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CONSUMER SURVEY ON USE OF SUNSCREEN PRODUCTS

[1]Dr. C. Vijitha,[2]Mrs. V. Padmaja,[3]Mr. M. Ranadheer Kumar
[1]Professor,[2]Associate Professor,[3]Assistant Professor
[1,2]Department of Pharmacognosy
[3]Department of Pharmaceutics
Vaagdevi Institute of Pharmaceutical Sciences, Bollikunta, Warangal. Telangana.

ABSTRACT

OVERVIEW: While the effects of ultraviolet (UV) filters on aquatic environments have been well examined, little is known about ambient exposures. The quantity of sunscreen products and therefore UV filters that may be emitted into the environment is directly influenced by consumer consumption.

OBJECTIVE: To conduct a review of the literature on prior studies on the thickness of sunscreen application, create a questionnaire protocol to semi-quantify sunscreen usage by US consumers, and carry out a large-scale survey to establish a more precise sunscreen application thickness (for the face and body) than conservative defaults. The US Food and Drug Administration (US FDA) advises using sunscreen at a rate of 2 mg/cm2. This figure is often used as a worst-case scenario when evaluating UV filters for environmental exposure.

METHODS: A new method for estimating the thickness of lotion sunscreen application was designed. It included creating an online questionnaire procedure and utilizing the respondents' self-reported height and weight as well as visual references. Additionally, a study of the literature was done to gather data on past sunscreen consumption.

RESULTS: Following dataset refinement, the sunscreen application thickness of more than 9000 US respondents was approximated using reported sunscreen quantities and computed body surface area. For face application thickness, the mean and median values for survey participants are 3.00 and 1.78 mg/cm2, respectively, and for body application thickness, they are 1.52 and 1.35 mg/cm2, respectively. 36 of the 38 values, according to earlier studies from 1985 to 2020, are below the US FDA's recommended application thickness of 2 mg/cm2 (range: 0.2–5 mg/cm2).

IMPACT STATEMENT: This web-based survey is the first of its type and was created especially to measure the amount of sunscreen used by a wide range of customers. This approach makes it possible to analyze and comprehend data at a more detailed level by reaching a wider audience. Sunscreen ingredient exposure evaluations usually use conservative criteria. These data may improve such evaluations and enable more knowledgeable, scientifically supported risk management choices.

Keywords: UV radiation; exposure modeling; chemicals in goods.

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I. INTRODUCTION

Solar ultraviolet (UV) radiation is a known human carcinogen [1]. Sunscreens and other sun protection products protect people from the harmful effects of UV radiation [2] by using organic and inorganic ingredients known as UV filters. UV filters can be used in various combinations and concentrations in skincare product formulations to provide broad-spectrum protection against premature aging and various skin cancers caused by sun exposure. Protection against UV radiation is measured by a numerical sun protection factor (SPF) [3]. While sunscreens play an important role in protecting human health, in recent years there have been numerous scientific and media publications investigating the potential impact of UV filters on environmental health [4–7]. The potential hazard of organic UV filters in the aquatic environment has been well studied, but environmental exposure(s) remain(s) understudied [8]. Consumer habits and practices directly influence the amount of sunscreen and sun protection products, and subsequently UV filters, potentially released into the aquatic environment (i.e.,). Therefore, it is critical to understand consumer use of and preferences for sunscreens and sun protection products when conducting environmental risk assessments (ERA). In the United States, the Food & Drug Administration (US FDA) is responsible for the regulation of all products that claim sun protection under the Over-the-Counter (OTC) Sunscreen Monograph. From this point forward, all sun protection products will be referred to as sunscreens including those that are not designed specifically for use at the beach but instead for daily/routine SPF protection.

The US FDA's standard sunscreen test methods for determining SPF mandate a dermal application of 2.0 milligrams per centimeter squared (mg/cm2) [3], which the agency also recommends for consumer use (i.e., application thickness). This value is often used as a default assumption in environmental exposure and risk assessments. However, research over the years indicates that the amount of sunscreen products applied by consumers may be less than the dose used to determine SPF values [real-world application amounts reportedly range from 0.2–1.27 mg/cm2] [9–12]. Much of this research determined the application thickness amount by measuring how much of the product was applied by volunteers and the application site's surface area. Generally, these studies were conducted in specific sub-populations (e.g., skin cancer survivors, beach tourists, etc.). Additionally, there has been little research around routine sun protection habits and practices, including application to the face as part of a daily skincare regimen and the increase in multifunction skincare products with the additional benefit of sun protection (e.g., moisturizing plus SPF). Therefore, new methods are needed to estimate sunscreen application and additional research is needed to determine if previously published application thickness values are representative of the general population and account for more routine use.

In 2022, the National Academies of Sciences, Engineering, and Medicine (NASEM) published the consensus study report Review of Fate, Exposure, and Effects of Sunscreens in Aquatic Environments and Implications for Sunscreen Usage and Human Health [13]. This report reviews the state of the science "on the sources and inputs, fate, exposure, and effects of UV filters in aquatic environments, and the availability of data for conducting ERAs." The report acknowledges that consumer behavior

directly affects the environmental exposure of UV filters from sunscreen products. The NASEM report identified several data needs for environmental exposure including amount and type of sunscreen applied, rates of sunscreen application per person, and body coverage of sunscreen. However, there are several challenges with conducting sunscreen application investigations. They are resource intensive, requiring human subjects and time to conduct studies with an acceptable sample size. Due to the resources required, these studies often target study populations of interest to the investigators. Therefore, alternative methods requiring fewer resources that can be applied to understanding the habits and practices of the general population are still needed. An online platform is one option to reach a larger number of people, increasing the statistical power of the investigation, and allowing more granular analysis of the results. Using this approach, the sunscreen application thickness can be estimated using a visual reference (amount applied) and the volunteers' disclosed height and weight (skin surface area). The objective of this research was to develop a web-based survey protocol designed to quantify sunscreen usage by general US consumers, conduct a large-scale survey to determine the application thickness of sunscreen products to participants' face and body, and perform a literature review of previous research into sunscreen application thickness. Using an online platform to reach a large and diverse sample set, participants were asked about their sunscreen use in general and the amount applied by comparing their use to a visual reference with measured dispensed sunscreen amounts. The desired outcome was to generate a more accurate estimate of dermal application rate of sunscreen products based on current consumer use patterns and preferences that can be used to estimate environmental exposure to UV filters more accurately.

II. METHODS

Online survey of sunscreen usage

An online survey was conducted of the general population in the United States of America. The objective of the survey was to quantify the amount of sunscreen consumers use per sunscreen application. The questionnaire (see Appendix S1) queried participants about their general sunscreen habits, if any, and how much sunscreen they typically apply to the face and both arms. A previous study was conducted using an online survey in Korea to identify common chemicals contained in household and personal care products and how much the respondents use of each product with the goal of conducting an aggregate human exposure assessment [14]. For this research, the survey method was refined with the addition of visual reference photos (Fig. 1) to aid participants in selecting the amount of sunscreen they typically apply per application. The panel included adults between 18–70 years old that reside in the United States of America. Data from the United States Census Bureau were used to determine quotas for participant genders, ethnicities, ages, and states of residence. Participant ethnicities were included to address possible cultural differences in sunscreen usage among subpopulations. Non-Caucasian ethnicities may be under-studied in sunscreen-related research. To account for this, the present study intentionally over-sampled for African American participants (up to 35%) and balanced the remaining participant ethnicities according to US Census data (see Table S1). The questionnaire consisted of multiple-choice questions regarding demographic characteristics,

sunscreen usage behaviors, reasons for usage, etc. Participants were asked if they applied sunscreen in the last 12 months. If the answer was yes, the participant was directed to a set of sunscreen user questions. If the answer was no, the participant was directed to a set of sunscreen non-user questions.

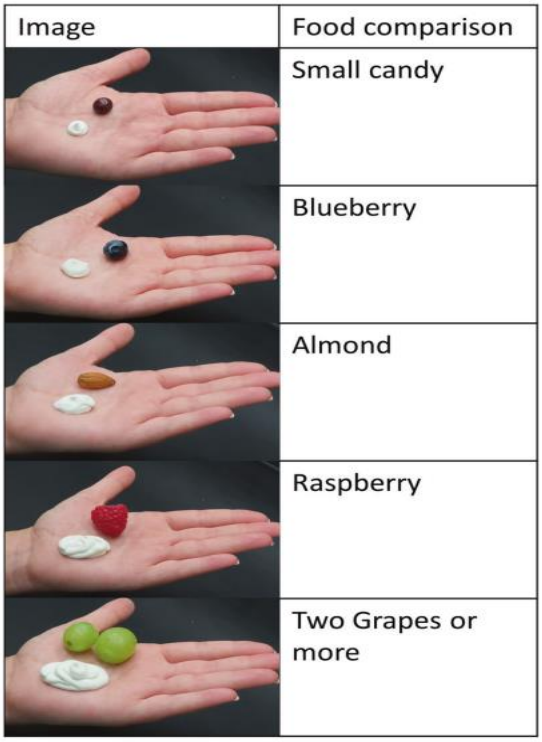

Fig. 1 Visual reference used in novel web-based consumer questions.

Candidates were invited to participate in the online self-administered survey hosted by Qualtrics (www.qualtrics.com). Qualtrics uses a mixed- method to recruit individuals. Respondents that previously registered with Qualtrics received a generic email invitation to participate in this study. If the participant agreed to participate, the link in the invitation email directed them to a detailed informed consent form. The participant was asked to review the informed consent and select "agree" to continue with the questionnaire or "disagree" to stop completion of the questionnaire. Double opt-in systems help to ensure data quality by screening out marginally-interested participants. This survey relied on participant selfreporting as the research team had no interaction with them.

III. LITERATURE REVIEW

A literature review was conducted to serve as a test of validity of the survey results [18] and searched for all previously published studies quantifying sunscreen application thickness. A review of several websites using a set of keywords was used to identify a base set of papers. The initial search was conducted with Science Direct, PubMed, and Google Scholar using a combination of the following keywords: sunscreen application, sunscreen use/usage, consumer sunscreen application rate. Only papers published in English were searched. Once the base set of papers was curated, inclusion and exclusion criteria were applied to identify the most relevant papers. Only those studies conducted with adults (>18 years old) were included. Studies that included measurements of the sunscreen application thickness to volunteers' face and body were included. In addition, only studies that used lotion type products were included; therefore, studies measuring application of spray products, make-up, or lip products were excluded from the review. There were no geographic exclusion criteria. After applying inclusion and exclusion criteria, a snowballing technique [19] was used on the core set of papers. For each paper, the text (forward snowballing) and the reference list (backward snowballing) were reviewed for further research to include in this literature review. Additionally, to ensure inclusion of the greatest number of relevant studies, the most frequently cited papers were selected for additional searching using Connected Papers

(https://www.connectedpapers.com/). This website connects publications based on their similarity and allows the identification of additional relevant publications. Each paper was reviewed, and the reported application thickness amounts were collected along with the year of the study, details of the study population, geographic location, the method of measurement, and the study aim.

Statistical analysis

After each individual sunscreen application thickness was estimated, a logarithmic multiple variable regression analysis was conducted using IBM SPSS Statistics (version: 28.0.0.0 (190)) software to determine if any of the independent variables were significant predictors of sunscreen application thickness to the face or both arms. For this analysis, the statistical significance level used is 0.05. Non-numeric independent variables were transformed to numeric values (Table S4). Summary statistics were also calculated for each data set using IBM SPSS Statistics.

IV. RESULTS

The following sections summarize the history of published application thickness values since 1985 and the estimated application thickness values for sunscreen use on the face and body.

Semi-quantification of sunscreen application thickness to consumer's face and arms

The questionnaire was in the field January 2022 and after Qualtrics removed incomplete and straight-lined (i.e., same response for each question) responses, a total of 9102 valid participant responses from the United States remained. Nearly 70% of respondents (n = 6325 of 9102 total) had used sunscreen at least once in the past 12 months (Table S3). The data from the 6325 respondents that reported sunscreen use in the past 12 months were separated into two datasets: face application thickness and both arms application thickness. For each of these datasets, blank responses for that application site were removed along with any that responded "I typically don't apply sunscreen to my face" or "I typically don't apply sunscreen to my arms." Next, in order to quickly identify incongruent height and weight combinations (e.g., 7'10" and 80 pounds), body mass index (BMI) [20] was estimated for each response and the dataset was sorted smallest to largest. The use of BMI as a filter to the dataset is not used to determine healthiness of the participants and was simply used to refine the current dataset recognizing the possibility of data entry errors. A BMI range of 14–40 (roughly equivalent to the 5th and 95th percentiles) was applied to each dataset as inclusion criteria for values falling within this range, resulting in 5399 responses for face application and 5203 responses for both arms application. The final filter applied to the data was removal of responses from individuals that did not use a lotion product in the last 12 months. The final dataset used to conduct the analysis is comprised of 4338 responses for face application and 3443 responses for both arms application.

Table 1. Comparison of summary statistics results for sunscreen application thickness from a large-scale online survey and a follow-up refined survey of the US population.

Application site	Face 1	Both arms 1	Face 2	Both arms 2
Sample size	4338	3443	2192	2020
Range	0.51–15.38 mg/cm^2	0.15–4.94 mg/cm^2	0.39–14.33 mg/cm^2	0.14–4.26 mg/cm^2
Mean	3.00 mg/cm^2	1.52 mg/cm^2	2.78 mg/cm^2	1.44 mg/cm^2
Standard deviation	2.9	1.1	2.59	1.06
Median	1.78 mg/cm^2	1.35 mg/cm^2	1.70 mg/cm^2	1.27 mg/cm^2
Variance	8.385	1.201	6.723	1.127
Skewness	1.79	0.661	1.888	0.641

The summary statistics for each dataset are listed in Table 1. The mean value for the face application thickness for all respondents is 3.00 mg/cm2 and 1.52 mg/cm2 for the application thickness of both arms. The median values for face and arm application thickness are 1.78 mg/cm2 and 1.35 mg/cm2 , respectively. The range of values between the two datasets is also quite different. The dataset for face application thickness is highly skewed and has a large

amount of variance. The mean and median values for the arm application thickness dataset are much closer in value when compared to the face application thickness value, further illustrating the skewness of the face dataset. Based on the frequency distributions, the median (1.78 mg/cm2) of the face application dataset is likely more relevant whereas the mean (1.52 mg/cm2) of the arms application dataset is the more relevant value. The application thickness results for both arms are more closely aligned with published values while the face application thickness dataset is quite different. Possible reasons for this difference will be discussed. The initial histograms for application thickness illustrated a significant positive skew (Fig. S3); therefore, the application thickness values for both the face and arms were logarithmically (log10) transformed before conducting logarithmic regression and additional statistical analysis. To determine which variables impacted application thickness on the face or arms, a multiple regression analysis of the log transformed values was conducted for each dataset. The variables included: state of residence, gender identity, age range, ethnicity, self-reported skin response to sun exposure (i.e., tendency to burn), Fitzpatrick skin type [21], reported history of skin cancer, the SPF range of the typical sunscreen used, if children are part of the household, use of sunscreen when planning to spend more than 30 min outdoors, use of sunscreen as part of their daily skincare routine, and residence in a warm or cold state (classified based on an average annual temperature from 1901–2000 above (warm) and below (cold) 50 °F [22]). For the log transformed face application thickness variable, the R2 is 0.030 ($F(12, 4331) = 11.109$, $p < 0.001$) and for the log transformed arms application thickness the R2 is 0.066 ($F(12, 3442) = 20.093$, $p < 0.001$; Tables S5 and S6). The predictors that had statistical significance for the face application thickness variable were age ($p = 0.004$), ethnicity ($p = 0.030$), reported skin response to sun exposure ($p < 0.001$), reported history of skin cancer ($p = 0.018$), product SPF range used ($p < 0.001$) and the use of sunscreen in a regular skincare routine ($p < 0.001$). The predictors that had statistical significance for both arms application thickness variable were gender identity ($p < 0.001$), ethnicity ($p = 0.045$), Fitzpatrick skin type ($p < 0.001$), reported history of skin cancer ($p = 0.020$), and product SPF range used ($p < 0.001$). In Table 2, the significance of each independent variable to the dependent variable of application thickness is provided. For facial application thickness, age range has a negative correlation indicating younger sunscreen users will apply more sunscreen. There is a positive correlation of ethnicity to application thickness but no valuable interpretation can be gained from this due to the fact that ethnicity is not a scaled variable. A person's tendency to burn (skin response to sun exposure) is negatively correlated with thickness application meaning those that tend to burn more will apply a greater amount of sunscreen to their face. The same can be said of those with a self-reported history of skin cancer and those that regularly use a sunscreen product as part of their skincare routine. The product SPF range used by participants is positively correlated to facial application thickness meaning those that use a higher SPF product tend to apply more sunscreen per application. For application to both arms (i.e., body), gender identity is negatively correlated to application thickness suggesting women typically apply a greater amount of sunscreen to their body. Both

Fitzpatrick skin type and history of skin cancer are negatively correlated to application thickness. Those with lighter skin tone and/or a history of skin cancer apply a greater amount of sunscreen to their body. Like facial application, product SPF range is positively correlated to application thickness indicating the higher product SPF used then the more sunscreen is generally applied. Again, ethnicity is positively correlated but no interpretation can be made based on these results. The second survey was in the field during May 2022 and resulted in a sample size of 2192 participants. Though some refinement of the dataset was achieved, the results for the followup survey had very similar results as the first study (see Table 1). For facial sunscreen application thickness, the dataset was still highly skewed (skewness = 1.888) and had significant variability (range: 0.39–14.33 mg/cm2 ; variance: 6.723). The second survey asked participants if they apply a greater amount of sunscreen to their face compared to their body (Fig. S4). Participants agreed strongly or somewhat agreed that they apply a greater amount of sunscreen to their face (69%).

Previously reported application thickness

The literature review search criteria initially identified 43 papers related to sunscreen application. After the inclusion and exclusion criteria was applied (quantified lotion sunscreen application thickness to the body and/or face in adult volunteers), 25 publications measuring sunscreen application thickness were included in the review. Each paper was reviewed, and data were extracted into summary Table S2. It should be noted that a critical review of each study's method of measuring application thickness was not conducted; instead, results are reported as published. In

Table 2. Significance of variables to the dependent variable of the log transformed sunscreen thickness values.

Dependent variable	Independent variable	Unstandardized *B*	Standardized coefficients *β*	*t*	Significance
Face application thickness (log_{10})	(Constant)	0.414		9.660	<0.001
	State of residence	0.001	0.030	1.948	0.051
	Gender identity	−0.003	−0.009	−0.562	0.574
	Age range	−0.012	−0.054	−2.900	0.004
	Ethnicity	0.006	0.043	2.173	0.030
	Skin response to sun exposure	−0.019	−0.073	−4.385	<0.001
	Fitzpatrick skin type	0.001	0.010	0.524	0.600
	History of skin cancer	−0.034	−0.037	−2.373	0.018
	Product SPF range used	0.029	0.091	5.958	<0.001
	Children in the household	0.011	0.016	0.996	0.319
	Use of sunscreen when outdoors more than 30 min	−0.009	−0.029	−1.467	0.142
	The use of sunscreen in skincare routine	−0.020	−0.067	−3.403	0.001
	Residence in a warm or cold state	−0.004	−0.005	−0.351	0.726
Arms application thickness (log_{10})	(Constant)	0.095		1.875	0.061
	State of residence	0.000	0.017	0.988	0.323
	Gender identity	−0.074	−0.206	−11.881	<0.001
	Age range	0.005	0.023	1.113	0.266
	Ethnicity	0.006	0.044	2.001	0.045
	Skin response to sun exposure	0.008	0.028	1.533	0.125
	Fitzpatrick skin type	−0.009	−0.067	−3.323	<0.001
	History of skin cancer	−0.040	−0.040	−2.329	0.020
	Product SPF range used	0.039	0.114	6.813	<0.001
	Children in the household	0.004	0.005	0.301	0.763
	Use of sunscreen when outdoors more than 30 min	0.000	0.000	−0.021	0.983
	The use of sunscreen in skincare routine	0.001	0.003	0.114	0.909
	Residence in a warm or cold state	0.018	0.022	1.291	0.197

total, 39 values of application thickness were identified from the 25 studies that were conducted around the world (Fig. S1). Only four studies reported sunscreen application thickness to the face. The majority of studies measured and reported values for the whole body, including the head. All reported values are collated in Fig. 2 and cover the years 1985–2020. The data were not consistently reported in the literature with summary statistics including a mixture of mean and median values for application amounts. For the years 1985–2017, 14 reported median values ranged from 0.2 to 2.4 mg/cm2 [11, 23]. For the years 1992–2020, 25 reported mean values ranged from 0.46 to 5 mg/cm2 [24, 25]. The red line in Fig. 2 represents the US FDA's recommended application thickness (2 mg/cm2). This figure illustrates how consumers have consistently applied an inadequate amount of sunscreen over the years. Petersen and Wulf [12] conducted a review of sunscreen application thickness and also observed the lower sunscreen application amount versus authority recommendations. They stated, "there is a discrepancy between the amount of sunscreen applied during testing and in reality". Of note, two values from a 2020 study [24] were above the FDA-recommended application thickness and were obtained from

volunteers with a history of skin cancer applying sunscreen to their face. This confounding variable likely accounts for higher use compared to other sub-populations. The literature review also summarized the methods employed to measure sunscreen application thickness from all the reviewed studies. Five measuring techniques are identified along with their respective percentage use in determining the 39 reported application thickness measurements (Fig. S2). The most common technique was to simply weigh the sunscreen product before and after application to determine the amount applied. Then, the investigators estimated the application surface area using different BSA calculation methods [17, 26, 27]. Additional methods such as tape stripping [11, 28], skin swabbing [29], and fluorescence dose-response [30, 31] have been investigated to determine application thickness but have not been widely adopted based on the results of this literature review.

V. DISCUSSION & CONCLUSION

The results of this research illustrate how a large-scale online consumer survey can be used successfully to collect data for consumer application of sunscreen products. The estimated sunscreen application thickness for both the participants' arms (mean = 1.52 mg/cm2 ; median = 1.35 mg/cm2) is greater than several of the measured values reported in the literature (mean range 0.46–5 mg/cm2 ; median range 0.2–2.4 mg/cm2); however, both values are still below the US FDA recommended application thickness of 2 mg/cm2 . In addition, the observed variability of the application thickness to both arms from this research also reflects a similar range as compared to the historical data set (this study: 0.15–4.94 mg/cm2 and literature review results: 0.2–5 mg/cm2 [11, 24]). For body estimates of sunscreen application, the method designed for this study is a viable option to reach a large population of sunscreen users.

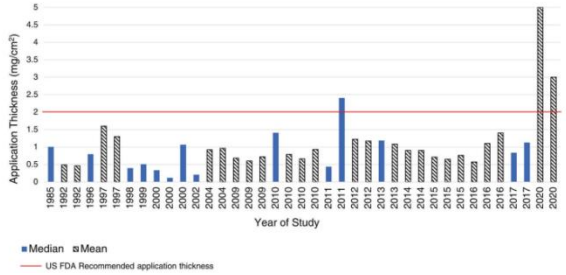

Fig. 2 Measured sunscreen application thickness values published since 1985. The figure includes the published application thickness values (mean - blue solid bar, median black and white striped bar) that have been reported in the literature (1985–2020).

As previously mentioned, exposure models usually include the US FDA-recommended application thickness in order to account for consumer usage and give a degree of conservativeness in the evaluation. However, there is a need to improve UV filter environmental emissions in order to move toward more accurate environmental exposure evaluations that can better guide risk management choices. According to the NASEM study, "UV filter environmental impact models that rely on sunscreen dosages that are currently recommended likely overestimate environmental outcomes and would be considered upper bounds [13]." The current mean value of 1.52 mg/cm2 (both arms application thickness) from this research seems to be somewhat close to the US FDA suggested application thickness of 2 mg/cm2, yet a basic exposure model may be used to illustrate the importance. We'll take Honolulu County, Hawaii's Waikiki Beach as an example. 9,284,101 people visited the beach in 2021 (https://emergencyservices.honolulu.gov/). This data may be used to approximate and

compare the total potential sunscreen emission to the aquatic environment, along with a few other assumptions. It is possible to calculate the potential direct release of sunscreen from a single application by assuming that the annual visitation is evenly distributed for each day (25,463 per diem), that 70% of visitors apply sunscreen, that 50% of beachgoers enter the water (conservative assumption), that 75% of each person's body is covered in sunscreen, that 24% [32] of the UV filter is rinsed off the body, and that the average body surface area is 18,352.59 cm2. In the worst-case scenario, up to 59 kilos of sunscreen may be applied on Waikiki Beach per day, based on the US FDA's recommended 2 mg/cm2 application rate. Nonetheless, based on the research's results, up to 45 kilos of sunscreen—roughly 24% less than the upper limit value—might find their way into the ecosystem at Waikiki Beach each day. By contrasting these two findings, one can see the need of improving conservative emissions estimates and the applicability of consumer research on sunscreen use. There are two things you should be aware of. First off, these are very cautious assumptions that are only meant to serve as examples. They shouldn't be used to guide risk management choices or be included into any kind of environmental risk assessment. The target compounds' environmental destiny and any kind of degradation are not included in this scenario. Second, neither the content of the UV filter formula nor variations in reapplication thickness are taken into consideration; this is the whole amount of sunscreen from a single application. In order to increase the accuracy of this approach for estimating the thickness of sunscreen application on the face, additional development and consumer research are required. The face application thickness dataset exhibits a high degree of variability (range: 0.52–15.38 mg/cm2; variance: 8.385) and is strongly skewed (skewness: 1.79). The market for sunscreen is expanding and changing to include sunscreen that isn't only meant for beach usage. Products with SPF protection and multipurpose items for everyday sun protection are already available on the market [33]. When questioning participants about how much sunscreen they use on a daily or regular basis, the survey used for this study did not make a distinction between lotion products intended for use at the beach (traditional sunscreen) and those intended for daily or routine sun protection. More research is required to determine the frequency of usage and the quantity of sunscreen used and reapplied to the face due to the shift in consumer behavior that has occurred since the US FDA OTC Sunscreen monograph was released in 1972. The literature review's findings show that, historically, customers have not used enough sunscreen lotion to obtain the UV protection factor that is listed on the label. Furthermore, since stated measuring techniques and data interpretation vary, it is impossible to quantify the relevance of the overall trend toward rising application volumes over time. Anecdotally, the expanding demand for sunscreen and the increasing popularity of online skincare gurus may be signs of this developing tendency [15]. Survey respondents could not be visiting the beach as often as they usually would because of the COVID outbreak, and they might not remember using sunscreen as much as they usually do. Similar to this, the self-reporting used in these surveys restricts the amount of reliable data that can be collected. Furthermore, the distribution of the data is limited by the fact that the research's conclusions are semi-quantitative rather than

providing an accurate measurement of sunscreen application levels. It's also possible that respondents misinterpreted the application amount question and responded by indicating that they applied the whole amount for the day rather than just one application. Compared to earlier research that used more regulated sunscreen application, the combination of these factors might result in higher uncertainty. However, earlier research demonstrating comparable patterns for body application thickness corroborates the findings of this investigation. When seeking to ascertain the effects of various UV filters on the environment and human health, the data nevertheless provide fresh value despite the possible increase in ambiguity. The present study dataset and previous data indicate that consumers are not applying the required quantity of sunscreen to their bodies. Consequently, an overestimation of exposure is likely to result from utilizing 2 mg/cm2 as an estimated application thickness in any UV filter exposure and/or risk assessment (such as the maximum use trial (MUsT) as carried out and mandated by US FDA [34, 35]). In order to validate existing human health exposure and risk assessments for UV filters and other sunscreen chemicals for both beach and regular daily sun protection products, data and insights from this study may be employed. Since UV filters are present in various personal care products and many sunscreens include several UV filters per product, using more accurate estimates of sunscreen consumption may also help to inform co-exposure evaluations. These revelations may also be used to enhance advice and awareness-raising initiatives for responsible sun exposure. The most common cancer in the US to be diagnosed is skin cancer [13]. When compared to other malignancies that may be prevented, the incidence of skin cancer in 2019 was six times greater than it was forty years earlier [13]. A total of $1.8 billion was spent on medical care for 39.5 million Americans who sought treatment in 2013 for skin damage caused by the sun [36]. "Regular application of broad spectrum, SPF 30 sunscreen when outdoors lowers the risk of developing skin cancer (keratinocyte carcinomas and melanomas), photoaging, and sunburn," according to the NASEM paper. This study shows that a large number of individuals do not use enough sunscreen to protect themselves against the damaging effects of prolonged sun exposure, and that the severity of these effects has been rising over time. Therefore, it is important to include the significance of sunscreen usage for human health while doing environmental risk evaluations of UV filters. More realistic exposure and risk assessments will come from replacing excessively cautious assumptions with more accurate values that reflect actual consumer sunscreen usage. This will help to educate and balance risk management activities for the health of people and the environment.

The purpose of this study's survey and questionnaires was to evaluate the effectiveness of an online tool for estimating the thickness of sunscreen application. The outcomes show how effective this strategy is. To be more clear about which independent factors predict the thickness of sunscreen application and how much each variable affects the application thickness of various subpopulations, the present research design has to be further refined. In addition, the visual reference for applying sunscreen to the face has to be improved. Utilizing such high doses for such a tiny region of the body might increase the participants' wide range and potential for misinterpretation. To have a deeper

knowledge of the thickness and frequency of sunscreen reapplication on the face and body by consumers, further study is also required. Ultimately, this research shows that a person's use of sunscreen is influenced by a variety of conditions. The study's findings support the notion that most people do not slather their bodies with the appropriate quantity of sunscreen. Customers who use sunscreen on their faces use more of it than they had previously thought. While further work is required to enhance ERAs for UV filters in face sunscreen products, this data may be utilized to improve risk assessments of UV filters applied to the body and directly enter the environment at the beach.

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