Impact of COVID-19 Pandemic on Plastic Waste Management: A Bibliometric Analysis by using Dimension.ai

Nezha Mejjad[1], Rida Farhan[2], Nabil Chakhchaoui[3,4], Nisha Shankhwar[5], Aynur Unal[6], Hari Murthy[7], Prosenjit Saha[8], Omar Cherkaoui[4] and Sabu Thomas[9]

[1]*Laboratory of Applied Geology Geomatics and Environment, Faculty of Sciences Ben M'Sick, Hassan II University, Casablanca, Morocco*

[2] *Laboratory of Physics of Condensed Matter (LPMC), Faculty of Sciences Ben M'Sick, Hassan II University, Casablanca, Morocco*

[3]*BGIM Laboratory, Higher Normal School (ENS), Hassan II University, Casablanca, Morocco*

[4]*REMTEX Laboratory, Higher School of Textile and Clothing Industries, Casablanca, Morocco*

[5]*Department of Physics, Indian Institute of Technology Guwahati, Guwahati, India*

[6]*Digital Monozukuri, Palo Alto, California, United States of America*

[7]*Department of Electronics and Communication Engineering-CHRIST((Deemed to be University), Kanmanike, Bengaluru, India*

[8]*Centre for Interdisciplinary Sciences, JIS Institute of Advanced Studies and Research Kolkata, JIS University, Kolkata, India*

[9]*School of Chemical Sciences, Mahatma Gandhi University, Kerala, India*

Keywords: Bibliometric study, dimensions.ai, COVID-19, waste management, plastic waste, facemask.

Abstract: Plastic waste is one of the most pressing environmental problems causing biodiversity loss and threatening human well-being. Globally, many actions and strategies have been proposed, and efforts have been made to minimize plastic production and consumption to fight against plastic pollution. This paper aimed to measure the interest in increasing covid-19 related plastic waste, including medical-grade plastic (PPE) and packaging food waste, through analyzing the related scientific production between 2019 and 2021. We utilized the information system "dimension.ai" to carry out this analysis, which showed that the most studied topics are related to the psychological impacts of COVID-19 and waste disposal management. The effect of the COVID-19 pandemic across the end of the life cycle of several plastic products is assessed as well in the present study. The abrupt change in the structure and quantity of waste underlines the need for an effective, flexible waste management method to tackle plastic waste issues, especially during the COVID-19 era. Multiple strategies and approaches are proposed to minimize the likely effect of the pandemic on global waste management systems.

1 INTRODUCTION

The present Coronavirus has made rapid progress, as seen in the worldwide statistics (MacKenzie, 2020). One of the immediate ecological consequences of the epidemic is the rapid rise in the request and usage of disposable products such as personal protective equipment (PPE), including disposable masks and gloves (Mejjad et., 2021). The general use of protecting gear during COVID-19 created significant upstream supply chain disruptions worldwide (Rowan et Laffey 2020; Guan et al., 2020), making waste management and elimination processes more complicated and challenging. However, plastic presents societal benefits for humans and used since approx—1600 BC (Hosler et al., 1999). Then, plastics constitute a crucial component of the range of used materials in modern society as all aspects of our daily lives comprise plastics or rubber (e.g. clothing and footwear).

Besides, plastics provide many public health goods and benefits such as medical and surgical equipment and facilities also clean drinking water supplies (Andrady et al., 2009). Therefore, due to the multiuse of plastic and its application importance for our daily life, we face tremendous obstacles to eliminating plastic waste while preserving our current lifestyles. Currently, the use of face masks is

Mejjad, N., Farhan, R., Chakhchaoui, N., Shankhwar, N., Unal, A., Murthy, H., Saha, P., Cherkoui, O. and Thomas, S.
Impact of COVID-19 Pandemic on Plastic Waste Management: A Bibliometric Analysis by using Dimension.ai.
DOI: 10.5220/0010740700003101
In *Proceedings of the 2nd International Conference on Big Data, Modelling and Machine Learning (BML 2021)*, pages 538-545
ISBN: 978-989-758-559-3

mandatory to prevent the transmission of COVID-19. Consequently, plastics are gaining more importance as the facemasks are mainly made by plastics (polypropylene) (Benson et al., 2021), resulting in a substantial plastic waste quantity that may be discarded everywhere (Mejjad et al., 2021). However, during COVID-19, single-use plastics like surgical masks and plastic cups rare became vital in supporting society.

Nevertheless, plastics and their processing are still a significant global problem as they are also contaminated with bacteria and should be dealt with as toxic waste. Before the pandemic onset, plastic waste management was still considered a considerable environmental problem due to increasing worries about increasing the plastic pollution rate in earth and ocean ecosystems (Verma et al., 2016; Wright et al., 2017; Rajmohan et al., 2019). The global waste management system has not been able to accord satisfactorily with current plastic junk, and the amount of trash during a pandemic is set to increase, which will impact negatively the management system of waste, medical capacity, and existing health care.

Eventually, the deposit of medical waste in uncontrolled areas can directly affect the environment and health through soil contamination and groundwater. During incineration, if they do not perform proper filtering, the air can also be polluted and cause disease for the surrounding population. Thus, it is mandatory to consider environmental impact assessment of used methods for waste treatment, particularly medical-related waste.

Ferguson et al., 2020; anticipate the pandemic to rise in the second quarter of 2020 when the request for heat decreases in the generality of the northern hemisphere due to warmer climate conditions because the issue is linked to the incompatibility among the supply and demand for the temperature recovered. In the context of the world is experiencing through the large spread of the epidemic, we may be faced with the option of setting priorities for the efficient elimination of toxic waste, even though most of the waste-to-energy facilities may not be in a suitable location for energy recovery. Xu et al., 2019 have summarised the possible options for recovery of waste heat and demonstrates the obstacles preventing large implementation of recovery of this heat at the low temperature. However, it remains unclear whether systems can be designed for optimal energy recovery to be installed on short notice or carry the mobile units to manage quickly rising amounts of medical junk.

We realize a significant growing demand for personal protective equipment (PPE), which comprises various plastic and rubber products, for our ongoing struggle to combat COVID-19. So, this current work sought to (i) measure the interest in increasing covid-19 related plastic waste, including medical-grade plastic (PPE) and packaging food waste; and to (2) provide a point of view on how the disruption affected by Coronavirus can act as a catalyst for the time being changes in plastic waste management practices worldwide.

2 METHOD AND MATERIAL

2.1 Bibliometric Analysis Tool (VOSviewer)

In the bibliometric study of the present paper, the publications were recorded from the information system "dimensions.ai," which covers many documents and allows easy downloading and exploration of datasets. Dimensions.ai includes patents, awarded grants and clinical trials together with publication (conferences proceeding, papers, chapter book, and books), policy reports and Altmetric attention data (Hook et al., 2018). A number of bibliometric studies were carried out by using demensions.ai as source for analyzing datasets (García-Sánchez et al., 2019; Hook et al., 2020 & 2021; Martin Martin Martín-Martín et al., 2021).

The research fields related to plastic, facemasks and COVID-19 are mainly "Medical and health sciences", "clinical sciences", "Engineering", among others fields, as shown in the figure. This reflects that the full concern and the main scientific contribution related to COVID-19 and facemasks is given to health and medical sciences and clinical sciences.

2.2 Literature Review

We conducted a literature search using available online databases and internet search tools such as ResearchGate, Google Scholar Science Direct, Web of Science (WoS) to perform a bibliographic database based on peer-reviewed scientific publications, policy and technical reports. The literature search was initially focused on the studies related to the influence of the covid-19 on plastic waste, secondly PPE use rate and related waste generation among healthcare workers and management of COVID-19 related waste. In this sense, more than 80 peer-reviewed papers, technical and policy reports were consulted and investigated.

3 RESULTS AND DISCUSSIONS

3.1 Bibliometric Analysis using VOSviewer

6030 publications of recorded publications from dimensions.ai information system that corresponding to our search query for Facemask-COVID-19 include articles (N=4636 ; 76.88%); preprint (N=728; 12.08%); chapter (N=518 ; 8.59%) ; proceeding (N=120 ; 1.69%) ; edited book (N=102 ; 1.69) ; monograph (N=32 ; 0.53%); While 5.60 % (338) were policy documents, 1.22% were patents (74); 0.48% clinical trial (29); and 0.48% were datasets (29). A total of 4636 scientific research work were published in more than 122 journals, mostly in medRxiv (N= 423; 9.12%), The SSRN Electronic Journal (N=162; 3.49%) ; International Journal of Environmental Research and Public Health (N= 124; 2.67%) ; PLOS ONE (N=118; 2.54%).

The visualization map for publications carried out between 2020 and 2021 (Fig.1) shown the leading scientific publication topics for Facemask-COVID-19. The circle/node size defines the number of published studies related to the keywords, while the line represents the connection between every keyword. The link between every keyword is strong when the line is short.

The analysis of the keywords map/visualization map indicates that the most recurrent keywords are "SARs CoV" (co-occurrence : 1147); "mask" (co-occurrence: 1346); "patient" (co-occurrence: 1244); "knowledge" (co-occurrence: 462) which present biggest sizes. The most studied topics related to COVID-19 and facemasks management are the survey research aimed to understand the psychological impact of the COVID-19 cluster (Red circle; 130 items/keywords), followed by waste disposal management cluster (Green circle; 101 items/keywords), covid-19 related symptoms cluster (Blue circle: 78 items/keywords), covid-19 transmission way/mode cluster (Yellow circle: 69 items/keywords), and facemasks types and efficiency cluster (Purple items/keywords).

The occurrence of keywords "knowledge" and "questionnaire" is due to the lack of knowledge regarding the COVID-19 related topics, which lead to explore them through using "survey research". For example, during the lockdown, it was not possible to carry out a survey in the field to understand the people feeling toward the propagation of this virus (Mejjad et al., 2021) or understanding the people behaviour toward the use and management of facemasks (Mejjad et al., 2021) so almost all studies were based on online surveys.

In addition, waste disposal management (WSM) has been challenging since the beginning of the covid-19, especially with the increase of discarded personnel protective equipment, which increased the concern about the WSM among scientists.

The density map shows that the circles "patient", "participant", "SARs COV", "mask, "challenge" and "knowledge" presents high density indicating that these keywords have a solid association with other links as they occupied the brown area. Besides, the higher density means that the keywords situated in the brown area are more developed and well studied. The other keywords occupying the clear area (orange and yellow) are less studied or investigated.

3.2 The Influence of the Covid-19 on Plastic Waste

While governments and institutions are looking for alternatives after the Chinese government decided to reduce its solid waste imports to zero early in 2020, news began pouring in China about the new Coronavirus. Within a few weeks, the whole world was under the weight of the epidemic, which imposed a range of sanitary measures such as social distancing, restricted movement across borders, shut down of all human activities. Consequently, these taking measures have caused the temporary suspension of circular economy and green economy-related projects and made the waste recycling sector return its accounts. Then, this sector is expected to face unprecedented losses as a result of declining quantities entering the waste collection systems, disruptions related to transportation procedures, diminishing potential demand for materials, excluding packaging waste, and lower long-term investments, in addition to buyers abandoning sustainability measures due to their preoccupation with other concerns. The world currently produces about 450 million tons of plastics a year (Ritchie, 2018). The percentage of plastic waste recycling in the European Union is 30 percent, 22 % in China, and in the United States, it drops to 8.4 percent (Ritchie, 2018).

The pandemic diffusion has contributed to significant difficulties in treating hazardous PPE waste since the general population also uses such medical equipment. Between 20 January and 31 March, there was an estimated 207 kt of accrued medical waste in all of China. For example, medical junk increased from the usual level of 40 t/d to reach a peak around 240 t/d, override the extreme burning

capacitance of 49 t/d in Wuhan city (Tang, 2020). The burning cost of harmful medical junk in China is ranged from 281.7 to 422.6 USD /t compared to 14.1 USD/t for municipal solid waste (Klemes et al., 2020). Figure 2 demonstrates the trends of the waste stream in comparison to treating capacitance. Treating systems designed for the amount and qualities of the waste under usual conditions have to adapt to the sudden changes that bring irregular operations. Technology research is necessary to ensure that these systems are fit to manage the pandemic's dynamic existence and development. Another concern is that there is still a gap of knowledge regarding the virus itself because it is unclear which products and techniques will be required to deal with the epidemic.

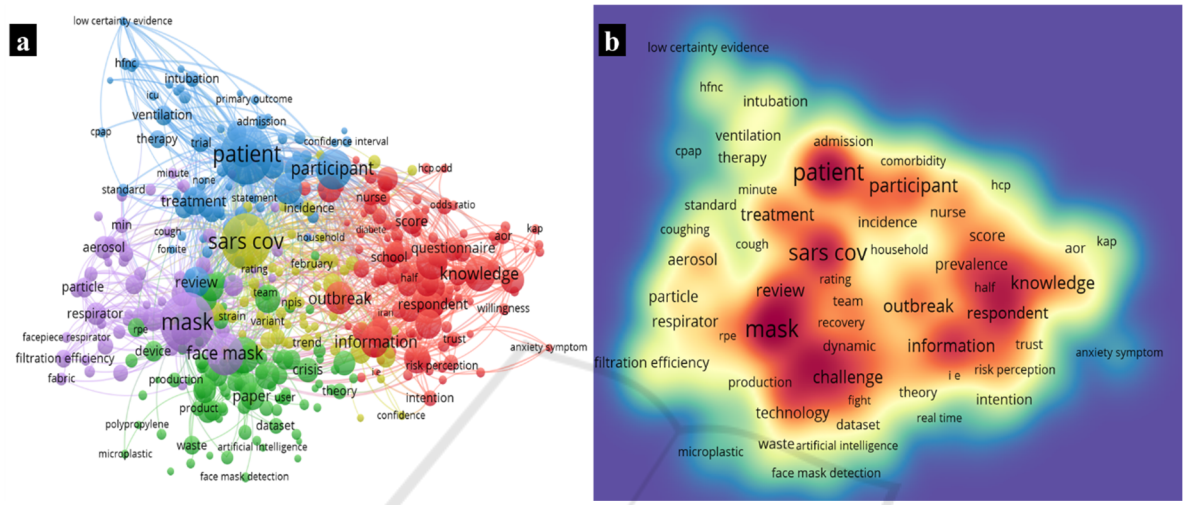

Figure 1: Visualisation map (a); density map (b).

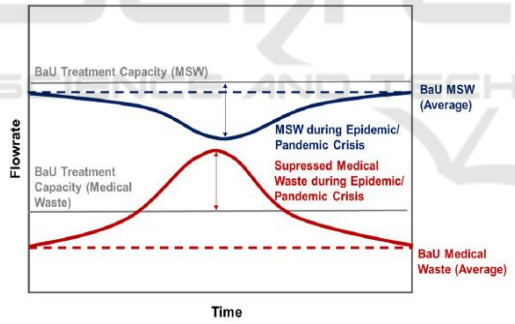

Figure 2. The predicted increase in medical and MSW waste flow along with the coronavirus crisis (Klemes et al., 2020).

3.3 PPE Use Rate and Related Waste Generation among Healthcare Workers

The COVID-19 pandemic has shown the primordial role of plastic as a protector of human life where PPEs, including gloves, facemasks, and packing all sorts of materials, have played a crucial role in reducing the spread of the virus among humans. According to Kalina and Tilly 2020, across the globe, the consumption of facemasks and medical gloves during the COVID-19 per month are 129 billion and 65 billion, respectively. At the same time, the World health organisation has reported that the demand for PPE is projected to increase and reach 89 million facemasks, 76 million gloves and 1.6 million goggles per month as a part of sanitary and safety measures. Besides, it was estimated that the disposable mask market has increased from about $800 million during 2019 to $166 billion in 2020. On the other hand, the market size of plastic packaging is projected to significantly increase because of pandemic response and pass from $909.2 billion recorded in 2019 to 1012.6 billion by 2021, with an annual growth rate of 5.5% (Business insider, 2020). Accordingly, this high, increasing rate of PPE usage during the COVID-19 is due mainly to awareness rise among healthcare workers where the adherence rate of PEEs usage was about 85% in COVID-19 wards in a study carried out in Hospital University in Germany (Neuwirth et al., 2020).

Table 1 below displays the estimated medical waste generated per day before and during the pandemic in different cities worldwide and an estimated quantity of generated medical waste worldwide (Liang et al., 2021). The generated medical waste in selected cities is six times higher during COVID-19 compared with before COVID-19

(e.g. Manila (the Philippines, Jakarta (Indonesia); Kuala Lumpur (Malaysia)), while worldwide, the M.W. output has increased from 200t/day on 22 February to 29 000 by the end of September 2020. This increase is mainly related to increased daily generated healthcare waste because of the significant increase in COVID-19 cases and the number of beds in hospitals where the average values of healthcare waste increased from 2.5kg/bed/day to 3.5/bed/day.

Table 1: Estimated values of generated Medical waste throughout some countries around the world (tonnes).

Cities worldwide	Before COVID-19	During COVID-19	References
Wuhan (China)	40t/day	247t/day	Wardani & Azizah, 2020
Manila (Philippines)	47Mt/day	280t/day	ADB, 2020
Jakarta (Indonesia)	35Mt/day	212t/day	ADB, 2020
Kuala Lumpur (Malaysia)	35Mt/day	210t/day	ADB, 2020
Bangkok (Thailand)	27Mt/day	160t/day	ADB, 2020
Ha Noi (Vietnam)	26Mt/day	154t/day	ADB, 2020
Catalonia (Spain)	275/month	1200t/month	ACR, 2020
Tehran (Iran)	52-74t/day	80-100t/day	Sangkham, 2020
South Korea	-	By mid-July 2600t	MoE Korea, 2020
Worldwide	200t/day	29000 t/day	Liang et al., 2021

3.4 MSW Handling and Disposal Procedures before and during the Epidemic

Figure 3 compares the management and mismanagement of COVID-19 related waste impact on the environment and shows that the mismanaging and mixing of hazardous waste with domestic waste disturb the processes of MSW, which may represent environmental threats to biodiversity and coastal areas. Through Figure 3, we can clearly show how the COVID-19 pandemic has impacted waste treatment and disposal, where during this pandemic, all kinds of waste are mixed, making the treatment and recycling of this waste impossible. Instead, good management of Covid-19 related waste allows safe collection and disposal of municipal and medical waste.

It is worthily mentioned that household waste during this pandemic is mixed with PPE, such as single-use facemask that could be infected (Mejjad et al., 2021), which means that this waste will be treated by incineration as it cannot be reused, recycled for industrial, agricultural or practical causes (DEFRA, 2014)]. Consequently, these situations negatively impact the recycling industry and programs and increase the quantity of waste received by landfills that exceed the capacity of the waste management facilities, as reported in many countries around the world.

4 CONCLUSION

The bibliometric analysis showed an increasing trend toward studying medical waste and the management approach to reduce the PPE associated risk. However, the studies carried out on psychological effects of COVID-19, and its origin is still well developed and investigated compared to COVID-19 related impact on the environment.

This review study shows that medical waste has dramatically grown worldwide during the COVID-19 pandemic. This increasing trend calls for better control (in terms of medical waste monitoring, care and disposal) to enhance performance in medical waste treatment. Therefore, Medical waste presorting and disinfection should be promoted and designed to advance their future recyclability.

It is required to establish new business models for plastic waste selection, collection and sorting. These processes and exposure to hazardous waste are among the critical barriers facing the economics of mechanical recycling for recycling companies. Besides, forging local initiatives seems to be a suitable solution for rebuilding confidence in the safety of separated waste and preparing clean and homogeneous plastic supplies for recycling companies.

Consumables can be made from biomass resources, compostable plastics or bio-degradable.

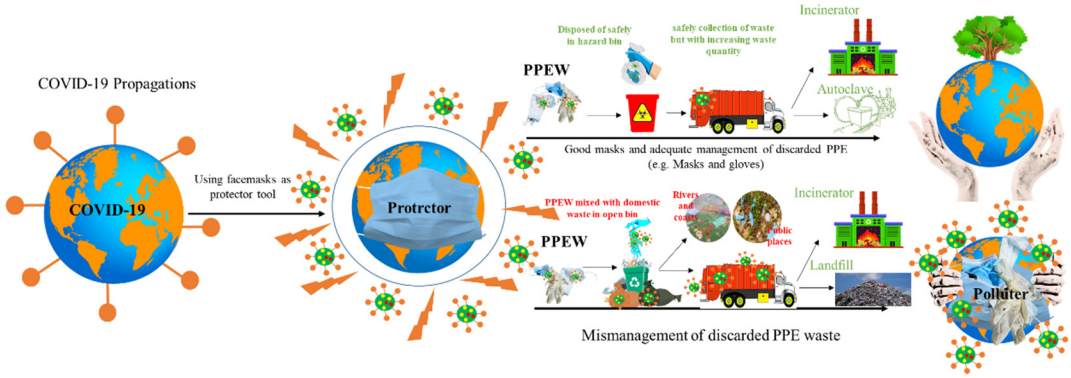

Figure 3: Management and mismanagement of COVID-19 related waste (PPEW Personal Protective equipment waste). (Credit: Nezha MEJJAD)

"Biodegradable" plastics may be decomposed into harmless, minor molecules with the action of existing organisms in the normal environment. In order to break down "compostable" plastics into simpler chemical compounds, composting facilities under regulated conditions (e.g. additional nutrients and certain temperatures) are required. Polylactide (PLA) (Kulkarni & Anantharama, 2020) is a compostable bioplastic manufactured from fermented starch sugar. Many biomass products, such as cellulose, chitosan, cotton, and lignin, can also be used to produce biodegradable materials. Indeed, there is also a need for better marking and guidelines for safe biodegradables and compostables, which is the same with plastic recycling.

Adopting and helping to spread the circular economy approach based on minimizing, reusing, and recycling philosophy will reduce the daily amount of received plastics junks by rivers and coasts and minimise greenhouse gas. Also, there is a need to advocate corporations to respect their promises to minimise plastic waste and urge them not to lose sight of longer-term environmental goals. More concern also needs to be addressed to the plastic waste management methods and techniques through developing technologies and promoting scientific research to win the battle against plastic waste. Managing sufficiently plastic waste sounds much more complicated than managing COVID-19 which means that all actors, including governments, NGOs, industry, academics, and the public, must win this battle. Thus, working together to build synergistic methods is an urgent need for conserving both earth and marine ecosystem services and healthy life, but this can only be realised by adopting a constructive action and behaving more actively for a better environment and life.

ACKNOWLEDGEMENTS

This research paper has been made possible thanks to the Dimensions.ai database.

REFERENCES

ACR., 2020. La Agencia de Residuos de Cataluña ha establecidodiferentes opciones para tratar los residuos sanitarios en el pe-riodoCOVID-19. Available online at the website of . http://residus.gencat.cat/es/actualitat/noticies/detall/residus-sanitaris-COVID19-00001 (Accessed 11 June 2020).

ADB (Asian Development Bank);, 2020. Managing Infectious Medical Waste during the COVID-19 Pandemic.https://www.adb.org/publications/managing-medical-waste-covid19.

Andrady, A. L., & Neal, M. A., 2009. Applications and societal benefits of plastics. *Philosophical transactions of the Royal Society of London. Series B, Biological Sciences*, 364(1526), 1977–1984. https://doi.org/10.1098/rstb.2008.0304.

Benson, N.U.; Fred-Ahmadu, O.H.; Bassey, D.E.; Atayero, A.A., 2021. COVID-19 pandemic and emerging plastic-based personal protective equipment waste pollution and management in Africa. *J. Environ. Chem. Eng.*, 9, 105222.

Business Insider, 2020., COVID-19 impact on packaging market by material type, application and region-global

forecast to 2021., https://markets.businessinsider.com/news/stocks/covid-19-impact-on-packaging-market-by-material-type-application-and-region-global-forecast-to-2021-1029187123.

DEFRA-Department for Environment Food & Rural Affairs, Government of U.K., 2014. Energy recovery for residual waste: A carbon-based modelling approach.

Ferguson, NM., Laydon, D., Nedjati-Gilani, G., Imai, N., Ainslie K, Baguelin M, Bhatia S, Boonyasiri A, Cucunubà, Z., Cuomo-Dannenburg, G., Dighe, A., Dorigatti, I., Fu, H., Gaythorpe, K., Green, W., Hamlet, A., Hinsley, W., Okell, LC., van Elsland, S., Thompson, H., Verity, R., Volz, E., Wang, H., Wang, Y., Walker, PGT., Walters, C., Winskill, P., Whittaker, C., Donnelly, CA., Riley, S., Ghani, AC., 2020. Reports 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand. London, UK: *Faculty of Medicine, Imperial College*., https://doi.org/10.25561/77482.

García-Sánchez, P., Morab, A.M., Castilloc, P.A., Pérez, I.J., 2019. A bibliometric study of the research area of video games using Dimensions.ai database. 7th International Conference on Information Technology and Quantitative Management (ITQM2019). *Procedia Computer Science.* 737-744.

Guan, D., Wang, D., Hallegatte, S. et al. 2020. Global supply-chain effects of COVID-19 control measures. *Nat Hum Behav*. 4, 577–587. https://doi.org/10.1038/s41562-020-0896-8.

Hook, D. W., Porter, S. J., and Herzog, C., 2018. Dimensions: building context for search and evaluation. *Front. Res. Metrics and Analytics* 3. doi:10.3389/frma.2018.00023

Hook, D., Porter, S., and Porter, S., 2020. How COVID-19 is changing research culture. *Report. Digital Science.*

Hook, W.D ., Porter S. J., Draux, H., and Herzog, C.T., 2021. Real-Time Bibliometrics: Dimensions as a Resource for Analyzing Aspects of COVID-19. *Front. Res. Metr. Anal.*

Hosler, D.; Burkett, SL.; Tarkanian, MJ., 1999. Prehistoric polymers: rubber processing in ancient mesoamerica Science.; 284 (5422):1988-91. DOI: 10.1126/science.284.5422.1988.

Kalina, M., Tilley, E., 2020. "This is our next problem": Cleaning up from the COVID-19 response. *Waste Manag*. 108:202-205.

Kulkarni, B.N., Anantharama, V., 2020. Repercussions of COVID-19 pandemic on municipal solid waste management: Challenges and opportunities, *Science of The Total Environment.* 743, 140693. https://doi.org/10.1016/j.scitotenv.2020.140693.

Klemes, J.J., Fan, Y.V., Tan, R.R., Jiang, P. 2020. Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19, *Renew. and Sustabl. Energy Reviews*. 127,109883. https://doi.org/10.1016/j.rser.2020.109883.

Liang, Y., Tan, Q., Song, Q., Li, J., 2021. An analysis of the plastic waste trade and management in Asia Waste Manag., 119, pp. 242-253.

MacKenzie, D., 2020. Covid-19 goes global, *NewScientist* 245,7.https://doi.org/10.1016/S02624079(20)30424-3.

Martín-Martín, A., Thelwall, M., Orduna-Malea, E. et al., 2021. Google Scholar, Microsoft Academic, Scopus, Dimensions, Web of Science, and OpenCitations' COCI: a multidisciplinary comparison of coverage via citations. *Scientometrics* 126, 871–906. https://doi.org/10.1007/s11192-020-03690-4

Mejjad, N., Cherif, E.K., Rodero, A., Krawczyk, D.A., El Kharraz, J., Moumen, A., Laqbaqbi, M., Fekri, A., 2021. Disposal Behavior of Used Masks during the COVID-19 Pandemic in the Moroccan Community: Potential Environmental Impact. *Int. J. Environ. Res. Public Health*, 18, 4382. https://doi.org/10.3390/ijerph18084382.

Mejjad, N., Yaagoubi, H., Gourmaj, M., Moumen, A., Chakhchaoui, N., Farhan, R., Refat Jahan, Md. R., In the proceeding of the 3rd Edition of the International E-Conference on "Quantitative and Qualitative Approach and Techniques for Applied Sciences" (Kenitra, Morocco, July 17 - 18, 2021). SHS Web of Conferences 119(2021):8. https://10.1051/shsconf/202111907007.

Ministry of Environment of South Korea (MoE Korea). *PressRelease, Minister of Environment 2020*, Check the Manage-ment of Wastes Related to COVID-19 cited in Liang et al., 2021.

Neuwirth, C., Gruber, C., & Murphy, T., 2020. Investigating duration and intensity of Covid-19 social-distancing strategies. *Sci Rep* 10, 20042; https://doi.org/10.1038/s41598-020-76392-9.

Rajmohan, KVS., Ramya, C., Viswanathan, MR., Varjani, S. 2019. Plastic pollutants: effective waste management for pollution control and abatement, *Current Opinion in Enviro. Science & Health* 12,72–84. https://doi.org/10.1016/j.coesh.2019.08.006.

Ritchie, H., 2018. Plastic pollution. Available at https://ourworldindata.org/faq-on-plastics.

Rowan, N. J., & Laffey, J. G., 2020. Challenges and solutions for addressing critical shortage of supply chain for personal and protective equipment (PPE) arising from Coronavirus disease (COVID19) pandemic—case study from the Republic of Ire-land. *Sci. Total Environ*, 725, 138532.

Sangkham, S., 2020. Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia. *Case Studies in Chemical and Environmental Engineering*.https://doi.org/10.1016/j.cscee.2020.100052.

Tang, W., 2020. The medical waste related to COVID-2019 is cleaned up every day—the medical waste treatment market needs to be standardised. 21st Century Business Herald; accessed 08.04.2020, www.21jingji.com/2020/3-12/xNMDEz OD-FfMTU0MjIxNQ.html.

Verma, R., Vinoda, K.S., Papireddy, M., Gowda, ANS., 2016. Toxic pollutants from plastic waste- *A review, Procedia. Environ. Sci.*, 35,701–708. https://doi.org/10.1016/j.proenv.2016.07.069.

Wardani, R. A., Azizah, R., 2020. Management of solid medical waste on one of the COVID19 referral

hospitals in Surabaya, East Java. Journal Kesehatan Lingkungan. /10.20473/jkl.v12i1si.2020.38-44. Vol. 12 No.1, 38-44.

Wright, S.L.; Kelly, F.J., 2017. Plastic and human health: a micro issue?. *Environ. Sci. Technol.*, 51,6634–6647. https://pubs.acs.org/doi/abs/10.1021/acs.est.7b00423.

Xu, Z.Y., Wang, R.Z., Yang, C., 2019. Perspectives for low-temperature waste heat recovery. *Energy*, 176, 1037 –43.