Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Short Communication

Environmental and nutritional impacts of dietary changes in Spain during the COVID-19 lockdown

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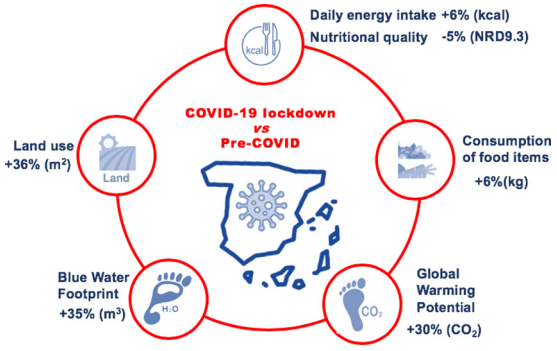
HIGHLIGHTS

- An energy- and nutrient-based functional unit was applied to compare diets.
- COVID diet with higher energy and lower nutritional quality than pre-COVID diets.
- Larger environmental impacts of the COVID diet compared with Planetary Health Diet.
- Need for short guidelines promoting sustainable food habits during lockdowns.
- Environmental sustainability must be integrated in the National Dietary Guidelines.

GRAPHICAL ABSTRACT



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ABSTRACT

The COVID lockdown has affected food purchases and eating habits. In this regard, this short communication assesses the nutritional and environmental impacts of these changes during the COVID lockdown in Spain, by applying Life Cycle Assessment and an energy- and nutrient-corrected functional unit. Three environmental impacts were studied (Global Warming Potential, Blue Water Footprint and Land Use) and a total of seven weekly diet scenarios were designed: two pre-COVID diets for March and April in 2019 (MAR19, APR19), one COVID diet (COVID) and two alternative diets, one based on the National Dietary Guidelines (NDG) and another one on the Planetary Health Diet (PHD). Results show that the COVID diet had larger energy intake and lower nutritional quality, as well as higher environmental impacts (between 30 and 36%) than the pre-COVID eating patterns. Further research is needed to account for food affordability within this assessment, as well as to analyze how eating patterns will evolve after the COVID lockdown. Finally, the definition of short guidelines for sustainable food behaviors for future possible lockdowns is suggested, as well as the introduction of sustainable indicators within NDGs.

1. Introduction

The coronavirus disease (COVID-19) pandemic has forced many countries to establish partial or total lockdowns to stop the exponential

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increases of deaths and to prevent the collapse of health services. These lockdowns have led to a significant decrease of human and industrial activities, resulting in short-term positive environmental side effects, such as improved water quality (Yunus et al., 2020) and better air quality in urban areas due to lower air pollutants emissions (Li et al., 2020; Nakada and Custodio, 2020; Tobías et al., 2020; Wang and Su, 2020). However, staying indoors and working remotely can affect daily food habits, increasing the energy intake and the craving for "comfort food" due to boredom and stress (Muscogiuri and Barrea, 2020).

Food purchase in Spanish households has changed abruptly since the beginning of the containment measures on March 14th 2020 when compared with the same period in previous years (MAPA, 2020b). Besides the potential nutritional effects, these changes can have an impact on the environment, related to the environmental impacts embedded in purchased food. In this regard, this study assesses the nutritional and environmental impacts - Global Warming Potential (GWP), Blue Water Footprint (BWF) and Land Use (LU) - of food consumption of an average Spanish citizen during the COVID-19 lockdown. Moreover, these results are compared with the impacts in the same period in 2019, as well as with two alternative diets: one following the National Dietary Guidelines (Tur-Marí et al., 2010) and the other one based on the Planetary Health Diet, defined by the EAT-Lancet Commission (Willett et al., 2019). To do so, Life Cycle Assessment (LCA) was applied using an energy-and nutrient-based functional unit (Batlle-Bayer et al., 2019b). Finally, the ultimate goal of this study is to extract lessons learned from the COVID-19 lockdown and suggest strategies related to food consumption in the event of possible undesirable lockdowns in the future.

2. Methodology

2.1. Functional unit

Considering that the function of diets is to provide the correct daily intake of energy and nutrients, this study uses an energy- and nutrient (E&N)-based functional unit proposed by Batlle-Bayer et al. (2019a, 2019b). Hence, the functional unit is defined as the weekly food basket that provides the required intake of energy and nutrients. To fulfill this functional unit, the environmental impacts (EI in Eq. (1)) of the food baskets were corrected (represented with c- in Eq. (1)) on the basis of energy and nutritional aspects (Eq. (1)).

$$c{-}EI_{diet} = \frac{EI_{diet}}{\alpha * NS} \quad (1)$$

where,

$$\alpha = ES = \frac{DE_{diet}}{DE_{rec}} \; if \; DE_{diet} < DE_{rec} \quad (2)$$

$$\alpha = \frac{1}{ES} \; if \; DE_{diet} \geq DE_{rec} \quad (3)$$

$$NS = \frac{NRD9.3_{diet}}{NRD9.3_{rec}} \quad (4)$$

Component α in Eq. (1) accounts for energy intake. When the daily energy contained in a diet (DE_{diet}) is lower than the recommended value (DE_{rec}), α is defined as the Energy Score (ES): DE_{diet} divided by DE_{rec}. Otherwise, α is the inverse of the ES (Eq. (3)). The DE_{rec} is based on the recommendations from the European Food Safety Authority (EFSA, 2017), and it depends on gender, age and physical activity. In this study, two DE_{rec} were applied:

- For diets in 2019: the DE_{rec} was 2221 kcal per day, considering the age distribution of the population in 2019 (INE, 2020) and the average physical activity (INE, 2018) of the Spanish population.
- For diets during the COVID lockdown: the DE_{rec} was 1970 kcal per day, assuming low physical activity.

The Nutritional Score (NS; Eq. (4)) is defined as the ratio between the nutritional qualities - estimated with the Nutrient Rich Diet 9.3 index (NRD9.3; further explained by Van Kernebeek et al., 2014) - of a diet ($NRD9.3_{diet}$) and the recommended one ($NRD9.3_{rec}$). This study considered the Planetary Health Diet as the recommended diet, and two $NRD9.3_{rec}$ were estimated based on the two recommended energy intakes of the two periods under study: before and during the COVID lockdown.

2.2. System boundary

The system boundary of this study uses a cradle to grave approach, thus considering all processes from primary production to consumption and the management of food being wasted at the consumer stage; packaging waste management was not considered.

2.3. Dietary scenarios

This study considers seven weekly diet scenarios, four of them corresponding to the 2019 period before the lockdown and three during the lockdown (Table 1):

- **Reference diets**: The reference diets of this study are the food consumption patterns occurred in March and April of 2019 (**MAR19**, **APR19**). The average weekly food baskets of these two diets include both household and food-away-from-home (FAFH) consumptions. The household consumption was based on the monthly average household food consumption of an average Spanish citizen in 2019, published by the Spanish Ministry of Agriculture, Fisheries and Food (MAPA, 2020a, 2020b). FAFH consumption was retrieved from the data of 2018 (MAPA, 2019); assuming that the values of 2018 constitute a good proxy for 2019.
- **Diet in the COVID lockdown**: The average eating pattern during the lockdown (**COVID**) was based on the average weekly food consumption from the week 11 (March 9th–15th) to the 17 (April 20th–26th) of 2020. To estimate the composition of the food basket of this COVID diet, national data on weekly average changes of in-home food consumption in 2020 (MAPA, 2020b), compared with the same week in 2019, were used. Hence, the food basket of the COVID diet was estimated as the sum of the average weekly in-home consumption of March and April in 2019 and the weekly average relative change of food consumption during the COVID lockdown (TS1).
- **NDG-based diets**: Two alternative diets based on the recommendations on quantity and frequency of food intake of the National Dietary Guidelines (NDG; Tur-Marí et al., 2010) were designed. One NDG-based diet supplied a caloric energy of 2221 kcal (**NDG2221**), as recommended during the pre-covid period (explained in subsection 2.1); while the other one supplies the energy of 1970 required during the COVID lockdown (**NDG1970**).
- **PHD-based diets**: Two alternative diets followed the Planetary Health Diet (Willett et al., 2019); one supplying the daily energy intake

Table 1
Diet scenarios modelled to compare the difference in environmental impacts between pre-COVID and COVID eating habits.

Pre-COVID diets	Diets in the COVID lockdown
MAR19	COVID
APR19	NDG1970
NDG2221	PHD1970
PHD2221	

recommended before COVID (**PHD2221**) and the other one providing the energy recommended during the lockdown (**PHD1970**).

2.4. Data collection

2.4.1. Food baskets

The average weekly food baskets before the lockdown (MAR19 and APR19) include both household and food-away-from-home (FAFH) consumptions. Household consumption was based on the monthly average household food consumption of a Spanish citizen in 2019, published by the Spanish Ministry of Agriculture, Fisheries and Food (MAPA, 2020a, 2020b). FAFH consumption was retrieved from the data of 2018 (MAPA, 2019); assuming that the values of 2018 constitute a good proxy for 2019.

To estimate the composition of the average food basket during the lockdown (COVID), national data on weekly average changes of in-home food consumption (MAPA, 2020b), compared with the same week in 2019, were used. Hence, the food basket of the COVID diet was estimated as the sum of the average weekly in-home consumption of March and April in 2019 and the weekly average change of food consumption during the COVID lockdown (TS1).

2.4.2. Life cycle inventory of individual food products

Data on the embedded greenhouse gas emissions to produce, distribute and consume the food products considered within the food baskets were based on Batlle-Bayer et al. (2019a), except for the production of eggs, which was updated to the Spanish context (Abín et al., 2018). Furthermore, mushrooms and strawberries were added in the food baskets due to data availability within the Spanish context (Leiva et al., 2015; Romero-gámez and Suárez-rey, 2020). Data on blue water and land use for all food products were based on Batlle-Bayer et al. (Batlle-Bayer et al., 2020a, 2020b), whereas data on food loss and waste along the whole supply chain were retrieved from Garcia-Herrero et al. (2018).

2.5. Assumptions

Food purchase during the COVID confinement was assumed to be consumed (i.e., ingested and wasted) within the same week of purchase. Hence, no food storage was taken into account. However, large amounts of food purchase were reported in the first week of the confinement, which could be related to the behaviour of citizens stock-piling food as a way to cope with possible future food shortages or low food accessibility. Hence, to avoid the overestimation of food being consumed in one specific week, this study used the average weekly changes of food purchase during the first 6 weeks of confinement. In addition, it was assumed that no changes with respect to previous trends occurred in household food waste generation and management during the COVID lockdown. In addition, FAFH consumption was assumed to be zero during the lockdown.

3. Results

During the COVID lockdown, the average weekly food purchase of a Spanish citizen (ca. 13.8 kg per capita; see Fig. 1a) increased compared with household consumption in the same period in 2019. However, it did not exceed the total amount of food of MAR19 and APR19 (about 14.3 kg per capita), which considered the household and FAFH consumption.

In terms of food composition, the COVID food basket presented lower amounts of beverages (especially beer and coffee), a slight increase in the acquisition of eggs and red meat, and a substantial increase of plant-based foods (especially processed vegetables, fruits, nuts and pasta/rice) as compared the food baskets in 2019. Nevertheless, the consumption of plant-based food products was still below those recommended by dietary guidelines, whereas red meat consumption remained high (Fig. 1a).

The daily energy intake of the COVID diet was 2509 kcal (Fig. 1b), which represented an increase of 6% with respect to 2019 (i.e., MAR19 and APR19), and 27% higher than the recommended value (PHD1970; see Table 2). Regarding the nutritional quality, the NRD9.3 of the COVID diet was 5% lower than the ones of MAR19 and APR19, and 33% lower than the one of PHD1970 (Table 3).

In terms of diet-related environmental impacts, the COVID diet had 30%, 35% and 36% higher values for corrected GWP, BWF and LU, respectively, than the ones of APR19 and MAR19 (Fig. 2a, c, e). This is mainly due to the nutritional aspect - the low values of the energy intake and the nutritional scores calculated for the COVID diet (Table 2), which

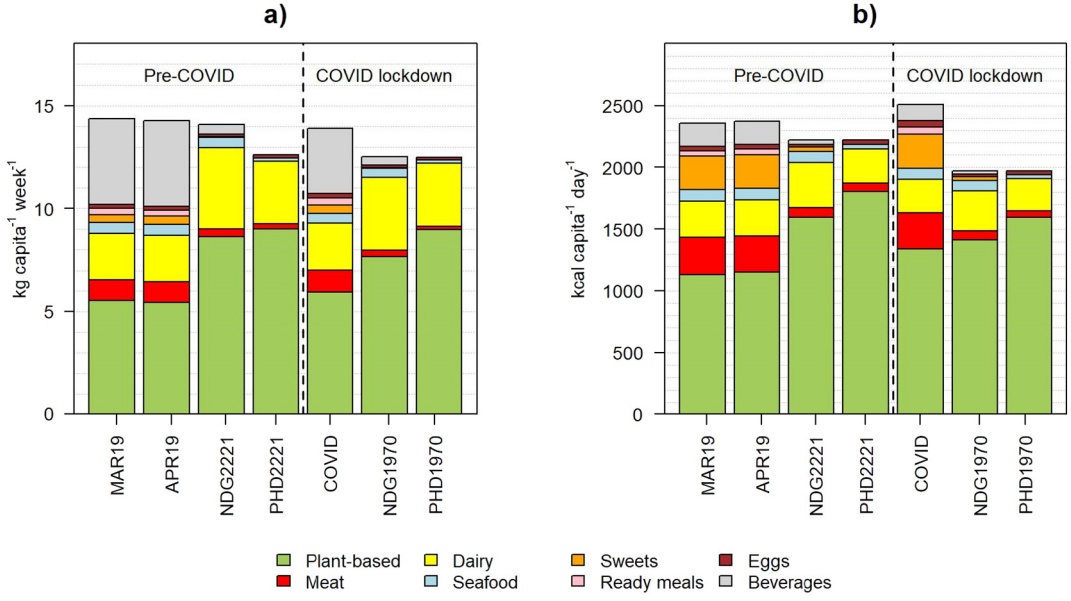

Fig. 1. Food composition in weekly kg (a) and daily energy intake in kcal (b) of all dietary scenarios. More detailed information is given in the supplementary material (TS2).

Table 2
Energy intake and the α value for all diet scenarios.

Diet scenarios	Energy intake (kcal)	α
Pre-COVID		
MAR19	2358	0.94
APR19	2373	0.94
NDG2221	2221	1.00
PHD2221	2221	1.00
COVID lockdown		
COVID	2509	0.79
NDG1970	1970	1.00
PHD1970	1970	1.00

are used to correct the environmental impacts of diets -, since little differences are found when correction is not applied (Tables S1, S2 and S3). Compared with the NDG- and PHD-based diets, the COVID diet has much larger values for all three environmental impacts. This is due to the food composition of these recommended diets, that rely on substantially lower red meat intake and more plant-based food, as well as the nutritional aspect (i.e., α, NS).

Fig. 2b, d and f show the contribution of all food categories to GWP, BWF and LU, respectively, for the seven dietary scenarios. For the alternative (PHD- and NDG-based) diets, the contribution of meat-based products to all environmental impacts decrease, while it increases the contribution of dairy and plant-based products since both guidelines recommend higher amount of these products than the current consumption (Fig. 1a).

4. Discussion

The novelty of this study resides in that, to our knowledge, it is the first one to comprehensively assess the nutritional and environmental impacts of dietary changes occurring during the COVID lockdown in Spain. In addition, the methodological novelty is related to the comparison of the environmental performance between diets that differ in energy and nutritional intakes as well as in the recommended intake values.

Results show that the average COVID eating pattern consumes 539 kcal more than the recommended diet during confinement; it has lower nutritional quality, and increases environmental impacts by approximately 30–35% as compared with the diet in the same period in 2019. Furthermore, the COVID diet presented a threefold increase in environmental impacts when compared to the Planetary Health Diet.

These results suggest the requirement to establish strategies to ensure sustainable food habits in the future, including those occurring in a possible future lockdown, such as designing short sustainable food production and consumption guidelines. As highlighted in previous studies (Batlle-Bayer et al., 2020a; Blackstone et al., 2018; Song et al., 2017; Springmann et al., 2018), there is a need to integrate sustainability aspects within NDGs, as discussed predominantly in the current study. In this regard, the Planetary Health Diet has been considered as the reference guideline for sustainable diets, gaining worldwide recognition. In fact, fourteen cities of the global network C40 have recently committed to achieve this diet by 2030 (C40 Cities, 2019). Hence, further improvement of Spanish dietary guidelines is needed by adding environmental metrics. Moreover, the results of the current study may also be articulated with nationally-determined contributions to mitigate GHG emissions linked to future diets (Vázquez-rowe et al., 2019) and, together with a broader spectrum of social, economic and environmental indicators, with the Sustainable Development Goals (Gheewala, 2020; Vanham et al., 2019).

Despite the importance of the results presented, several limitations to this study must be highlighted. First, changes in food loss and waste along the supply chain during the COVID lockdown were not considered. However, changes in household food waste generation can be expected (Aldaco et al., 2020; Jribi et al., 2020). They can either increase due to overbuying or inappropriate food storage, or decrease if consumers are making better use of the stocked food and leftovers. Second, the economic aspect of food affordability (defined as the food expenditure from the consumption income) of dietary patterns was not considered due to lack of data on the consumption income during the COVID lockdown. This analysis will be required once data are available, and focus should be given to low income households, since the purchasing power of this socioeconomic group is bound to have decreased during the pandemic. Within this group, special attention should be paid to certain vulnerable groups, such as migrants and refugees, which may have distinct dietary patterns to those of the rest of the country. In this respect, we suggest the application of the methodology proposed by Batlle-Bayer et al. (2020b) to integrate the economic, nutritional and environmental assessment of diets. Third, adding changes in food packaging formats and materials during the COVID lockdown may be of interest to analyze their impact on the metrics that have been analyzed in this study, but also other incipient indicators, such as marine plastics. Finally, further research will be needed to evaluate how food consumption will evolve during the lockdown de-escalation and post-COVID, if no other lockdowns are enforced due to re-growth of the disease. If the lockdown measures need to be maintained or intermittently applied during the next months or years, policies to minimize the environmental impacts of lockdown related to diets should be developed.

Table 3
Nutritional quality (NRD9.3) and nutritional scores (NS) for all diet scenarios.

Diet scenarios	Nutritional quality (NRD9.3)	Nutritional score
Pre-COVID		
MAR19	511	0.72
APR19	507	0.71
NDG2221	710	0.99
PHD2221	714	1.00
COVID lockdown		
COVID	485	0.67
NDG1970	717	0.98
PHD1970	728	1.00

CRediT authorship contribution statement

Laura Batlle-Bayer: Writing - original draft, Methodology, Conceptualization, Formal analysis. **Rubén Aldaco:** Investigation, Formal analysis. **Alba Bala:** Methodology, Formal analysis. **Rita Puig:** Methodology, Formal analysis. **Jara Laso:** Investigation. **María Margallo:** Investigation, Formal analysis. **Ian Vázquez-Rowe:** Investigation, Formal analysis. **Josep Maria Antó:** Investigation, Formal analysis. **Pere Fullana-i-Palmer:** Funding acquisition, Conceptualization, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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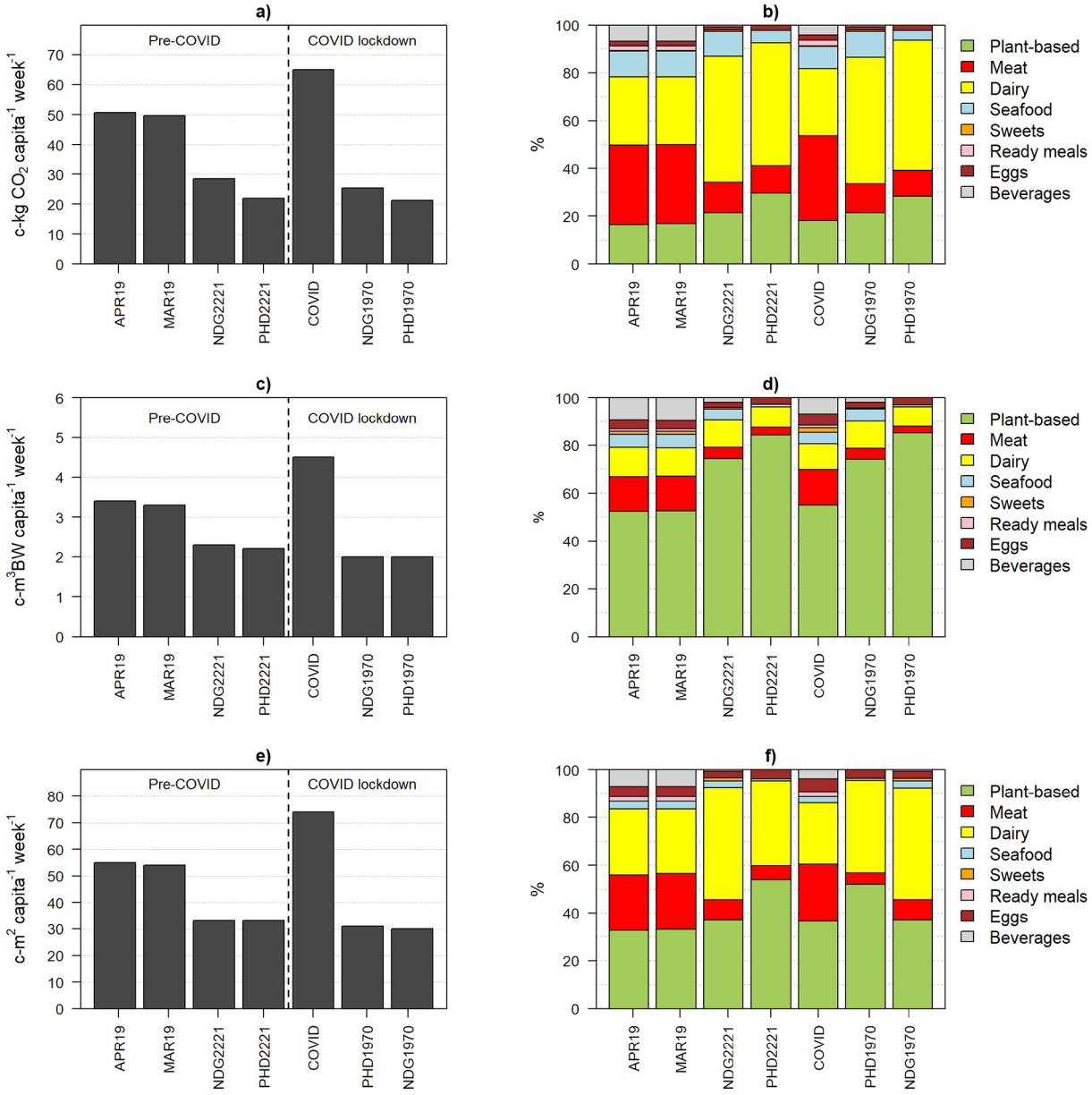

Fig. 2. Average weekly corrected environmental impacts - Global Warming Potential (a), Blue Water Footprint (c) and Land Use (e) - and the contribution of all food categories to these impacts (b, d, f) for the 7 dietary scenarios.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2020.141410.

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