Social Dynamics of Face Masks as Single-Use Waste from the COVID-19 Pandemic

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Abstract — **The impact generated by Municipal Solid Waste (MSW) is associated with the risk in the population due to the lack of knowledge of the proper final disposal of single-use waste, specifically with face masks during the COVID-19 pandemic. With the objective of carrying out a national diagnosis on the management and final disposal of waste, a national survey was prepared with the support of the digital tool google form, to obtain data to evaluate the environmental impact on the use and disposal of urban masks of mandatory use during the pandemic. It was identified that 35 % of the interviewees mix the face masks with household waste, which is a potential factor for public health and environmental problems. Of these, 61.5 % indicated that they were unaware of the existence of a COVID-19 waste management plan. This demonstrated the lack of knowledge about it, which causes inadequate management of these residues. The results of this research demonstrated the importance of implementing treatment alternatives to reduce the impact of the masks, highlighting that the most appropriate remediation treatment should be economically viable and with minimal environmental impact to properly manage MSW-COVID -19.**

Keywords — **SARS-CoV-2 (COVID-19); facemask; waste; environmental impact; final disposal.**

Resumen — **El impacto generado por los Residuos Sólidos Municipales (RSM) está asociado al riesgo en la población debido a la falta de conocimiento sobre la disposición final adecuada de los desechos de un solo uso, específicamente las mascarillas durante la pandemia de COVID-19. Con el objetivo de llevar a cabo un diagnóstico nacional sobre la gestión y disposición final de los residuos se preparó una encuesta nacional con el apoyo de la herramienta digital Google Form, con el fin de obtener datos y evaluar el impacto ambiental en el uso y la disposición de mascarillas urbanas de uso obligatorio durante la pandemia. Se identificó que el 35 % de los encuestados mezcla las mascarillas con los residuos domésticos, lo que representa un factor potencial de problemas de salud pública y ambientales. De estos, el 61.5 % indicó que desconocía la existencia de un plan de gestión de residuos de COVID-19. Esto demostró la falta de conocimiento al respecto, lo que provoca una gestión inadecuada de estos residuos. Los resultados de esta investigación resaltan la importancia de implementar alternativas de tratamiento para reducir el impacto de las mascarillas, enfatizando que el tratamiento de remediación más adecuado debe ser económicamente viable y con un mínimo impacto ambiental para gestionar adecuadamente los RSM de COVID-19.**

Palabras Clave — **SARS-CoV-2 (COVID-19); mascarilla facial; residuos; impacto ambiental; disposición final.**

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I. INTRODUCTION

In December 2019, a health emergency of viral origin that was considered unknown until then began in the world. The first cases of this pathology were reported in the city of Wuhan in China, where it was determined as a disease with characteristics of pneumonia of unknown etiology [1]. This was due to the symptomatology and severity that characterizes the disease and that generated its imminent spread to several countries. The World Health Organization (WHO) officially declared the beginning of the COVID-19 pandemic, caused by the SARS-CoV-2 virus, on March 11, 2020 [2]. They also indicated that the research indicated that this virus belongs to the subgenus Sarvecovirus, which can infect humans and animals [2]. The structure of SARS-CoV-2 virus can be polymorphic or round, with a diameter between 60-140 nm, and its nucleocapsid protein encapsulates its genome [2][3][4].

Moderate symptoms caused by SARS-CoV-2 virus in humans include fever, cough, fatigue, loss of smell and taste. In more severe cases there is the development of pneumonia, acute respiratory distress and very low hemoglobin, as well as a decrease in lymphocytes and eosinophils; and death in the worst case [4][5][6]. Because of this, the virus is classified as highly contagious, since its transmission is carried out by the emission of fluid droplets with a size of 5 microns, which come into direct contact with the individual through the aerosol emitted by sneezing and other mucous secretions or by contact with infected objects [7]. Globally, deaths were significant; according to WHO estimates, between January 1 2020 and December 31 2021, the number of deaths associated with the SARS-CoV-2 virus amounted to approximately 14.9 million people [8]. In the specific case of Mexico, it was one of the countries with the highest incidence of deaths during 2020, with estimates ranging from 18 310 to 32 014 deaths from June 17 to July 7 of that year, maintaining a case fatality rate of 12 deaths per 100 infected persons [9].

The easy spread of this disease and its significant case fatality rate worldwide led to the establishment of sanitary measures for the health sector and the general public in order to reduce the number of infections. As a result, confinement and zero contact with persons carrying the virus was recommended. However, this measure was also generalized for the general public due to asymptomatic individuals, who can transmit the virus [10][11]. Another established measure was proper hand washing with soap and water, as well as disinfection with 70% alcohol due to its efficacy in denaturing the virus, when in contact with infected surfaces as a probable source of contagion [12][13][4]. Another important measure to reduce the spread of SARS-CoV-2 was the use of masks, in order to reduce the transmission of viral infection through the respiratory tract [14][15][16].

WHO recommended the use of facemasks for people with symptoms as well as for health care workers as the main protective equipment. However, in the mid-2020's, the use of face masks became generalized to the general public [17][18]. Commonly used face masks for the general population are of three types: those recognized as surgical, N95 or KN95, and fabric. The first two are single use, while the third is reusable [19]. Single-use masks are made from nanofibers or microfibers of polymers such as polypropylene, polyurethane, polyacrylonitrile, polystyrene, polycarbonate, polyethylene or polyester [20]. The effectiveness of these varies depending on the type and certification of each. However, these plastics are resistant to liquids and remain for a long time after disposal in final landfills [21].

The implementation of sanitary measures against SARS-CoV-2 brought as a main consequence the alteration of the social dynamics in the generation of waste; besides causing changes in its composition. Among these changes derived from the pandemic is the excessive generation of sanitary waste, such as syringes, supplies for taking samples and all those materials that are part of personal protective equipment (PPE), which in a high percentage consist of face masks [22][23][24][25]. The increasing generation of waste around the world implies the recognition of a critical scenario in the environmental aspect, many of these, such as masks, are single-use, and are also associated with the release into the environment of plastics that degrade into microplastics that reach aquatic systems, beaches and the ocean affecting marine life [26][27].

The concern about the increase in waste is complemented by the deficiency in the systems that control its management, since in most countries there was no engineering system focused on this type of sanitary waste, which, due to its characteristics and origin, requires management both for hospitals and private homes [28]. In the case of Wuhan China, where the pandemic originated, according to estimates there was an average of 240 tons of sanitary waste during the pandemic [29].While in Latin America the issue of waste management is deficient in terms of information and adequate enforcement, the problem of healthcare waste management is even greater [30]. Globally, it is estimated that the inadequate final disposal of 1 % of the single-use mouthpieces is approximately 10 million of these, which is equivalent to 40 thousand kg of plastics whose final disposal in inadequate places generates contamination of streets, rivers, beaches and oceans; therefore, citizen responsibility is fundamental to contribute to the solution of this problem [31].

In Mexico, during the COVID-19 pandemic, the Secretariat of Environment and Natural Resources (SEMARNAT) established a classification of the waste generated; it states that "normal waste is that generated in homes and non-hospital organizations with residents without apparent contagion" [32]. While the other type of waste corresponds to those considered dangerous under the infectious biological criteria, they are described as "those containing infectious agents that make them hazardous, which include containers, packaging and soils that have been contaminated when transferred to another site and, therefore, represent a danger to ecological balance or to the environment" [33]. COVID-19 waste is that "generated by a household or non-hospital organization where one or more infected persons reside, as well as all urban solid waste generated by airports and passengers, whether maritime or terrestrial terminals [32]. According to SEMARNAT estimates, each COVID-19 patient generates an average of 2 to 2.2 kg of infectious biological hazardous waste per day.

It has been reported that single-use sanitary waste that has not been properly managed is treated as urban waste from its collection to its final disposal destination, which implies a dangerous transmission mechanism of the SARCOV-2 virus for those who meet it [34][35]. Therefore, it should be considered that the deficiencies in the waste management system were not caused by the pandemic, but by the incorrect planning of waste management [36]. In developing countries such as Mexico, most of the waste is incinerated or simply transported to final disposal sites such as open dumps without any control, abandoned landfills that require rehabilitation to continue waste disposal [37]. This inadequate management implied a great interest in finding alternatives and integral solutions for the treatment of waste, of which single-use plastics are the most important, with the purpose of reducing their impact on the environment [28], [38][39].

Currently, research has focused on developing these alternatives for the remediation of the impact of various types of pollutants, among which single-use wastes such as plastic bottle caps can also be included. One of the most recurrent bioremediation treatments is the application of microorganisms, plants or enzymes to degrade the pollutant; the application of these is reductive and mitigating in water or soil [40][41].

The most widely used bioremediation methods include the application of microbial consortia. These have shown positive results with respect to the degradation of hydrocarbons, from which plastics are derived, since microorganisms promote the degradation of the hydrocarbon structure found in soil and water [42]. Likewise, it has been demonstrated that there are dominant genera in microbial consortia such as Burkholderia, Escherichia, Klebsiella, Salmonella, Shigella and Proteus, which can act in the hydrocarbon biodegradation process [43].

Several factors influence the inadequate management of municipal solid waste in combination with COVID-19 waste generated in households, such as face masks, representing a threat to the environment due to the plastic contamination it generates. The objective of this research was to evaluate the final disposition of these urban solid wastes, single-use mouthpieces, in order to know their impact on the environment in Mexico during the COVID-19 pandemic and thus generate important information that can support the development of possible alternatives for the treatment of these wastes.

II. METHODOLOGY

A. Methodological approach

The present investigation corresponded to the descriptive type, since a diagnosis was made on a current problem of the final disposal of face masks during the COVID-19 pandemic and recommendations on environmental management alternatives are established. The use of a survey and the search for information were considered techniques for obtaining information. For the survey, a sample size was considered for the national diagnosis on the social dynamics of urban solid waste. Meanwhile, the second part consisted of consulting information through academic search engines using key words referring to the topic, such as: COVID-19 waste, COVID-19 household waste, COVID-19 waste management and COVID-19 personal protective equipment. In addition, reliable and reputable online platforms such as media and policy were consulted.

B. Population and sample calculation

The population is defined as the grouping of some common characteristics of individuals or elements that we wish to study. According to INEGI statistics, Mexico has a total population of 126 014 024. With these data, the sample was calculated from the population [2][44].

In order to obtain the minimum size of the total sample, it was determined to perform a random sampling without replacement of a finite population where N is equal to 126 014 024 inhabitants, with a confidence level of 95 % and with an error of 0.05; the values of P and Q of 0.50. The following Equation (1) was applied to define the number of people surveyed [45].

Equation 1

$$n = \frac{(N * Z^2 * P * Q)}{(Z^2 * P * Q + (N-1)(e)^2)} \tag{1}$$

Where:
n = Sample size sought
N = Population size
Z = Statistical parameter that depends on N
e = Maximum accepted estimation error
p = Probability that the event occurs
q = (1-p) = Probability of the event not occurring

C. Obtaining information on the use and management of single-use waste (masks)

A digital survey was designed using the Google Forms Platform to obtain information on the handling of face masks by the population. The survey was disseminated through social networks because of its practicality and its link to the contingency measures regarding social isolation. This questionnaire was disseminated throughout Mexico and the information was collected respecting the anonymity and reliability of the participant's data. The structure of the survey consisted of 12 closed questions, which were mainly focused on the topic of the handling of face masks in urban solid waste generated in the COVID-19 pandemic, specifically on sanitary safety measures, type of masks and number of these used weekly, investment in personal protective equipment, and knowledge about the correct final disposal of single-use waste such as masks. In addition, general sociodemographic data of the participants, such as age and sex, were collected.

D. Calculation of the total number of face masks used in Mexico

An estimate was made of the total number of masks used in Mexico by the urban population according to eEquation (2) established by [46][47] and modified by [48]. The calculation of the use of face masks is established based on the use of the economically active and non-active population during the pandemic as a variable (1). With this, the social dynamics will be obtained with respect to the flow of exposed people and the use of masks as protection [46][47] . This equation will provide the total number of masks generated at the national level, and considering the weight of each type of mask, an approximation of tons of polypropylene generated could be established [18].

Equation 2

$$\begin{aligned} DFM = [(Tp * Up * Ar1 * Ac * Ep) + (Tp * Up * Ar2 * \\ Ac * (1 - Ep))] \end{aligned} \tag{2}$$

Where:
DFM: Total daily disposable face masks
Tp: Total population in the region
Up: Urban population in the region (%)
Arx: Face masks acceptance rate
Ac: Average daily number of disposable masks per capita
Ep: Economically active population

The data analysis was carried out by means of descriptive statistics to group the data based on their representativeness for the groups analyzed. The values of DFM and DFM % were transformed to natural logarithm because they did not have a normal distribution; an ANOVA was performed with a Tukey test ($p<0.05$). The data were projected in a table and spatially by means of a descriptive map, using Arcmap 10.5 software (ESRI, California, USA), in order to make a spatial comparison of the magnitude of the use of masks with respect to the population of each region of the country.

III. RESULTS

A. Sociodemographic data

The total population participating in this research corresponded to 408 people. The age of the participants in this research showed that the most representative group corresponded to the range between 31 and 40 years old with 28.60 %; followed by the 21 to 30 years old group with 21.60 %. Meanwhile, 15.70 % of the participants belonged to the 41 to 50 years age group. In the case of the population over 60 years of age, which corresponds to the age group with the highest risk of getting SARS-CoV-2, these corresponded to 8.10 % of the participants. The age group that presented the lowest participation in this research corresponded to those under 20 years of age with 4.20 %.

With respect to the gender of the survey participants, the largest group corresponded to the female with 54.70 %. The male was less representative with 45.30 % of the population analyzed.

The representativeness of the survey at the national level indicated that the highest percentage of participants was from the state of Veracruz with 43.9 %, 16.9 % corresponded to the state of Jalisco, 15.2 % resided in the state of Mexico, 4.9 % in Puebla, 3.7 % in Mexico City, 2.7 % in Oaxaca, 2.0 % in Tlaxcala, and the states of Chiapas and Tabasco with 1.7 %. The states of San Luis Potosí, Sonora and Yucatán accounted for 1 % each; and the state of Hidalgo accounted for only 0.7 %. The states of Campeche, Michoacán, Nuevo León and Tamaulipas accounted for 0.5 %. The states with the lowest number of participants were Baja California, Coahuila, Colima, Morelos, Querétaro and Quintana Roo.

B. Urban solid waste management and COVID-19

The use of personal protective equipment reported by the participants in this research corresponded to 71.3 % (Fig. 1), highlighting the use of face masks as a protective measure against COVID-19. This highlighted the fact that this was the product with the greatest impact on use and consumption in Mexico. For their part, 22.3 % of the participants indicated that in addition to the use of masks, they complement their protection with the use of full-face shields as facial protectors.

The material of the masks reported by the respondents in this research corresponded mostly to fabric (35.3 %), mainly because this material can be reused, it is inexpensive and easy to manufacture. Due to the frequent use of this type of masks, 68.1% of the respondents indicated the use of soap and water as the main method of disinfection of this type of material. N95 masks accounted for 33.3 % of use, followed by surgical types with 16.9 %, most of which are made of polymers (Fig. 2).

The number of masks used per week by the individuals interviewed varied according to the duration of use and the type of mask, as well as according to the degree of hygiene of each person and the sanitary requirements of the places frequented by the interviewees. A percentage of more than 80% indicated that they used between 1 and 5 masks per week. On the other hand, 15.2 % indicated using between 6 and 10 per week.

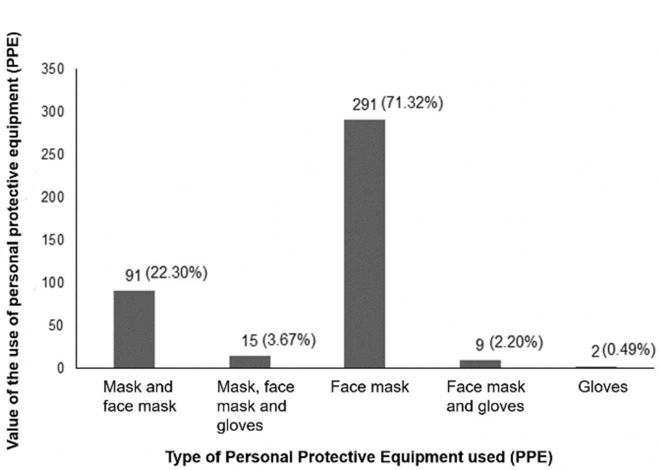

Fig. 1. Personal protective equipment (PPE) used by the participants in this research.

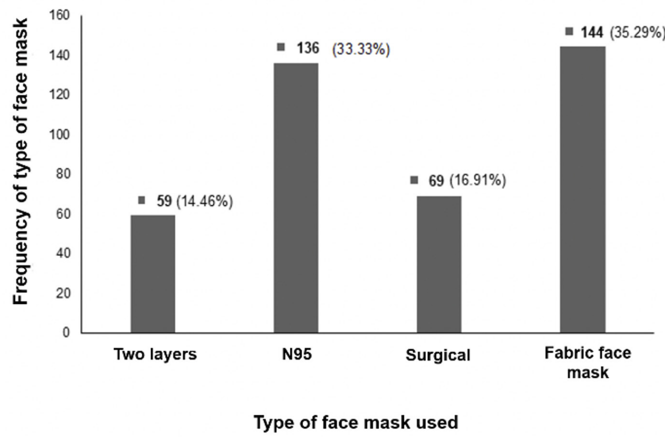

Fig. 2. Type of masks used by the general population in Mexico

A percentage of 23.5 % of the participants in this research indicated making an economic investment of $5.73 USD and $11.46 USD per month in the purchase of COVID-19 prevention and protection items. Meanwhile, 1.5% of people indicated a monthly investment between $ 51.57 USD and $ 57.30 USD for this same use. Regarding the presence of a COVID-19 patient in their family, 14.7% of the participants indicated the presence of at least one infected person at home. In contrast, a higher percentage (85.3%) reported not having a sick person at home.

The disposal method used by most of the population (35 %) indicated that they mixed this single-use waste with the other solid waste produced in the household (Fig. 3). Of the participants, 29.9 % indicated that they placed the bottle caps in an individual bag to prevent them from being mixed with the rest of the urban waste. For their part, 27.2 % indicated that they performed the above action except that they labeled this type of waste so that it could be detected by public cleaning personnel and thus avoid contamination. This indicates that there is a risk of environmental and sanitary problems because of the lack of adequate treatment of urban solid waste such as masks and PPE.

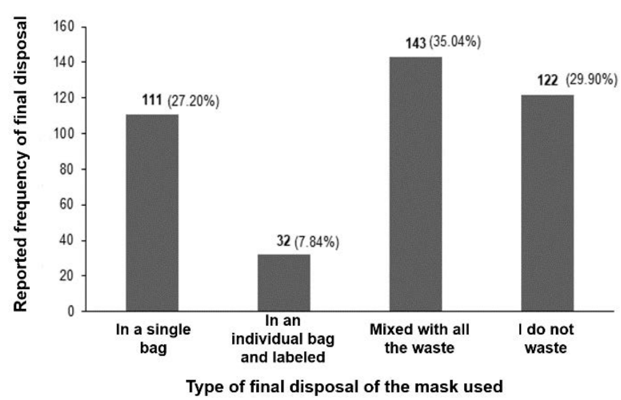

Fig. 3. Method used for the final disposal of the masks

The final disposal in Mexico of single-use mouth covers generated in households is not considered hazardous waste according to NOM 052-SEMARNAT-2005 [49], so they can be disposed of with the rest of the household waste. Those interviewed in this research indicated that inadequate management of this type of waste is carried out, which could generate a resurgence of COVID-19. A total of 84.3 % mentioned that they were aware of the health risk involved in the inadequate management of this type of waste, while 15.7 % considered that there is no health risk despite the current declaration of a pandemic. Likewise, 61.5 % of the respondents answered that they were unaware of any specific management measure for PPE waste such as masks generated in their homes during the COVID-19 pandemic, which are discarded along with other waste without any type of separation or process, while the remaining 38.5 % of the participants indicated that they were aware of some method for handling them and thus avoiding the proliferation of the virus because of inadequate waste management.

The use of masks by the general population generates a volume of this waste in different regions of the country, which can be estimated by calculating the number of masks [46]. These estimates should consider the urban population of the different cities, which in the case of Mexico represents 79 % according to the Population and Housing Census 2020 [50].

The calculation of the environmental impact of the use and disposal of single-use mouthpiece waste generated in the states of the Mexican Republic showed that considering the daily consumption of masks per inhabitant during a week was 1 to 5 (80 %). Fig. 4 shows the data obtained in Table 1 for each region of the country considering its total population, as well as the daily generation of single-use masks in each region.

The urban population of the country's main cities, which represents 79 % of the total population, generated approximately 78 141, 672 single-use masks daily in Mexico (Table 1). The Southcentral region, with the largest population, contributed 22.2 % (17 258 858 disposable mouthpieces), far exceeding the Southeast region, the smallest producer of waste, with 5.8 % (4 564 713 disposable masks). A significant statistical difference ($p<0.05$) was detected in the DFM values for the Southeast and Central South regions. In contrast, no statistically significant differences ($p>0.05$) were detected for the DFM % values in all the regions analyzed, indicating a homogeneous use of face masks by the general population in Mexico.

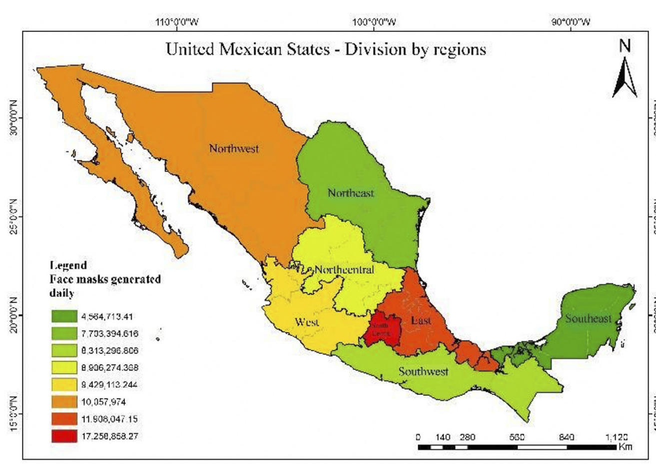

Fig. 4. Masks generated daily in Mexico by region

According to the four types of face masks reported by the participants in this research, N95 and fabric masks represented the highest percentage. N95 are the ones that generate the highest contribution of plastics [51].

The estimate in tons of polypropylene generated by the type of mask used obtained an approximate value of 1 778 135 623 tons of discarded polypropylene waste (Table 2). This calculation helped to generate a picture of the amount of single-use plastic products such as masks that were discarded daily during the pandemic. Disposal sites were mostly in inappropriate locations such as streets, avenues, parking lots, beaches, lagoons, rivers, and seas. Previous handling of these wastes may have increased the contamination generated by plastics and in turn transported pathogens.

IV. DISCUSSION

The demographic characteristics of the participants obtained in this research can contribute to generating strategies for the management of these wastes according to the age groups and sex ratio of the participants. Coinciding with the above, [52] indicated that most of the participants in their research were between 18 and 25 years old, corresponding to 58 %; of these, 62.4 % (8 172 people) were women; of the latter, half indicated that they had completed university studies (51.2 %).

According to the results obtained in this research, 35 % of the participants mix the masks with household waste without considering any sanitation measures and have no knowledge of the correct handling or management of single-use waste. The above highlights the lack of knowledge about the environmental impact of masks and the impact of the lack of implementation of sanitary management practices according to official technical specifications. Coinciding with the above, [52] it is recommended to educate the entire population on sustainable and environmentally friendly ways to dispose of used masks, such work should be independent of age, sex, educational level, income level or place of residence of the population.

It has been reported that the increase in marine litter is directly related to the excessive consumption of plastic products and the lack of education and environmental awareness of the general population [53]. However, in the Mexican legislation, disposable plastic bottle caps used by individuals are considered hazardous waste [49]. However, they can be disposed of together with municipal solid waste.

In Mexico, regulations were generated as a mechanism to address emergencies during the SARS-CoV-2 pandemic (COVID-19), through the declaration and application of a "State of Emergency" that includes the provision of the necessary economic resources to deal with it [29]. Currently, these mechanisms do not include how to manage the use of masks and PPE by public cleaning service personnel in Mexico.

Masks used during the COVID-19 pandemic should be treated as biological-infectious waste and should be classified as waste with hazardous characteristics. Because face masks represent the most significant input in the health security of the population in the current pandemic. However, inadequate handling of masks contributes as a potential source of SARS-CoV-2 infection, particularly for people in charge of MSW collection and processing.

Within the public health problem, public cleaning personnel run the risk of transmission of bacterial and parasitic diseases, the risk of wounds and infections due to sharp objects present as part of MSW, as well as contact with skin contamination. It should be noted that the main people affected are public cleaning personnel and informal recycling collectors. It is therefore advisable to apply advanced disinfection techniques and, failing that, incineration, to dispose of MSW safely.

From the environmental point of view, the relevance of proper waste management is emphasized, especially in the case of mouth covers, due to the ease of dispersion of the waste in coastal aquatic ecosystems [52]. In those that can be brought in by the action of water and wind drag, they can be incorporated mainly on beaches and in the sea (Fig. 5), which implies that their degradation requires more time to occur and, therefore, they can only fragment into microplastics. The presence of these can cause marine life to ingest these microplastics, putting their development at risk, since these compounds release toxic substances. In addition, they reduce the ability of organisms to carry out their physiological processes, causing their death under certain conditions [53].

The different types of PPE and their composition also represent an environmental problem, since most of them are composed of hydrocarbon derivatives, which cannot be reused, as the quality of the product degrades. It has been found that the use of PPE disinfection technologies modifies in most cases their properties and characteristics for which they were created, so their final disposal would represent the most correct management.

TABLE I
DAILY ESTIMATION OF COVID-19 MASKS GENERATED IN THE STATES OF THE MEXICAN REPUBLIC

Region	State	T_P	E_P (%)	DFM (units)	DFM (%)
Northwest	Baja California	3 769 020	96.7	2 358 659	3.01
	Baja California Sur	798 447	95.4	494 241	0.63
	Chihuahua	3 741 869	97.2	2 351 452	3.00
	Durango	1 832 650	96.1	1 141 125	1.46
	Sinaloa	3 026 943	97	1 888 092	2.42
	Sonora	2 944 840	95.5	1 824 405	2.33
		16 113 769	96.316	10 057 974	
Northeast	Coahuila de Zaragoza	3 146 771	93.3	1 913 301	2.44
	Nuevo León	5 784 442	95.4	3 580 586	4.58
	Tamaulipas	3 527 735	96.8	2 209507	2.82
		12 458 948	95.166	7 703395	
West	Colima	731 391	96.9	458 471	0.58
	Jalisco	8 348 151	95.3	5 163 164	6.60
	Michoacán de Ocampo	4 748 846	98.8	3 023 990	3.86
	Nayarit	1 235 456	98.3	783 488	1.00
		15 063 844	97.325	9 429 113	
East	Hidalgo	3 082 841	96.6	1 927 635	2.46
	Puebla	6 583 278	95.9	4 092 283	5.23
	Tlaxcala	1 342 977	94.6	825 688	1.05
	Veracruz de Ignacio de la Llave	8 062 579	97.1	5 062 442	6.47
		19 071 675	96.05	11 908 047	
North Central	Aguascalientes	1 425 607	95.1	880 218	1.12
	Guanajuato	6 166 934	95.1	3 807 675	4.87
	Querétaro	2 368 467	93.4	1 441 315	1.84
	San Luis Potosí	2 822 255	96.7	1 766 172	2.25
	Zacatecas	1 622 138	96.2	1 010 895	1.29
		14 405 401	95.3	8 906 274	
South Central	Ciudad de México	9 209 944	94.8	5 672 083	7.25
	México	16 992 418	93.4	10 340 622	13.23
	Morelos	1 971 520	97.9	1 246 153	1.59
		28 173 882	95.366	17 258 858	

Southwest	Chiapas	5 543 828	96.7	3 469 337	4.43
	Guerrero	3 540 685	97.7	2 234 284	2.85
	Oaxaca	4 132 148	97.8	2 609 676	3.33
		13 216 661	97.4	8 313 297	
Southeast	Campeche	928 363	97.7	585 826	0.74
	Quintana Roo	1 857 985	91.1	1 108 316	1.41
	Tabasco	2 402 598	90	1 419 364	1.81
	Yucatán	2 320 898	96.6	1 451 208	1.85
		7 509 844	93.85	4 564 713	
Grand total				78 141 672	

DFM: Total daily disposable masks
T_P: Total population in the region
U_P: Urban population in the region (79 %)
A_{rx}: Mask acceptance rate; Ar1=81.4%; Ar2= 15.2 %
A_c: Average daily number of disposable face masks per capita (equivalent to 1)
E_P: Economically active population [54].

TABLE II
DAILY ESTIMATION OF TONS OF POLYPROPYLENE GENERATED BY TYPE OF FACE MASK USED IN THE MEXICAN REPUBLIC

Face mask	Population	Masks (pcs)	% of masks	Polypropylene (g)	Polypropylene (ton)
Two layers	18 272 033	11 330 542	14.5	1.28	14 503 094
N95	41 962 670	26 021 177	33.3	10	260 211 767
Surgical	21 296 370	13 205 943	16.9	5.12	67 614 426
Fabric	44 482 950	27 584 010	35.3	0	0
					342 329 287

Fig. 5. Final disposal of facemasks on public roads and beach areas in the coastal zone of Veracruz

The volume of plastics used in different activities generates the proposal of strategies for their degradation, such as the use of some hydrocarbonoclastic microorganisms that have the capacity to biodegrade petroleum-derived polymers. Among these, the application of bacterial consortia in aerobic and anaerobic conditions stands out. This procedure is feasible for the management of single-use masks, since these can be used by bacteria as a carbon source [55]. It has been described that the degradation capacity of microorganisms depends mainly on hydrolytic enzymes that allow breaking polymeric bonds and thus obtaining carbon. In the case of masks, enzymes attack small segments, which generates products of lower molecular weight that can be degraded to carbon dioxide and water [56].

Other alternatives implemented in different regions for the utilization of the waste coverings include the use of these residues as raw material to produce hydraulic concrete, which would improve its resistance. The implementation of this strategy does not generate modifications in the water-cement ratio because the material from which the masks are made does not absorb water.However, the need to disinfect them by methods such as ultraviolet germicidal radiation has been pointed out due to the sanitary risk that this alternative represents for public cleaning collection personnel. The need for tests to determine the efficiency of the optimal disinfection method has been indicated [57]. Another waste management method considers that pyrolysis allows the reduction of surgical masks and gloves, since it does not require the separation of plastic waste, and these can be converted into products such as crude oil and coal for energy generation at elevated temperatures of 400°C during one hour of operation [58]. The latter is a measure that allows reducing pollution from PPE waste and can provide energy sources. It should be noted that this alternative requires further research on the technical process; as well as determining the economic and environmental impact of such a method.

The alternatives implemented for the degradation of plastic require the development of scientific research to allow its implementation in the treatment of large volumes of waste. The option considered as the most viable would be the degradation of plastics by means of microorganisms, since the impact on the environment would be lower, economically the investment should be considered for its implementation. However, the application of microbial consortia has only been carried out at an experimental level in the laboratory. It is necessary to continue with the evaluation of this technology on a larger scale.

V. CONCLUSIONS AND RECOMMENDATIONS

Analysis of the management of solid waste such as single-use masks has shown that large quantities of plastic waste are generated. These can have a high impact on the aquatic environment by being incorporated into it by dragging currents and wind, until they are deposited in inadequate places such as the terrestrial and marine environment, which can contribute to plastic contamination of ecosystems affecting terrestrial and aquatic fauna.

In the analysis of the use of masks, knowledge about the final disposal of these is important to establish base information for the development of strategies. Likewise, it can contribute to the development of public policies such as NOM-052-SEMARNAT-2005, in relation to the management of this type of biological-infectious waste generated in homes, which should have been considered during the COVID-19 pandemic. In the present investigation, the perspective on sanitary practices in the spread of the virus was evidenced, which would imply the implementation of awareness and sensitization actions towards the population, for the separation and labeling of waste masks or PPE in general. All this in order to avoid the infection of public cleaning personnel and informal collectors.

Strategies for the final disposal of single-use masks generally consider incineration as the most effective method for the disposal of plastic waste generated during the COVID-19 pandemic. In the case of Mexico, it should be noted that there is inadequate management of MSW, with a predominance of open dumps and landfills without separation management measures, causing environmental contamination. Therefore, knowing the social dynamics in the use of masks allows a more precise evaluation of the implementation of strategies for the treatment of this type of waste that generate a lower impact on the environment, such as the degradation of plastics by means of hydrocarbonoclast microorganisms, which by enzymatic processes degrade hydrocarbons; therefore, as masks are generally derived from polypropylene, they could be degraded in the same way.

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