal protective equipment (PPE, such as face masks, gloves, clothing, aprons, caps, covers, glasses/goggles), syringes, tubes, oropharyngeal cannulas, suction probes, catheters, and many others (Czigány and Ronkay, 2020). The medical sector's demand for these products has increased significantly, as needs PPEs (mainly masks) purchased by the population in general (the global medical plastics market size during this COVID-19 pandemic is projected to grow from USD 25,1 billion in 2020 to USD 29,4 billion by 2021, with the largest share of medical disposables segment (Research and Markets, 2020).

A huge challenge associated with the massive use of PPEs is a greater volume of biomedical (non-recyclable) plastic waste and the disruption of the waste disposal system - they ought to be handled as hazardous waste. Still, its amount far exceeds the available capacity for its treatment (Klemeš *et al.*, 2020). Benson *et al.* (2021) estimate that globally, approximately 3,4 billion single-use facemasks/face shields are discarded daily because of pandemic (in Asia it is about 1.8 bln, in Europe 445 mln, in Africa 411 mln, in the Americas 624 mln, in Oceania 22 mln). Before the announcement of a global pandemic, occurrences of facemask litter were nearly negligible as a proportion of the total collected debris, rising to >0.8% internationally, with some nations increasing to >6% (for example, in October 2020, the United Kingdom estimated that facemasks accounted for >5% of all tagged litter, with gloves and wipes present at ~1.5%, respectively, Roberts *et al.,* 2021). There is a growing concern that these untreated terrestrially derived biomedical and domestic wastes can be redistributed into the environment and transported to the marine systems through runoff and atmospheric deposition, which invariably exacerbates the already plastic pollution problems (Fred-Ahmadu *et al.,* 2020).

Another pandemic challenge is the growth of municipal plastic waste, in particular single-use. This results from lockdown measures that have led to the growing demand for home-delivered food and groceries and many other products purchased online (with more people working from home and businesses digitizing their services). There has also been a change in consumers' views about the function of the single-use packaging, i.e., the hygiene and protection of the product are being perceived more strongly again. Understandably, the pandemic's beginning brought a slowdown even on the European plastic packaging market (rapid spread of COVID-19 pandemic has interrupted the supply chain of manufacturing industries, impacting the plastic packaging market as well).

However, the plastic packaging industry in the EU has gone up quite quickly. According to projections, it is expected to grow from USD 909 billion in 2019 to USD

1,013 billion by 2021—with the plastic segment leading the market (in 2018, plastic packaging was the most extensive application for plastics globally - representing around 30% of their total volume, Research, and Markets, 2020). A similar situation applies in the EU, where plastic packaging is the single largest end-use market for plastics (39,6% of plastic use).

The plastic packaging market in the EU is expected to register a CAGR (compound annual growth rate) of 4.4% during the period 2020 – 2025 (Research and Markets, 2021). The major drivers for the packaging industry include the increased demand for fast-moving consumer goods (purchased frequently consumed rapidly, priced low, and sold in large quantities), pharmaceutical packaging, and rising e-commerce sales.

Single-use plastics waste is a considerable challenge, both from an environmental and an economic perspective. They account for about 62% of the plastic waste in the EU. The vast majority (79%) accumulate in landfills or are burned off, increasing emissions and air pollution (Eurostat, 2021). The reason is that single-use plastics are designed to be used only once. They are usually very inhomogeneous and comprise a wide range of material, shape, color, and size types requiring separation - a costly, time and energy-intensive process which often leads to lower-quality materials. Appropriate and cost-effective technology is needed for this and consumer awareness of how to separate different types of plastic waste (Hestin, 2015; Material Economics, 2018). It is estimated that the economic losses resulting only from the single-use plastic packaging amount to 95% of their material value, which is between EUR 70 and 105 billion per year (EPRO, 2018).

The lockdowns: the implications for the recycling industry: While European manufacturers in the consumer plastic packaging market have been reaching their limits in terms of capacity, the other players from the plastics industry have been confronted with a considerable drop in demand. It should be noted that the European plastics industry is vast (it includes plastics raw materials producers, plastics converters, plastics recyclers, and plastics machinery manufacturers). The market sectors with the highest plastic converter demand are, packaging (consumer + industrial, 39,7%), building and construction (19,8%), automotive (10,1%), electrical and electronic (6,2%), household, leisure and sports (4,1%), agriculture (3,4%) and others (PEMRG, 2018; Eurostat, 2020).

The estimates of production for plastics in 2020 finds that at the global level, results remain stable (a slight decrease of 0.3% compared to 2019), but Europe's production decreased by more than 5%, which is a loss of 1 point of market share to 15% (China increased its plastics production and market share from 31 to 32% and the North American market share remained stable at around 19% of the global production). The decrease in demand was strongly driven by a decline in production in two main application sectors: industrial packaging (the amount of plastic used in the packaging sector decreased by 2.5% in 2020 compared to 2019) and automotive (production numbers decreased by more than 23%). The plastic demand remained stable only in

two sectors, consumer packaging and building/construction (Eurostat, 2021). The difficulties in the plastic sector are indicated by initial statistics and the entrepreneurs themselves (de Vet *et al.,* 2021). Before the coronavirus crisis, the top three concerns for plastics companies were selling prices, sales volume, and material costs. In 2020, selling prices became the top position (75%). The second and third main concerns are now suppliers' delivery capability (55%) and logistics (49%) – highlighting the effects that the shutdowns and other problems have had on plastics companies (PIE, 2020).

On the one side, various studies have reported that the environmental benefit arises from the lockdowns or restrictions of human activities (Le Quér *et al.,* 2020; NASA, 2020). It can therefore be deduced that benefits also occur as a result of lower production in the plastic sector (global plastic production absorbs 6% of the world's demand for oil) and lower CO2 emissions (CO2 emitted during plastics production represents around 20% of the chemicals industry's emissions EU-wide, EMAF, 2017).

Furthermore, the main trends indicate that the collection of "common waste" mainly remained unchanged - although the volume of consumer plastic waste has increased, the amount of commercial plastic waste has decreased. Unfortunately, this situation is not favorable for the recycling industry. Although public attention focuses on consumers' plastics waste discarded, the most valuable pare obtained are obtained from industrial sources (Van Fan, 2021) - primarily the automotive, construction, agriculture, and industrial packaging industries (industrial plastic waste is more homogeneous and less contaminated than consumer plastic waste). About 60% of companies use industrial plastic waste as input material, 16% rely exclusively on municipal, and the remainder uses both (Kirilyuk *et al.,* 2020). Therefore, lockdowns in industrial production have significantly reduced the supply of this high-value material (this recyclers' dependence on industrial sources suggests that the European recycling industry is still technologically undeveloped).

Social distancing measures have also restricted collection and sorting capacities. Many local authorities had to prioritize waste services to adapt to the changes in waste generation and staff shortage; civic amenity sites were closed, and on-demand collection was interrupted. (e.g., France has had to switch from separate to an eclectic collection of all household waste to adjust pickups to the reduced workforce available, resulting in a waste stream that is more difficult to recycle and a larger share of the valuable material dumped in landfill or incinerated. The collection has come to a standstill in Spain, Italy, and Eastern Europe (Tudball, 2020).

Although plastic recycling has been upswing before the pandemic, the European recycling industry faced numerous challenges. More than half of recycling companies indicated that their business had grown at a rate below GDP, stagnated, or even shrunk. The industry highlighted two main challenges: unstandardized and poor product recyclability and the volatility of markets and customer demands. The lockdowns have reduced the supply of high-value material from post-industrial plastic waste and lowered the price attractiveness of recyclates compared to virgin plastics.

Oil prices that have plunged in 2020 to their lowest level for two decades (15 dollars per barrel in April 2020) have led to a 30% reduction in virgin plastic prices. This has lowered recycled plastic consumption and increased pure plastic consumption (ICIS, 2021). Meanwhile, the calculations show that for 60 USD per barrel, only a few types of plastic can be recycled at a profit (Gao *et al.*, 2020).

In May 2020, Plastics Recyclers Europe announced that the European Plastics recycling industry was closing production due to the market developments caused by the COVID-19 pandemic. It was a risk that "plastics recycling will cease to be profitable, hampering the attainment of the EU recycling targets and jeopardizing the transition towards circular plastics. In such a case, recyclable plastic waste will have no alternatives but to be sent to landfill or incineration (plastics recyclers. EU, 2020)" At the beginning of 2021, the situation has begun to stabilize in terms of differences between the prices of virgin and recycled plastic.

2.2 Future Outlook - Avoiding a Plastic Problem in a Post-COVID-19 Time

Plastic is omnipresent in daily lives, but the growing amount of plastic waste and undeveloped recycling solutions pose a severe challenge. The pandemic has exacerbated those problems as it has led to a sudden shift in the hierarchization of values (i.e., where health is considered a value despite environmental care). The exact impacts are challenging to quantify as the COVID-19 pandemic is ongoing. The long-term effects should be expected (for example, the adaptations arising from lifestyle changes in behavior are yet to be assessed). COVID-19 has highlighted the shortcoming of responding to an emergency and has slowed down a global battle to reduce plastic waste pollution. The pandemic crisis has affected the European recycling industry that required investment in new technologies even before the pandemic (they will probably be postponed). It has also intensified a price war between recycled and new plastic as the lower oil demand has cut its price (Vanapalli *et al.*, 2021; Silva *et al.*, 2020).

From the other side, the crisis could serve as an opportunity to restructure and enhance the robustness of the current waste management system. It was one of the reasons why recycling became one of the sectors supported by the EU Recovery Plan (in May 2020, the European Commission unveiled a €750 billion COVID-19 recovery plan to revitalize the EU economy). It is viewed as an opportunity to invest in the European Green Deal - Europe's new strategy for sustainable growth. The disruption caused by COVID-19 can therefore act as a catalyst for short-term and long-term changes in plastic waste management practices.

The circular economy can play a vital role in tackling the plastic waste issue and shaping an economic recovery in the post-pandemic time. It is essential to safeguard the positive developments within this market which is necessary to reduce Europe's use of virgin plastics and, therefore, for the survival of the secondary raw materials market and further investments in the recycling sector.

References:

Ambrogi, V., Carfagna, C., Cerruti, P., Marturano, V. 2017. Additives in Polymers. InȘ Jasso-Gastinel, C.F., Kenny, J.M. (Eds.). Modification of Polymer Properties, Elsevier.

Bel, J., Marengo, P. 2021. The impact of the COVID 19 pandemic on the municipal waste management systems. ACR+, Brussels.

Benson, N.U., Bassey, D.E., Palanisami, T. 2021. COVID pollution: impact of COVID-19 pandemic on global plastic waste footprint. Heliyon, 7(2).

CIEL. 2019. Plastic & climate: The hidden costs of a plastic planet. Center for International Environmental Law. Washington, DC. Retrieved from: https://www. ciel.org/wp-content/uploads/2019/05/Plastic-andClimate-FINAL-2019.pdf.

Czigány, T., Ronkay, F. 2020. The coronavirus and plastics. Express Polymere Letters, 14.

de Vet, J.M. et al. 2021. Impacts of the COVID-19 pandemic on EU industries. Study Requested by the ITRE Committee, Luxembourg.

Ellen Mac Arthur Foundation (EMAF). 2017. The new plastics economy - re-thinking the future of plastics & catalysing action. Retrieved from: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/NPEC-Hybrid_English_22-11-17_Digital.pdf.

European association of plastics recycling and recovery organizations (EPRO). 2020. Retrieved from: www.epro-plasticsrecycling.org.

European Commission. 2015. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Closing the loop - An EU action plan for the Circular Economy, Brussels.

European Commission. 2018. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A European Strategy for Plastics in a Circular Economy, Brussels.

European Commission. 2019. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal, Brussels.

European Commission. 2020. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A new Circular Economy Action Plan For a cleaner and more competitive Europe, Brussels.

Fred-Ahmadu, O.H., Bhagwat, G., Oluyoye, I., Benson, N.U., Ayejuyo, O.O., Palanisami, T. 2020. Interaction of chemical contaminants with microplastics: principles and perspectives. Science of the Total Environment,1.

Gao, W., et al. 2020. Plastics recycling: using an economic feasibility lens to select the next moves. McKinsey's Report. Retrieved from: https://www.plasticsrecyclers.eu/post/plastics-recyclers-cease-production.

Geyer, R., Jambeck, J.R., Law, K.L. 2017. Supplementary Materials for Production, Use, and Fate of All Plastics Ever Made. Science Advances, 3(7).

Ghisellini, P., Cialani, C., Ulgiati, S. 2016. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. Journal of Cleaner Production, 114.

Grima, S., Dalli Gonzi, R., Thalassinos, I.E. 2020. The Impact of COVID-19 in Malta and its Economy and Sustainable Strategies. Available at SSRN: https://ssrn.com/abstract=3644833.

Hestin, M., et al. 2015. Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment. Rettrieved from: http://www.plasticsrecyclers.eu/sites/default/files/BIO_Deloitte_PRE_Plastics%20Recycling%20Impact_Assesment_Final%20Report.pdf.

ICIC. 2021. Independent Commodity Intelligence Services. Retrieved from: www.icis.com.

Khan, S., Rabbani, R.M., Thalassinos, I.E., Atif, M. 2020. Corona Virus Pandemic Paving Ways to Next Generation of Learning and Teaching: Futuristic Cloud Based Educational Model. Available at SSRN: https://ssrn.com/abstract=3669832.

Kirilyuk, M., Mayer, M., Simons, T.J., Witte, C. 2020. Open interactive popup The European recycling landscape-the quiet before the storm? Mckinsey's articles. Retrieved from: https://www.mckinsey.com/industries/chemicals/our-insights/the-european-recycling-landscape-the-quiet-before-the-storm.

Klemeš, J.J., Van Fan, Y., Tan, R.R., Jiangc, P. 2020. Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. Renewable and Sustainable Energy Reviews, 127.

Le Quér, C., et al. 2020. Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement. Nature Climate Change, 10.

Ludovic, H., Alexandre, D., Ika, P., Camille, L., Ronan, J., Philippe, S., Guillaume, D. 2017. Occurrence and effects of plastic additives on marine environments and organisms: A review, Chemosphere, 182.

Material Economics. 2018. The circular economy - a powerful force for cli-mate mitigation. In: Enkvist, P.A., Klevnäs, P. (Eds.). Retrieved from: https://media.sitra.fi/2018/06/12132041/the-circular-economy-a-powerfulforce-for-climate-mitigation.pdf.

Meadows, D.H., Meadows, D.L., Randers, J., Behrens III, W.W. 1972. The Limits to Growth. New York, Universe Books.

Millennium Ecosystem Assessment (MA). 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington DC.

NASA Satellite data show 30 percent drop in air pollution over northeast U.S. 2020. Retrieved from: www.nasa.gov/feature/goddard/2020/drop-in-air-pollution-over-northeast.

PIE. 2020. Plastics Information Europe - A flash survey on business performance to gain insight into business trends in the European plastics industry during the coronavirus pandemic. Retrieved from: https://pieweb.plasteurope.com/default.aspx?pageid=311.

PlasticsEurope Market Research Group (PEMRG). 2021. Plastics - the Facts 2020. An analysis of European plastics production, demand, and waste data.

Research and Markets. 2020. Global Medical Plastics Market Outlook 2020-2021: Impact Assessment of the COVID-19 Pandemic. C&EN.

Roberts, K.P., et al. 2020. Lockdown Litter: A critical analysis of global COVID-19 PPE litter and 2 measures for mitigation. Research Square. Retrieved from: https://www.researchsquare.com/article/rs-134183/v1.

Rockström, J.S., Noone, W., Persson, K., et al. 2009. A safe operating space for humanity. In Nature, 461(24).

Silva, J.C., et al. 2020. Rethinking and optimising plastic waste management under COVID-19 pandemic: policy solutions based on redesign and reduction of single-use

plastics and personal protective equipment. Science of the Total Environment, 742.

The report of Research and Markets. 2020. COVID-19 Impact on packaging market by material type, application, and region global forecast to 2021.

The report of Research and Markets. 2020a. Global Medical Plastics Market Outlook 2020-2021: Impact Assessment of the COVID-19 Pandemic.

The report of Research and Markets. 2021. E-commerce plastic packaging market - growth, trends, covid-19 impact, and forecasts (2021-2026).

Tudball, M. 2020. Europe's recycling markets at risk of post-consumer bale shortages because of coronavirus. ICIS. Retrieved from: https://www.icis.com/explore/resources/news/2020/04/09/10494942/europe-s-recycling-markets-at-risk-of-post-consumer-bale-shortages-because-of-coronavirus.

Van Fan, Y., Jiang, P., Hemzal, M., Klemeša, J. 2021. An update of COVID-19 influences on waste management. Science of the Total Environment, 2.

Vanapalli, K.R., et al. 2021. Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic. Science of the Total Environment, 750.

Watkins, E., Brink, P. 2017. Marine Litter: Socio-Economic study. Brussels: A report by IEEP for UNEP.