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RESEARCH ARTICLE

A comprehensive health effects assessment of the use of sanitizers and disinfectants during COVID-19 pandemic: a global survey

Fallah Hashemi[1] · Lori Hoepner[2] · Farahnaz Soleimani Hamidinejad[3,4] · Daniela Haluza[5] · Sima Afrashteh[6] · Alireza Abbasi[1] · Elma Omeragić[7] · Belma Imamović[7] · Narin A. Rasheed[8] · Taqi M. J. Taher[9] · Fitri Kurniasari[10] · Dhuha Youssef Wazqar[11] · Özge Ceren Apalı[12] · Ayca Demir Yildirim[13] · Bo Zhao[14] · Zaruhi Kalikyan[15] · Cui Guo[16] · Andrea Chong Valbuena[17] · Magdalena Mititelu[18] · Carolina Martínez Pando[19] · Maria Saridi[20] · Aikaterini Toska[20] · Magalys Lopez Cuba[21] · Precious Kwablah Kwadzokpui[22] · Niguse Tadele[23] · Tohfa Nasibova[24] · Stefanie Harsch[25] · Luvsan Munkh-Erdene[26] · Wafaa Menawi[27] · Efi Evangelou[28] · Antoniya Dimova[29] · Dimitar Marinov[30] · Teodora Dimitrova[30] · Anna Shalimova[31] · Howieda Fouly[32] · Anna Suraya[33,34] · Juliana Pereira da Silva Faquim[35] · Bouadil Oumayma[36] · Maria Antonieta Annunziato[37] · Rezarta Lalo[38] · Evridiki Papastavrou[39] · Anju D. Ade[40] · Susanna Caminada[41] · Svetlana Stojkov[42] · Carmen Gloria Narvaez[43] · Lutendo Sylvia Mudau[44] · Ines Rassas[45] · Daphnee Michel[46] · Nur Sema Kaynar[47] · Sehar Iqbal[48] · Halla Elshwekh[49] · Irin Hossain[50] · Sadeq AL-Fayyadh[51] · Aniuta Sydorchuk[52] · Dua'a M. H. Alnusairat[53] · Asli Mohamed Abdullahi[54] · Neelam Iqbal[55] · Apsara Pandey[56] · Brenda Gómez-Gómez[57] · Aysenur Gunaydin Akyildiz[58] · Elena Morosan[18] · Daniella Dwarica[59] · Gantuya Dorj[60] · Sumaya Yusuf Hasan[61] · Noha M. Al-Shdayfat[62] · Bojana Knezevic[63] · Wendy Valladares[64] · Cecilia Severi[65] · Sofia Cuba Fuentes[66] · Sofia Augusto[67] · Elizaveta Sidorova[68] · Anita Dewi Moelyaningrum[69] · Tafaul Alawad[70] · Atiqa Khalid[71] · Nafisa M. K. Elehamer[72] · Anna Mihaylova[73] · Oxana Tsigengagel[74] · Aziza Menouni[75] · Agnieszka Wojtecka[76] · Rozita Hod[77] · Yusuf Banke Idayat[78] · Khadija Othman[79] · Rim M. Harfouch[80] · Tsonco Paunov[30] · Meruyert Omar[81] · Nana Christine Benderli[82,83] · Globila Nurika[69] · Sana Amjad[84] · Salma Elnoamany[85] · Fatma Elesrigy[85] · Marwa Mamdouh Shaban[86] · Doménica Acevedo-López[87] · Maria Kartashova[88] · Atika Khalaf[89,90] · Sabah Abdullah Jaafar[91] · Taisir A. Kadhim[91] · Nada Ab Hweissa[92] · Yulong Teng[93] · Fatima E. Mohammed[94] · Thayahlini Sasikumar[95] · Christabel Nangandu Hikaambo[96] · Aditi Kharat[97] · Ulyana Lyamtseva[98] · Maya Arfan Aldeeb[99,100] · Natalia Pawlas[101] · Lkhagvasuren Khorolsuren[102] · Roopeshwaree Pallavi Koonjul[103] · Halima Boubacar Maïnassara[104] · Priyanka Chahal[105] · Rose W. Wangeci[106] · Ainur B. Kumar[107] · Irina Zamora-Corrales[108] · Stella Gracy[109] · Maimouna Mahamat[110] · Jakub Adamczyk[111] · Haliza Abdul Rahman[112] · Lolita Matiashova[113] · Omneya Ezzat Elsherif[114] · Nazdar E. Alkhateeb[115] · Yamilé Aleaga[116] · Shima Bahrami[117] · Shaimaa Rahem Al-salihy[118] · Paula Cabrera-Galeana[119] · Mladena Lalic-Popovic[120] · Eugenie Brown-Myrie[121] · Divya Bhandari[122] · Cinderella Akbar Mayaboti[123] · Svetlana Stanišić[124] · Sanda Kreitmayer Pestic[125] · Muhammed Yunus Bektay[126] · Haleama Al Sabbah[127] · Saber Hashemi[128] · Bouchetara Assia[129] · Anne-Sophie Merritt[130] · Zhian Ramzi[131] · Himawatee Baboolal[132] · Juman Isstaif[133] · Rula Shami[134] · Rahma Saad[135] · Temwanani Nyirongo[136] · Mohammad Hoseini[137,138]

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Abstract
COVID-19 has affected all aspects of human life so far. From the outset of the pandemic, preventing the spread of COVID-19 through the observance of health protocols, especially the use of sanitizers and disinfectants was given more attention. Despite the effectiveness of disinfection chemicals in controlling and preventing COVID-19, there are critical concerns about their adverse effects on human health. This study aims to assess the health effects of sanitizers and disinfectants on a global scale. A total of 91,056 participants from 154 countries participated in this cross-sectional study. Information on the use of sanitizers and disinfectants and health was collected using an electronic questionnaire, which was translated into 26

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languages via web-based platforms. The findings of this study suggest that detergents, alcohol-based substances, and chlorinated compounds emerged as the most prevalent chemical agents compared to other sanitizers and disinfectants examined. Most frequently reported health issues include skin effects and respiratory effects. The Chi-square test showed a significant association between chlorinated compounds (sodium hypochlorite and per-chlorine) with all possible health effects under investigation (p-value <0.001). Examination of risk factors based on multivariate logistic regression analysis showed that alcohols and alcohols-based materials were associated with skin effects (OR, 1.98; 95%CI, 1.87–2.09), per-chlorine was associated with eye effects (OR, 1.83; 95%CI, 1.74–1.93), and highly likely with itching and throat irritation (OR, 2.00; 95%CI, 1.90–2.11). Furthermore, formaldehyde was associated with a higher prevalence of neurological effects (OR, 2.17; 95%CI, 1.92–2.44). Furthermore, formaldehyde was associated with a higher prevalence of neurological effects (OR, 2.17; 95%CI, 1.92–2.44). The use of sodium hypochlorite and per-chlorine also had a high chance of having respiratory effects. The findings of the current study suggest that health authorities need to implement more awareness programs about the side effects of using sanitizers and disinfectants during viral epidemics especially when they are used or overused.

Keywords COVID-19 · Sanitizers and disinfectants · Side effects · Health protocols

Introduction

COVID-19 is one of the great challenges to human health. According to the report of the World Health Organization, by November 16, 2022, 548 million people were infected and more than 6 million deaths worldwide had occurred (WHO, 2022). The emergence of new and mutated strains of the virus over time and the production of less effective vaccines have exacerbated this catastrophic health challenge (Hashemi et al., 2022b; Viveiros-Rosa et al., 2022). From the beginning of the COVID-19 outbreak, simultaneously with treatment measures, health and preventive measures such as strict quarantine, social distancing, hand washing, disinfection of various surfaces, and wearing a mask among others, as health protocols to reduce and cut off the transmission chain were on the agenda of governments and health organizations (Alimohamadi et al., 2022a; Amanollahi et al., 2021; Hashemi et al., 2022b; Sharun et al., 2022). With the hypothesis of the persistence of the virus on different surfaces and its transmission through skin contact, personal and public hygiene by hand washing and disinfection of different surfaces became more important. Among the various surfaces with the most frequent contact were door handles, smartphones, remote controls, keyboards, tables and chairs, light switches, and elevator buttons, etc. (Al-Sayah, 2020; Ghafoor et al., 2021; Jin et al., 2020; Yari et al., 2020). The literature shows that SARS-CoV-2 can float in the air for 3 h, on smooth surfaces (glass, plastic, banknotes) for 4 to 7 days, on the outer layer of the surgical mask for up to 7 days, on copper surfaces, cardboard, and paper for less than 3 h and stainless steel up to 72 h (Chin et al., 2020; Dhama et al., 2021; Doremalen et al., 2020). The shelf life of the virus depends on various factors such as temperature, relative humidity, and pressure (Dindarloo et al., 2020; Gharehchahi et al., 2023; Kampf, 2020). To reduce the spread of the virus and disrupt the transmission chain, disinfection using sanitizers and disinfectants for living and non-living surfaces as an efficient method was recommended by the World Health Organization (WHO) and the US Environmental Protection Agency in accordance with the issued instructions (Chen et al., 2021; Dindarloo et al., 2020). Sanitizers and disinfectants used include alcohol-based materials, oxidizing agents, detergents, chlorine-releasing agents (sodium hypochlorite, per-chlorine), phenol-based disinfectants, iodine-releasing agents, aldehydes, hydrogen peroxide, and quaternary ammonium compounds, etc. (Al-Sayah, 2020; McDonnell and Russell, 1999; Rutala and Weber, 2019). Using sanitizers and disinfectants may have adverse effects on human health, mainly because of the harmful and corrosive compounds in the composition of most sanitizers and disinfectants, such as chlorine-releasing agents, quaternary ammonium cations, or oxidizing agents (Bonin et al., 2020; Dumas et al., 2019; Emmanuel et al., 2004; Nabi et al., 2020; Rafiee et al., 2022). The severity of these side effects may vary depending on the type of chemicals, their target objects (living or non-living surfaces), the frequency and volume of the chemicals, and the risk status of the exposed individual (Prajapati et al., 2022). Lack of knowledge and insufficient experience in sanitizer and disinfectant use increases the rate of side effects due to the use of these chemicals (Gharpure et al., 2020; Rai et al., 2020). Potential acute side effects of using sanitizers and disinfectants include skin effects, itching, sore throat, eyes, and nose irritation, and ailments of the respiratory system (cough, sneezing, shortness of breath). Neurological effects such as headache, dizziness, and vomiting have been also reported (ECDC, 2020; Goh et al., 2021; Lachenmeier, 2008). Regardless of the sanitizer and disinfectant safety information and application instructions prolonged use of these products may cause chronic side effects including disorders of the central nervous system (CNS),

reproductive disorders, cancer, pulmonary obstruction, etc. (Choi et al., 2020). Although several studies have been conducted regionally in a variety of countries on some of the adverse health effects due to disinfectant use (Dawood et al., 2021; Dhama et al., 2021; Dindarloo et al., 2020; Ghafoor et al., 2021; Rosenman et al., 2021; Shah et al., 2021), the present study is a comprehensive survey aimed to estimate the health effects associated with the use of sanitizers and disinfectants among the general population on a global scale.

Methods

Design, participants, and sampling procedure

This study aims to assess the health effects of sanitizers and disinfectants on a global scale. There were no exclusion/inclusion criteria for participation in the study, and all individuals regardless of race, gender, occupation, and income level were included. The research project was approved by the ethics committee of Shiraz University of Medical Sciences (IR.SUMS.REC.1400.023). This study follows the principles of the Declaration of Helsinki. Survey design (non-interventional) is not considered a clinical trial under Directive 2001/20/EC and Regulation (Europe) No 536/2014. All participants provided online informed consent before the study.

Measurement tools

Questionnaire

The questionnaire was translated into 26 different languages by native language speakers. The questionnaire included three parts (including 26 items). The first part (7 questions) was referring to demographic information including age, gender, educational and occupational status, country, place of residence, and income level. The second part (6 questions) included the type, monthly usage volume, and the number of daily use of sanitizers and disinfectants for living and non-living surfaces. The chemicals which have been investigated included detergents (soap and toilet liquid, dishwashing liquid), alcohol or alcohol-based materials, hospital-grade sanitizers (savlon; antiseptic liquid), other commercial sanitizers (chlorhexidine gluconate, bronopol, triclosan), hospital disinfectants (quaternary ammonium, tetra-acetyl ethylenediamine), chlorine-based compounds (sodium hypochlorite, per-chlorine), hydrogen peroxide, and formaldehyde. The third part (13 questions) included health effects. Skin effects (itching and skin irritation, dryness, scaling, and urticaria), ocular (itching and eye irritation, and redness), irritation and itching of the throat, respiratory problems (itching and nasal irritation, runny nose, cough and sneezing, and shortness of breath), and neurological effects (headache, dizziness, and vomiting) were questioned. Questionnaire-related questions and options were reviewed by several specialists, including a dermatologist, otolaryngologist, ophthalmologist, pulmonologist, and chemist, as well as a biostatistics specialist.

Reliability and validity

The reliability of the questionnaire showed good internal consistency (Cronbach's alpha = 0.90). The validity of the questionnaire for only seven living languages (Arabic, English, French, German, Persian, Russian, and Spanish) which are considered official or secondary languages of several countries, was reviewed by 5 to 7 experts in each of the 7 languages with research backgrounds related and faculty members. These experts assessed the validity in light of five components of necessity, relevance, transparency, simplicity, and ambiguity related to each question.

Data collection procedure

The questionnaire was designed using Google Form®. In some countries (e.g., China), lack of access to Google or due to poor bandwidth, other internal platforms (e.g., wenjuanxing) and sites (e.g.; https://www.wjx.cn/) were used to create online links to the questionnaire. The questionnaire was distributed via email or social networks such as Telegram, WhatsApp, Instagram, Twitter, LinkedIn, and WeChat. The questionnaire was available online for 9 months from August 1, 2021 to April 30, 2022 to achieve maximum participation.

Statistical analysis

The data were analyzed using IBM SPSS for Windows, version 28.0 (IBM Inc., Armonk, NY, USA). The Chi-square test was used to analyze descriptive statistics (n, %), and to evaluate the significance of the association between variables. To assess risk factors for health outcomes in participants, a multivariable logistic regression analysis was performed, and the relationship between risk factors and adverse effects of using sanitizers and disinfectants are presented as odds ratios (ORs) and 95%CIs, after adjustment for confounders, including age, gender, educational level, occupational status, place of residence (rural and urban areas), and income level. A p-value of <0.001 was considered statistically significant.

Result

Study design and participants

Demographic characteristics are shown in Table 1. A total of 91,056 participants [58,845 (64.60%) females and 32,211

Table 1 Demographic characteristics of the study ($N = 91,056$)

Characteristics			N	Male	Female
Age	≤20		9861(10.8)	3502(3.8)	6359(7.0)
	21 to 30		37,577(41.3)	12,637(13.9)	24,940(27.4)
	31 to 40		22,250(24.4)	8093(8.9)	14,157(15.5)
	41 to 50		13,338(14.6)	4744(5.2)	8594(9.4)
	51 to 60		5746(6.3)	2150(2.4)	3596(3.9)
	60 and over		2284(2.5)	1085(1.2)	1199(1.3)
Place of residence	Urban		76,122(83.6)	25,987(28.5)	50,135(55.1)
	Rural		14,934(16.4)	6224(6.8)	8710(9.6)
Level of education	School education		14,784(16.2)	5662(6.2)	9122(10.0)
	Associate degree		12,546(13.8)	3673(4.0)	8873(9.7)
	Bachelor's degree		38,924(42.7)	13,457(14.8)	25,467(28.0)
	Masters		16,798(18.4)	6348(7.0)	10,450(11.5)
	Ph.D. and postdoctoral		8004(8.8)	3071(3.4)	4933(5.4)
Occupational status	Unemployed / housewife / student		12,571(13.8)	2443(2.7)	10,128(11.1)
	University Student		28,104(30.9)	9489(10.4)	18,615(20.4)
	Government employee		26,249(28.8)	10,038(11.0)	16,211(17.8)
	Private office employee		16,619(18.3)	645(7.0)	9974(11.0)
	Freelance (self-employed)		7513(8.3)	3596(3.9)	3917(4.3)
Income	Low		8877(9.7)	3004(3.3)	5873(6.4)
	Lower-middle		11,339(12.5)	4325(4.7)	7014(7.7)
	Middle		48,776(53.6)	17,165(18.9)	31,611(34.7)
	Upper-middle		18,308(20.1)	6276(6.9)	12,032(13.2)
	High-income		3756(4.1)	1441(1.6)	2315(2.5)
Number of participating countries by continent: N (RR*)	Africa	America	Asia	Europe	Oceania
	48 (24.6%)	19 (9.7%)	44 (22.5%)	39 (20%)	4(2%)
No participation: N	6	16	4	5	10

*Response Rate

(35.40%) males]. Respondents were well represented by ages 21 to 30 years (37,577, 41.30%), urban areas (76,122, 83.60%), bachelor's degree (38,924, 42.70%), and median income (48,776, 53.60%). In this study, the income level was considered relative to the average income of each country. Therefore, the majority of participants had an average income in their country. Out of 193 United Nations (UN) members (and 2 countries that are non-member observer states: the Holy See and the State of Palestine), 154 countries participated in this study. The global participation rate was reported

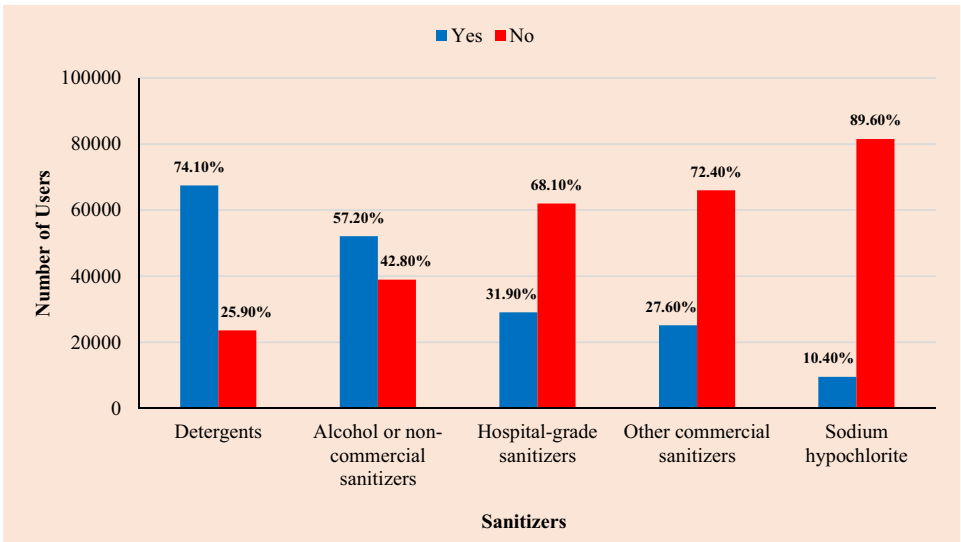

Fig. 1 Usage status of five groups of sanitizers

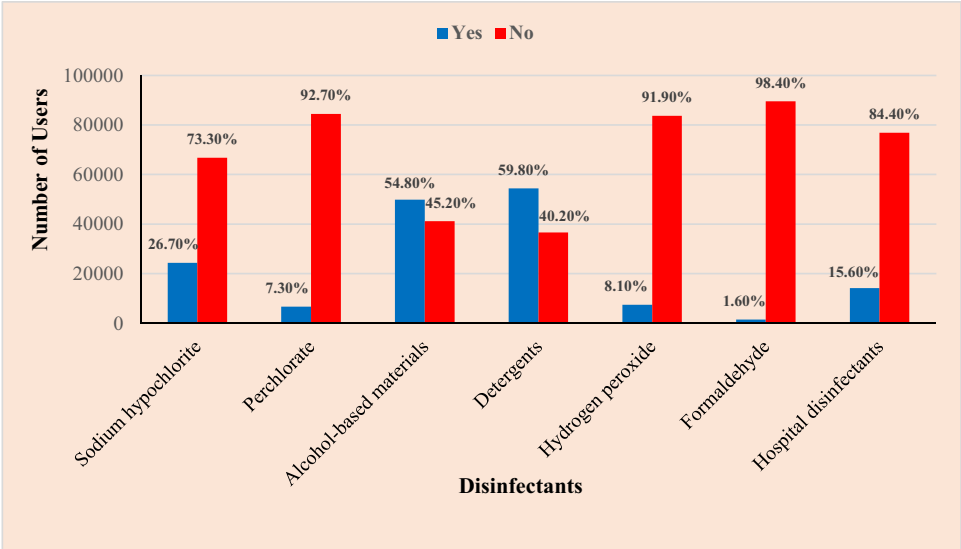

Fig. 2 Usage status of seven groups of disinfectants

to be 79%. 41 countries (21%) from different continents did not participate in the study. According to Table 1, the number of participating countries from each continent includes Africa (48), America (19), Asia (44), Europe (39), and Oceania (4) countries correctly completed the questionnaire.

Type and volume of sanitizers and disinfectants used

In the second part of the questionnaire, questions were asked about the type, volume, and number of times of daily use of 5 types of chemical compounds as sanitizers (Figure 1) and 7 types of substances as disinfectants (Figure 2). The status of the use of sanitizers and disinfectants is shown in Table 2 and Figures 1, 2, and 3. The usage status of the sanitizers for handwashing or other living surfaces is shown in Figure 1. Compared to other sanitizers, the highest use was detergents (soap and toilet liquid, dishwashing liquid) (67,445 users), and alcohol or non-commercial sanitizers (52,083 users). In contrast, chlorine compounds such as sodium hypochlorite (9490 users) were used less often as sanitizers. Additionally, the status of seven groups of disinfectants, which are used for the disinfection of various high-touch surfaces such as door handles, tables, chairs, remotes, keys, elevator buttons, etc., was explored (Figure 2). In this group, in addition to detergents (54,445 users) and alcohol-based products (49,879 users), which were most used compared to other disinfectants, the use of sodium hypochlorite was reported as a high-consumptive disinfectant (24,296 users). In contrast, formaldehyde (1441 users) and per-chlorine (6605 users) had the lowest usage as a disinfectant.

In terms of the frequency of daily use of sanitizers and disinfectants, the results showed that most participants tended to use sanitizers and disinfectants 1 to 3 times a day (29,778 users) and once a day (35,959 users), respectively. The volume of chemicals used was also one of the important factors in creating the scenarios of possible adverse effects and we found that most of the participants stated using the sanitizers and disinfectants at a volume of approximately 101–300 mL, and 0.5–1 L per month, respectively (Table 2).

Table 2 Usage status of sanitizers and disinfectants

	Frequency of daily use					Monthly usage volume (CC**)				
	Once a day	1–3/d	4–6/d	> 6/d	None	Low (≤100)	Average (101 to 300)	High (301 to 500)	Too much (≥500)	None
Sanitizers: N* (%)	11,069 (12.2)	29,778 (32.7)	27,407 (30.1)	21,608 (23.7)	1140 (1.3)	22,849 (25.1)	45,091 (49.5)	13,292 (14.6)	8572 (9.4)	1198 (1.3)
						Monthly usage volume (L***)				
	Once a day	1–3/d	4–6/d	> 6/d	None	Low (≤0.5)	Average (0.5 to 1)	High (1.1 to 2)	Too much (>2)	None
Disinfectants: N (%)	35,959 (39.5)	34,436 (37.8)	11,158 (12.3)	5159 (5.7)	3990 (4.4)	27,727 (30.5)	44,686 (49.1)	10,783 (11.8)	4978 (5.5)	2816 (3.1)

*The users of sanitizers and disinfectants. **It is expressed in CC due to its use for living surfaces. ***It is expressed in liters due to its use for non-living surfaces

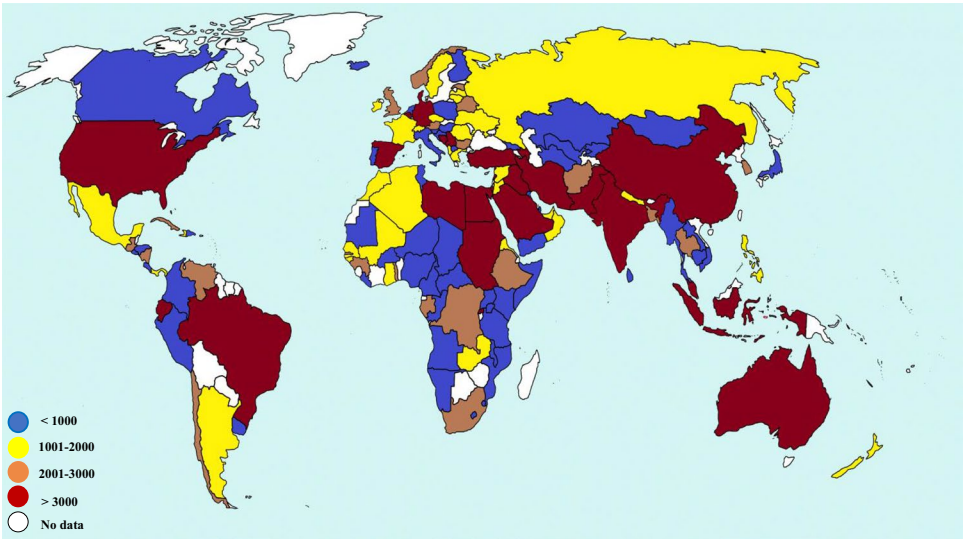

Fig. 3 Distribution of the use of sanitizers and disinfectants in different countries

The continental distribution of the inclination of users (individuals) to use sanitizers and disinfectants is shown in Figure 3. Four groups of countries were determined according to the sanitizers and disinfectant usage rate: countries with low usage (blue <1000), medium usage (yellow = 1001–2000), high usage (brown = 2001–3000), and countries that tend to consume too many sanitizers and disinfectants (red >3000). The number of countries that were less inclined to use sanitizers and disinfectants was in Africa, while the number of countries with the highest level of usage was in Asia. Similarly, the continental distribution shows that most countries with moderate usage of sanitizers and disinfectants were in continental Europe.

Adverse health outcomes of sanitizers and disinfectants

The distribution of the frequency of adverse events showed that the most common complaints reported by the participants were related to skin and respiratory system effects (Figure 4). The highest and lowest frequencies were related to skin dryness (65,680 cases) and neurological effects (headache, dizziness, and vomiting) (13,063 cases), respectively. Table 3 shows the possible adverse health outcomes as a result of the use of sanitizers and disinfectants based on the reports of the participants in this study. There was a significant relationship between the use of chlorine compounds such as sodium hypochlorite and per-chlorine with all the adverse effects ($p < 0.001$) (Table 3).

Skin effects

The use of detergents and alcohol or alcohol-based products resulted in a greater adverse effect on the skin than other chemicals (Table 3). Among the skin effects, the most commonly reported adverse effect was skin dryness. 45,259 and 39,573 of the participants complained of dry skin due to the use of detergents and alcohol or alcohol-based materials, respectively. There was a significant relationship between itching and skin irritation with all chemicals (except other commercial sanitizers and hospital disinfectants) ($p < 0.001$). Unlike other chemicals, there was no significant relationship between skin scaly with alcohols, commercial sanitizers, and hydrogen peroxide ($p > 0.05$).

Ocular effects

The contribution of sodium hypochlorite in causing ocular effects was greater than other chemicals. Participants reported itching and ocular irritation (15,407 cases) and ocular redness (11,302 cases) after using sodium hypochlorite. The data show a significant relationship between itching and ocular irritation with all sanitizers and disinfectants (except detergents and alcohol or alcohol-based materials) ($p < 0.001$) (Table 3).

Throat effects

Participants reported itching and irritation of the throat after using alcohol or alcohol-based products (12,591 cases), hospital-grade sanitizers such as savlon (6671 cases), and other commercial sanitizers (6035 cases). Itching and irritation of the throat as one of the possible side effects of sanitizers and disinfectants was significantly associated with some chemicals such as chlorine compounds (sodium hypochlorite and per-chlorine), hospital disinfectants, hydrogen peroxide, formaldehyde ($p < 0.001$) (Table 3).

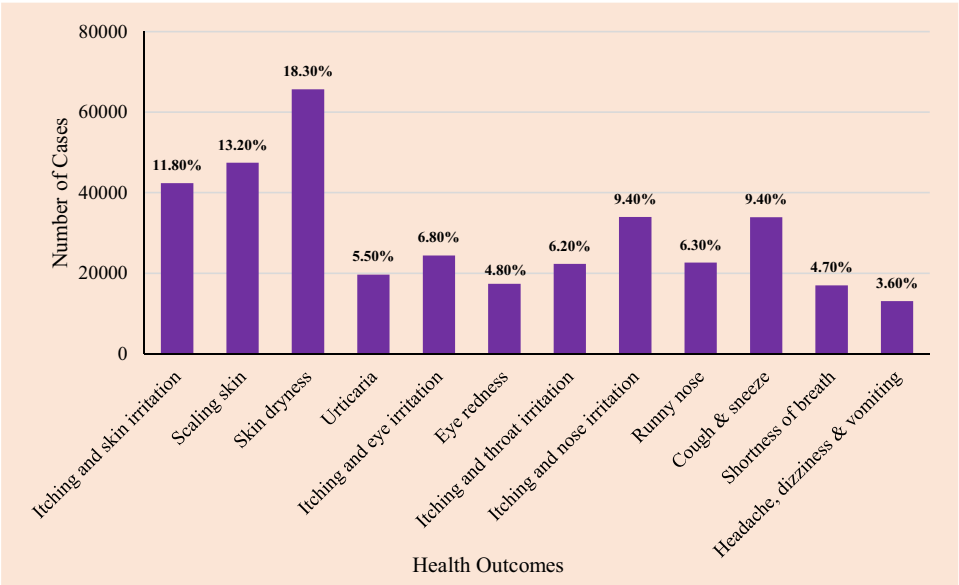

Fig. 4 The frequency distribution of 12 health outcomes studied

Respiratory system effects

Respiratory effects including itching and nose irritation (19,692 cases), runny nose (12,601 cases), and cough and sneezing (20,148 cases) were reported after using alcohol or alcohol-based products. There was a significant relationship between shortness of breath with all chemicals except detergents (all $p < 0.001$). In contrast, except for chlorine compounds, there was no significant relationship between cough, sneezing, and runny nose with the majority of sanitizers and disinfectants ($p > 0.05$) (Table 3).

Neurological effects

The present findings showed that less than eight percent of the participants had self-reported neurological effects including headache, dizziness, and vomiting after using sanitizers and disinfectants. In total, 7114 and 419 of participants complained of headache, dizziness, and vomiting after using alcohol (the most) and formaldehyde (the least), respectively. The results indicated that a statistically significant relationship was found between possible neurological problems due to the use of analyzed sanitizers and disinfectants (except detergents) (all $p < 0.001$) (Table 3).

Multivariable logistic regression analysis

After controlling for confounders (demographic characteristics), a multivariable logistic regression analysis was performed to determine the risk factors associated with adverse health outcomes (Table 4). The use of some sanitizers and disinfectants was associated with skin adverse effects (e.g., Itching and skin irritation after using alcohol or alcohol-based materials: OR, 1.86; 95%CI, $p > 0.05$; or as a result of using sodium hypochlorite: OR, 1.43; 95%CI, $p < 0.001$). In contrast, the use of some other sanitizers and disinfectants was associated with a lower chance of itching and skin irritation (hospital disinfectants: OR, 0.91; 95%CI, $p < 0.001$). The use of Per-chlorine (OR, 1.47; 95%CI, $p < 0.001$), alcohol-based materials (OR, 1.98; 95%CI, $p < 0.001$), formaldehyde (OR, 1.40; 95%CI, $p < 0.001$) were associated with higher odds of skin dryness, scaling of the skin, skin urticaria respectively.

Itching and ocular irritation were reported after using per-chlorine: OR, 1.83; 95%CI, $p < 0.001$; and sodium hypochlorite: OR, 1.33; 95%CI, $p < 0.001$. Similarly, ocular redness was associated with the use of per-chlorine (OR, 1.77; 95%CI, $p < 0.001$), and hydrogen peroxide (OR, 1.49; 95%CI, $p < 0.001$).

The results showed that one of the important risk factors for throat-related effects is chlorine-based compounds. Per-chlorine resulted in double the risk for throat-related effects (OR, 2.00; 95%CI, $p < 0.001$), and sodium hypochlorite use is also a serious risk factor for itching and throat irritation (OR, 1.66; 95%CI, $p < 0.001$). Furthermore, the use of sodium hypochlorite (OR, 1.74; 95%CI, $p < 0.001$), and formaldehyde (OR, 1.56; 95%CI, $p < 0.001$) were accompanied by coughing and sneezing. Similarly, shortness of breath was associated with the use of sodium hypochlorite (OR, 1.78; 95%CI, $p < 0.001$), and per-chlorine (OR, 1.67; 95%CI, $p < 0.001$). There was a strong association between the use of formaldehyde and the occurrence of neurological effects (OR, 2.17; 95%CI, $p < 0.001$).

Table 3 Frequency table and the relationship between sanitizers/disinfectants and health outcomes (Chi-square test)

Type of chemical		Itching and skin irritation		Skin dryness		Hand scaling		Skin urticaria (Hives)	
		Yes	No	Yes	No	Yes	No	Yes	No
		N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Detergents (Soap and toilet liquid, dish-washing liquid)	Yes	29,952(32.9)	30,996(34.0)	45,259(49.7)	15,688(17.2)	33,286(36.6)	27,662(30.4)	7037(7.7)	48,320(53.1)
	P-value	<0.001		<0.001		<0.001		<0.001	
Alcohol or alcohol-based materials	Yes	24,786(27.2)	27,300(30.0)	39,573(43.5)	12,513(13.7)	27,979(30.7)	24,107(26.5)	10,614(11.7)	41,472(45.5)
	P-value	<0.001		<0.001		<0.025		<0.001	
Sodium hypochlorite (bleach)	Yes	19,450(21.4)	7443(8.2)	33,453(36.7)	3440(3.8)	29,954(32.9)	6940(7.6)	4364(4.8)	12,529(13.8)
	P-value	<0.001		<0.001		<0.001		<0.001	
Hospital-grade sanitizers (savlon)	Yes	14,322(15.7)	14,698(16.1)	21,417(23.5)	7603(8.3)	15,369(16.9)	13,651(15.0)	6134(6.7)	22,886(25.1)
	P-value	<0.001		<0.001		<0.001		0.022	
Other commercial sanitizers	Yes	11,719(12.9)	13,372(14.7)	17,880(19.6)	7211(7.9)	13,082(14.4)	12,009(13.2)	5018(5.5)	20,073(22.0)
	P-value	0.592		<0.001		0.847		<0.001	
Hospital disinfectants	Yes	6501(7.1)	7685(8.4)	10,447(11.5)	3739(4.1)	6943(7.6)	7243(8.0)	3432(3.8)	10,754(11.8)
	P-value	0.057		<0.001		<0.001		<0.001	
Per-chlorine	Yes	4097(4.5)	2511(2.8)	5234(5.7)	1374(1.5)	4581(5.0)	2027(2.2)	1918(2.1)	4690(5.2)
	P-value	<0.001		<0.001		<0.001		<0.001	
Hydrogen peroxide	Yes	3788(4.2)	3592(3.9)	5387(5.9)	1993(2.2)	3925(4.3)	3455(3.8)	1872(2.1)	5508(6.0)
	P-value	<0.001		0.088		0.049		<0.001	
Formaldehyde	Yes	768(0.8)	676(0.7)	1000(1.1)	444(0.5)	923(1.0)	521(0.6)	436(0.5)	1008(1.1)
	P-value	<0.001		0.015		<0.001		<0.001	
Type of chemical		Itching and eye irritation		Eye redness		Itching and throat irritation		Itching and nose irritation	
		Yes	No	Yes	No	Yes	No	Yes	No
		N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Detergents (soap and toilet liquid, dish-washing liquid)	Yes	6294(6.9)	44,654(49.0)	11,255(12.3)	49,580(54.5)	964(1)	45,754(50.2)	12,976(14.3)	37,971(41.7)
	P-value	0.039		<0.001		<0.001		0.002	
Alcohol or non-commercial alcohol-based sanitizers	Yes	14,108(15.5)	10,309(11.3)	9289(10.2)	8077(8.9)	12,591(13.8)	39,495(43.4)	19,692(21.6)	32,394(35.6)
	P-value	0.034		<0.001		<0.001		0.068	
Sodium hypochlorite (bleach)	Yes	15,407(16.9)	11,487(12.6)	11,302(12.4)	12,592(13.8)	5502(6.0)	11,391(12.5)	17,551(19.3)	9342(10.3)
	P-value	<0.001		<0.001		<0.001		<0.001	
Hospital-grade sanitizers	Yes	7180 (7.9)	21,840(24.0)	5450(6.0)	23,570(25.9)	6671(7.3)	22,349(24.5)	10,359(11.4)	18,661(20.5)
	P-value	<0.001		0.126		0.321		0.210	
Other commercial sanitizers	Yes	6440(7.1)	18,651(20.5)	4482(4.9)	20,609(22.6)	6035(6.6)	19,056(20.9)	8911(9.8)	16,180(17.8)
	P-value	<0.001		<0.001		<0.001		0.055	
Hospital disinfectants	Yes	3310(3.6)	10,876(11.9)	2658(2.9)	11,528(12.7)	2978(3.3)	11,208(12.3)	4530(5.0)	9656(10.6)
	P-value	<0.001		0.274		<0.001		<0.001	
Per-chlorine	Yes	2614(2.9)	3994(4.4)	1922(2.1)	4686(5.1)	2624(2.9)	3984(4.4)	3484(3.8)	3124(3.4)
	P-value	<0.001		<0.001		<0.001		<0.001	

Table 3 (Continued)

Hydrogen peroxide	Yes	2084(2.3)	5296(5.8)	1750(1.9)	5630(6.2)	2049(2.3)	5331(5.9)	2579(2.8)	4801(5.3)
	P-value	<0.001		<0.001		<0.001		0.332	
Formaldehyde	Yes	525(0.6)	919(1.0)	410(0.5)	1034(1.1)	482(0.5)	962(1.1)	715(0.8)	729(0.8)
	P-value	<0.001		<0.001		<0.001		<0.001	
Type of chemical		Runny nose		Cough and Sneeze		Shortness of breath		Headaches, dizziness, and vomiting	
		Yes	No	Yes	No	Yes	No	Yes	No
		N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Detergents (Soap and toilet liquid, dish-washing liquid)	Yes	3296(3.6)	45,653(50.1)	5033(5.5)	36,868(40.5)	6248(6.9)	49,700(54.6)	4213(4.6)	52,335(57.5)
	P-value	0.002				0.065		0.118	
Alcohol or alcohol-based materials	Yes	12,601(13.8)	39,485(43.4)	20,148(22.1)	13,773(15.1)	9206(10.1)	42,880(47.1)	7114(7.8)	44,972(49.4)
	P-value	0.068				<0.001		<0.001	
Sodium hypochlorite (bleach)	Yes	5753(6.3)	11,141(12.2)	7833(8.6)	9061(10.0)	11,738(12.9)	13,156(14.4)	2929(3.2)	13,965(15.3)
	P-value	<0.001				<0.001		<0.001	
Hospital-grade sanitizers	Yes	6473(7.1)	22,547(24.8)	10,172(11.2)	18,848(20.7)	5091(5.6)	23,929(26.3)	3682(4.0)	25,338(27.8)
	P-value	0.210				<0.001		<0.001	
Other commercial sanitizers	Yes	5845(6.4)	19,246(21.1)	8857(9.7)	16,234(17.8)	4223(4.6)	20,868(22.9)	3368(3.7)	21,723(23.9)
	P-value	0.055				<0.001		<0.001	
Hospital disinfectants	Yes	2784(3.1)	11,402(12.5)	4460(4.9)	9726(10.7)	2164(2.4)	12,022(13.2)	2005(2.2)	12,181(13.4)
	P-value	<0.001				<0.001		<0.001	
Per-chlorine	Yes	2594(2.8)	4014(4.4)	3396(3.7)	3212(3.5)	1881(2.1)	4727(5.2)	1425(1.6)	5183(5.7)
	P-value	<0.001				<0.001		<0.001	
Hydrogen peroxide	Yes	7380(8.1)	5582(6.1)	2677(2.9)	4703(5.2)	1593(1.7)	5787(6.4)	1254(1.4)	6126(6.7)
	P-value	0.332				<0.001		<0.001	
Formaldehyde	Yes	537(0.6)	907(1.0)	708(0.8)	736(0.8)	428(0.5)	1016(1.1)	419(0.5)	1025(1.1)
	P-value	<0.001				<0.001		<0.001	

Table 4 Risk factors for health effects by Multivariable Logistic Regression Analysis

Type of chemical	Itching and skin irritation			Skin dryness			Skin scaling			Skin urticaria (Hives)		
	Adjusted OR	CI (95%)	*P*	Adjusted OR	CI (95%)	*P*	Adjusted OR	CI (95%)	*P*	Adjusted OR	CI (95%)	*P*
Detergents (Soap and toilet liquid, dish-washing liquid)	1.15	1.09–1.21	<0.001	1.06	1.02–1.10	<0.001	1.15	1.11–1.19	<0.001	0.94	0.90–0.97	<0.001
Alcohol or alcohol-based materials	1.86	1.77–1.96	0.020	1.30	1.26–1.34	<0.001	1.98	1.87–2.09	<0.001	0.86	0.83–0.89	<0.001
Sodium hypochlorite (bleach)	1.43	1.39–1.48	<0.001	1.40	1.35–1.46	<0.001	1.30	1.24–1.37	<0.001	0.90	0.87–0.93	<0.001
Hospital-grade sanitizers	1.08	1.05–1.12	<0.001	0.82	0.79–0.93	<0.001	1.01	0.98–1.04	0.394	0.86	0.83–0.89	<0.001
Other commercial sanitizers	0.90	0.87–0.93	<0.001	0.86	0.83–0.89	<0.001	0.95	0.92–0.98	0.005	0.82	0.79–0.85	<0.001
Hospital disinfectants	0.91	0.88–0.95	<0.001	1.10	1.06–1.15	<0.001	0.84	0.81–0.87	<0.001	1.26	1.21–1.32	<0.001
Per-chlorine	0.96	0.94–0.99	<0.001	1.47	1.38–1.56	<0.001	1.37	1.29–1.45	<0.001	0.95	0.90–1.01	0.125
Hydrogen peroxide	1.15	1.09–1.21	<0.001	0.95	0.90–1.01	0.125	0.96	0.91–1.01	0.136	1.37	1.29–1.45	<0.001
Formaldehyde	1.20	1.07–1.34	<0.001	0.85	0.76–0.96	0.011	1.46	1.31–1.64	<0.001	1.40	1.24–1.57	<0.001
Type of chemical	Itching and Eye Irritation			Eye Redness			Itching and Throat Irritation			Itching and Nose Irritation		
	Adjusted OR	CI (95%)	*P*	Adjusted OR	CI (95%)	*P*	Adjusted OR	CI (95%)	*P*	Adjusted OR	CI (95%)	P
Detergents (Soap and toilet liquid, dish-washing liquid)	0.95	0.92–0.98	<0.001	0.85	0.82–0.88	<0.001	0.69	0.62–0.76	0.063	1.21	1.17–1.24	<0.001
Alcohol or alcohol-based materials	1.11	1.07–1.15	0.002	1.05	1.01–1.08	<0.001	0.97	0.93–1.00	0.053	1.07	1.04–1.11	<0.001
Sodium hypochlorite (bleach)	1.33	1.27–1.40	<0.001	1.65	1.58–1.71	<0.001	1.66	1.58–1.74	<0.001	1.48	1.41–1.55	<0.001
Hospital-grade sanitizers	0.83	0.80–0.86	<0.001	0.90	0.86–0.93	<0.001	0.84	0.81–0.87	<0.001	0.87	0.84–0.89	<0.001
Other commercial sanitizers	0.89	0.86–0.92	<0.001	0.81	0.77–0.84	<0.001	0.89	0.86–0.93	<0.001	0.85	0.82–0.88	<0.001
Hospital disinfectants	0.90	0.86–0.94	<0.001	-	-	-	0.83	0.79–0.87	<0.001	0.82	0.79–0.86	<0.001
Per-chlorine	1.83	1.74–1.93	<0.001	1.77	1.68–1.88	<0.001	2.00	1.90–2.11	<0.001	1.87	1.78–1.97	<0.001
Hydrogen peroxide	1.15	1.09–1.22	<0.001	1.49	1.40–1.58	<0.001	1.19	1.13–1.26	<0.001	0.92	0.87–0.97	0.003
Formaldehyde	1.40	1.26–1.57	<0.001	1.34	1.19–1.52	<0.001	1.29	1.15–1.45	<0.001	1.56	1.40–1.73	<0.001
Type of chemical	Runny nose			Cough and Sneeze			Shortness of breath			Headaches, Dizziness, and Vomiting		
	Adjusted OR	CI (95%)	*P*	Adjusted OR	CI (95%)	*P*	Adjusted OR	CI (95%)	*P*	Adjusted OR	CI (95%)	P

Table 4 (continued)

Detergents (Soap and toilet liquid, dish-washing liquid)	0.93	0.90–0.97	<0.001	0.67	0.61–0.78	<0.001	0.94	0.90–0.98	0.004	0.95	0.92–0.99	0.019
Alcohol or alcohol-based materials	0.76	0.73–0.79	<0.001	1.05	1.02–1.08	0.005	0.91	0.87–0.94	<0.001	1.06	1.02–1.10	0.002
Sodium hypochlorite (bleach)	1.76	1.6–1.8	<0.001	1.74	1.65–1.83	<0.001	1.78	1.68–1.88	<0.001	1.32	1.27–1.38	<0.001
Hospital-grade sanitizers	0.76	0.73–0.79	<0.001	0.83	0.80–0.85	<0.001	0.77	0.74–0.80	<0.001	0.90	0.86–0.93	<0.001
Other commercial sanitizers	0.82	0.79–0.85	<0.001	0.83	0.81–0.86	<0.001	0.84	0.81–0.88	<0.001	0.81	0.78–0.84	<0.001
Hospital disinfectants	0.76	0.73–0.80	<0.001	0.81	0.77–0.84	<0.001	1.10	1.04–1.15	<0.001	0.80	0.76–0.84	<0.001
Per-chlorine	1.91	1.81–2.02	<0.001	1.47	1.42–1.52	<0.001	1.67	1.56–1.77	<0.001	1.72	1.62–1.81	<0.001
Hydrogen peroxide	1.06	1.00–1.13	0.031	0.97	0.92–1.02	<0.001	1.30	1.22–1.39	<0.001	1.36	1.28–1.44	<0.001
Formaldehyde	1.59	1.42–1.78	<0.001	1.56	1.40–1.73	<0.001	1.15	1.09–1.22	<0.001	2.17	1.92–2.44	<0.001

Adjusted for age, sex, educational level, occupational status, place of residence (rural and city), and income level

Discussion

Regarding the use of sanitizers and disinfectants in different continents, it was observed that in African countries, due to low-income levels, and lack of accessibility the tendency to use disinfectants was lower than in other continents. In contrast, in some less-resourced countries, such as Iran, and more-resourced countries, such as China, the USA, the UK, Germany, and Australia, etc., there was a greater tendency to use disinfectants. Adequate income levels, adequate education, and information, easy access to the types of sanitizers and disinfectants, and strict controlling measures by the governments have been effective in increasing the use of these chemicals (Becher et al., 2021; Bu et al., 2020; Tran et al., 2020; Unruh et al., 2022; Xu et al., 2020). Although our claim regarding some countries such as Venezuela, Iraq, Afghanistan, etc. was not correct. Contrary to the economic crisis prevailing in these countries, the use of sanitizers and disinfectants was high.

In addition to this more attention and the fear of contracting the disease, sometimes leads to the excessive usage of sanitizers and disinfectants, which leads to the occurrence of adverse effects due to the toxic nature of these chemicals on the population; finally, the body's resistance to other infectious agents may decrease (Tachikawa, 2020; Vogel, 2011). On the other hand, the denial of the existential nature of the COVID-19 disease by people from different countries (Afolabi and Ilesanmi, 2021; Buguzi, 2021; Cabral et al., 2021; Thagard, 2021) can be one of the main reasons for not tending to use sanitizers and disinfectants as part of health protocols. We found that the disinfectants with the highest rate of causing different adverse health effects are chlorine compounds (sodium hypochlorite and per-chlorine). One of the reasons for this finding could be the widespread use of these compounds as bleaches, cleansers, and vegetable washes, for washing different surfaces, water disinfection as well as easy access and affordability. In addition to the inherent effects of using chemicals as sanitizers and disinfectants, there are other reasons such as misuse (mixing several chemicals without following the instructions), excessive use, and counterfeit and unauthorized products that can cause side effects (Alhouri et al., 2020; Cook and Brooke, 2021). However, some disinfectants (e.g., detergents) may not have serious adverse effects on human health, but prolonged exposure and overuse of any chemical increase their harmful potential (Baldeo et al., 2022). Similar studies have shown that most disinfectants, such as alcohols and proxygene compounds, can be considered potential irritants or skin allergens (Goh et al., 2021; Lachenmeier, 2008; Murphy and Friedman, 2019). The US centers for disease control and prevention (CDC) reported an increase in calls to the center because of overuse and frequent exposure to cleaning

chemicals during the Covid-19 pandemic (CDC, 2020; Rosenman et al., 2021).

Various reports have claimed that long-term use of surfactants causes dryness and roughness of the skin (Goh et al., 2021; Paudel et al., 2022; Shibuya et al., 2022). Similarly, alcohol-based substances despite their low permeability to the skin had the most skin effects as a result of prolonged contact and regular and continuous use. Similar studies have reported increased exposure and frequency of alcohol use as a cause of skin irritation or dermatitis (Bouthoorn et al., 2011; Ghafoor et al., 2021; Lachenmeier, 2008). Unlike sanitizers and other disinfectants, alcohols were more effective in causing skin urticaria. In one study, skin urticaria was reported as a result of alcohol use (such as isopropanol) due to the combination of these alcohols with some solvents and organic matter (Berardi et al., 2020; Goh and Ahmed, 2020; Pecquet et al., 1992). The results obtained in this study regarding skin effects were in accordance with some scientific texts and similar studies (Bito et al., 2010; Chan and Maibach, 2008; Europe, 2017; Murphy and Friedman, 2019). The results of the multivariate regression analysis showed that detergents, alcohols or alcohol-based substances, and chlorine compounds have a higher potential of causing skin effects compared to other sanitizers and disinfectants.

Ocular effects (itching and irritation and eye redness) due to the use of sanitizers and disinfectants were less common than other effects. However, in terms of frequency, detergents and alcohol accounted for the largest share of ocular side effects. The results of some studies confirm our findings that itching and eye irritation are a result of the use of alcohol as a sanitizer/disinfectant (Ghafoor et al., 2021). Statistical results showed that among the chemicals studied, chlorine compounds had a higher chance of causing ocular effects compared to other disinfectants. This is probably due to the wide range of applications of chlorine compounds for different purposes as well as their ability to be mixed with other solvents. Studies have shown that the use of chlorine-based compounds in the form of sprays to disinfect surfaces will cause itching and eye irritation (Ghafoor et al., 2021; Schyllert et al., 2016; WHO, 2020). Since people used several types of chemicals separately or mixed to wash hands, face, and feet or to disinfect different surfaces, improper mixing of chemicals may release toxic gases and vapors that can affect the respiratory system. Studies have shown that mixing bleach with acidic cleaning agents leads to the release of highly irritating gases (PHE, 2015; Racioppi et al., 1994). Rosenman et al. claimed that not following hygienic instructions on how to use or mix cleansing products with other chemicals such as acid would create the conditions for chemical pneumonia or pulmonary edema (Rosenman et al., 2021). Our findings showed that chlorine compounds (sodium hypochlorite and per-chlorine) were involved in causing all effects related to the respiratory system. This claim was consistent with a list approved by the US Environmental Protection Agency (Alimohamadi et al., 2022b) that sodium hypochlorite is an irritant and allergen for the respiratory system (EPA, 2020). The results of multivariate regression analysis showed that formaldehyde had an immensely significant chance of causing neurological effects compared to other sanitizers and disinfectants. Formaldehyde, as a carcinogen by OSHA (Tarka et al., 2016), has an unpleasant odor and is an irritant that can cause many adverse effects on human health (Ghafoor et al., 2021).

Strengths and limitations

The present study holds significant value due to its comprehensive nature, covering 154 out of 192 United Nations member countries, indicating a truly global scope. The primary objective of this study was to achieve optimal participation across diverse segments of the general population. Regrettably, certain subgroups, namely villagers, individuals above the age of 60, non-academic individuals, and those employed in blue-collar occupations such as construction, manufacturing, and maintenance, exhibited lower levels of participation. This constraint constitutes a further limitation of the study. The main limitations of this study were the non-participation of individuals for personal reasons or lack of access to the internet, the drop-out of some countries (41 countries), and background effects such as exposure to various pollutants causing effects such as inflammation and respiratory effects, etc. (Hashemi et al., 2022a).

Conclusion

Our findings could serve as a useful source of information in reducing concerns related to the adverse health effects of sanitizers and disinfectant use through education and information by governments and health organizations during viral epidemics. Furthermore, the present results can be helpful for safety and health organizations overseeing the production of chemicals in updating instructions on how to use chemicals, as well as replacing low-risk, low-dose, high-impact chemicals in the production process if possible.

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Author contribution All authors contributed to the study's conception and design. Data collection was performed by Fallah Hashemi, Lori Hoepner, Farahnaz Soleimani Hamidinejad, Daniela Haluza, Sima Afrashteh, Alireza Abbasi, Elma Omeragić, Belma Imamović, Narin A. Rasheed, Taqi Mohammed Jwad Taher, Fitri Kurniasari, Dhuha Youssef Wazqar, Özge Ceren Apalı, Ayca Demir Yildirim, Bo Zhao, Zaruhi Kalikyan, Cui Guo, Andrea Chong Valbuena, Magdalena Mititelu, Carolina Martínez Pando, Maria Saridi, Aikaterini Toska, Magalys Lopez Cuba, Precious Kwablah Kwadzokpui, Niguse Tadele, Tohfa Nasibova, Stefanie Harsch, Luvsan Munkh-Erdene, Wafaa Menawi, Efi Evangelou, Antoniya Dimova, Dimitar Marinov, Teodora Dimitrova, Anna Shalimova, Howieda Fouly, Anna Suraya, Juliana Pereira da Silva Faquim, Bouadil Oumayma, Maria Antonieta Annunziato, Rezarta Lalo, Evridiki Papastavrou, Anju D. Ade, Susanna Caminada, Svetlana Stojkov, Carmen Gloria Narvaez, lutendo Sylvia Mudau, Ines Rassas, Daphnee Michel, Nur sema Kaynar, Sehar Iqbal, Halla Elshwekh, Irin Hossain, Sadeq AL-Fayyadh Aniuta Sydorchuk, Dua'a Mohammad Hasan Alnusairat Asli Mohamed Abdullahi, Neelam Iqbal, Apsara Pandey, Brenda Gómez-Gómez, Aysenur Gunaydin Akyildiz, Morosan Elena, Daniella Dwarica, Gantuya Dorj, Sumaya Yusuf Hasan, Noha M. Al-Shdayfat, Bojana Knezevic, Wendy Valladares, Cecilia Severi, Sofia Cuba Fuentes, Sofia Augusto, Elizaveta Sidorova, Anita Dewi Moelyaningrum, Tafaul Alawad, Atiqa Khalid, Nafisa Mhna Kmbo Elehamer, Anna Mihaylova, Oxana Tsigengagel, Aziza Menouni, Agnieszka Wojtecka, Rozita Hod, Yusuf Banke Idayat, khadija Othman, Rim M. Harfouch, Tsonco Paunov, Meruyert Omar, Nana Christine Benderli, Globila Nurika, Sana Amjad, Salma Elnoamany, Fatma Elesrigy, Marwa Mamdouh Shaban, Doménica Acevedo-López, Maria Kartashova, Atika Khalaf, Sabah Abdullah Jaafar, Taisir A. Kadhim, Nada Ab. Hweissa, Yulong Teng, Fatima Elbasri Abuelgasim Mohammed Yagoub, Thayahlini Sasikumar, Christabel Nangandu Hikaambo, Aditi Kharat, Ulyana Lyamtseva, Maya Arfan Aldeeb, Natalia Pawlas, Lkhagvasuren Khorolsuren, Roopeshwaree Pallavi Koonjul, Halima Boubacar Maïnassara, Priyanka Chahal, Rose Wangeci W, Ainur B. Kumar, Irina Zamora-Corrales, Stella Gracy, Maimouna Mahamat, Jakub Adamczyk, Haliza Abdul Rahman, Lolita Matiashova, Omneya Ezzat Elsherif, Nazdar Ezzaddin Rasheed Alkhateeb, Yamilé Aleaga, Shima Bahrami, Shaimaa Rahem Al-salihy, Paula Cabrera-Galeana, Mladena Lalic-Popovic, Eugenie Brown-Myrie, Divya Bhandari, Cinderella Akbar Mayaboti, Svetlana Stanišić, Sanda Kreitmayer Pestic, Muhammed Yunus Bektay, Haleama Al Sabbah, Saber Hashemi, Bouchetara Assia, Anne-Sophie Merritt, Zhian Ramzi, Himawatee Baboolal, Juman Isstaif, Rula Shami, Rahma Saad, Temwanani Nyirongo, Mohammad Hoseini.

Material preparation by Fallah Hashemi and Mohammad Hoseini, and data analysis by Lori Hoepner and Sima Afrashteh were performed. The first draft of the manuscript was written by Fallah Hashemi and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability There is no data to access online.

Declarations

Ethics approval The study sampling protocol was approved by the Ethics Committee of the Shiraz University of Medical Science (IR.SUMS.REC.1400.023).

Consent to participate All the people who participated in this study through an electronic questionnaire; Before answering the questions, they should have chosen the option of informed consent to participate in this research. It is necessary to explain that without choosing the option of informed consent, the participants were not able to enter the other sections of the questionnaire.

Consent for publication All authors declare their consent to publish this article.

Competing interests The authors declare no competing interests.

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Alimohamadi Y, Sepandi M, Rashti R, Sedighinezhad H, Afrashteh S (2022b) COVID-19: clinical features, case fatality, and the effect of symptoms on mortality in hospitalized cases in Iran. J Taibah Univ Med Sci 17(5):725

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Authors and Affiliations

Fallah Hashemi[1] · Lori Hoepner[2] · Farahnaz Soleimani Hamidinejad[3,4] · Daniela Haluza[5] · Sima Afrashteh[6] · Alireza Abbasi[1] · Elma Omeragić[7] · Belma Imamović[7] · Narin A. Rasheed[8] · Taqi M. J. Taher[9] · Fitri Kurniasari[10] · Dhuha Youssef Wazqar[11] · Özge Ceren Apalı[12] · Ayca Demir Yildirim[13] · Bo Zhao[14] · Zaruhi Kalikyan[15] · Cui Guo[16] · Andrea Chong Valbuena[17] · Magdalena Mititelu[18] · Carolina Martínez Pando[19] · Maria Saridi[20] · Aikaterini Toska[20] · Magalys Lopez Cuba[21] · Precious Kwablah Kwadzokpui[22] · Niguse Tadele[23] · Tohfa Nasibova[24] · Stefanie Harsch[25] · Luvsan Munkh-Erdene[26] · Wafaa Menawi[27] · Efi Evangelou[28] · Antoniya Dimova[29] · Dimitar Marinov[30] · Teodora Dimitrova[30] · Anna Shalimova[31] · Howieda Fouly[32] · Anna Suraya[33,34] · Juliana Pereira da Silva Faquim[35] · Bouadil Oumayma[36] · Maria Antonieta Annunziato[37] · Rezarta Lalo[38] · Evridiki Papastavrou[39] · Anju D. Ade[40] · Susanna Caminada[41] · Svetlana Stojkov[42] · Carmen Gloria Narvaez[43] · Lutendo Sylvia Mudau[44] · Ines Rassas[45] · Daphnee Michel[46] · Nur Sema Kaynar[47] · Sehar Iqbal[48] · Halla Elshwekh[49] · Irin Hossain[50] · Sadeq AL-Fayyadh[51] · Aniuta Sydorchuk[52] · Dua'a M. H. Alnusairat[53] · Asli Mohamed Abdullahi[54] · Neelam Iqbal[55] · Apsara Pandey[56] · Brenda Gómez-Gómez[57] · Aysenur Gunaydin Akyildiz[58] · Elena Morosan[18] · Daniella Dwarica[59] · Gantuya Dorj[60] · Sumaya Yusuf Hasan[61] · Noha M. Al-Shdayfat[62] · Bojana Knezevic[63] · Wendy Valladares[64] · Cecilia Severi[65] · Sofia Cuba Fuentes[66] · Sofia Augusto[67] · Elizaveta Sidorova[68] · Anita Dewi Moelyaningrum[69] · Tafaul Alawad[70] · Atiqa Khalid[71] · Nafisa M. K. Elehamer[72] · Anna Mihaylova[73] · Oxana Tsigengagel[74] · Aziza Menouni[75] · Agnieszka Wojtecka[76] · Rozita Hod[77] · Yusuf Banke Idayat[78] · Khadija Othman[79] · Rim M. Harfouch[80] · Tsonco Paunov[30] · Meruyert Omar[81] · Nana Christine Benderli[82,83] · Globila Nurika[69] · Sana Amjad[84] · Salma Elnoamany[85] · Fatma Elesrigy[85] · Marwa Mamdouh Shaban[86] · Doménica Acevedo-López[87] · Maria Kartashova[88] · Atika Khalaf[89,90] · Sabah Abdullah Jaafar[91] · Taisir A. Kadhim[91] · Nada Ab Hweissa[92] · Yulong Teng[93] · Fatima E. Mohammed[94] · Thayahlini Sasikumar[95] · Christabel Nangandu Hikaambo[96] · Aditi Kharat[97] · Ulyana Lyamtseva[98] · Maya Arfan Aldeeb[99,100] · Natalia Pawlas[101] · Lkhagvasuren Khorolsuren[102] · Roopeshwaree Pallavi Koonjul[103] · Halima Boubacar Maïnassara[104] · Priyanka Chahal[105] · Rose W. Wangeci[106] · Ainur B. Kumar[107] · Irina Zamora-Corrales[108] · Stella Gracy[109] · Maimouna Mahamat[110] · Jakub Adamczyk[111] · Haliza Abdul Rahman[112] · Lolita Matiashova[113] · Omneya Ezzat Elsherif[114] · Nazdar E. Alkhateeb[115] · Yamilé Aleaga[116] · Shima Bahrami[117] · Shaimaa Rahem Al-salihy[118] · Paula Cabrera-Galeana[119] · Mladena Lalic-Popovic[120] · Eugenie Brown-Myrie[121] · Divya Bhandari[122] · Cinderella Akbar Mayaboti[123] · Svetlana Stanišić[124] · Sanda Kreitmayer Pestic[125] · Muhammed Yunus Bektay[126] · Haleama Al Sabbah[127] · Saber Hashemi[128] · Bouchetara Assia[129] · Anne-Sophie Merritt[130] · Zhian Ramzi[131] · Himawatee Baboolal[132] · Juman Isstaif[133] · Rula Shami[134] · Rahma Saad[135] · Temwanani Nyirongo[136] · Mohammad Hoseini[137,138]

✉ Mohammad Hoseini
mohhoseini@sums.ac.ir

Fallah Hashemi
info.foo@gmail.com

Lori Hoepner
Lori.Hoepner@downstate.edu

Farahnaz Soleimani Hamidinejad
solfarahnaz@gmail.com

Daniela Haluza
daniela.haluza@meduniwien.ac.at

Sima Afrashteh
sima.afrashte3@gmail.com

Alireza Abbasi
alireza.abasi1986@gmail.com

Elma Omeragić
elma.omeragic@ffsa.unsa.ba

Belma Imamović
belma.imamovic@ffsa.unsa.ba

Narin A. Rasheed
narin.rasheed@gmail.com

Taqi M. J. Taher
ttahir@uowasit.edu.iq

Fitri Kurniasari
fitri.kurniasari04@ui.ac.id

Dhuha Youssef Wazqar
dwazger@kau.edu.sa

Özge Ceren Apalı
oapali@hacettepe.edu.tr

Ayca Demir Yildirim
ayca.demiryildirim@uskudar.edu.tr

Bo Zhao
zhaobo@yonsei.ac.kr

Zaruhi Kalikyan
zkalikyan@yandex.ru

Cui Guo
guocuicui815@gmail.com

Andrea Chong Valbuena
chong.valbuena@gmail.com

Magdalena Mititelu
magdalena.mititelu@umfcd.ro

Carolina Martínez Pando
martinezpando_carolina@hotmail.com

Maria Saridi
sarmar32@windowslive.com

Aikaterini Toska
Ktoska07@yahoo.gr

Magalys Lopez Cuba
mlcuba@uhas.edu.gh

Precious Kwablah Kwadzokpui
kwadzokpuipreciousk@gmail.com;
015pkwadzokpui@uhas.edu.gh

Niguse Tadele
niguse.tadele@aau.edu.et

Tohfa Nasibova
tnesibova@amu.edu.az

Stefanie Harsch
stefanie.harsch@ph-freiburg.de

Luvsan Munkh-Erdene
munkherdene@mnums.edu.mn

Wafaa Menawi
w.menawi@najah.edu

Efi Evangelou
evangeloue@hotmail.com

Antoniya Dimova
ant_dimova@abv.bg

Dimitar Marinov
dr.marinov.md@gmail.com

Teodora Dimitrova
tdimitrovatvd@gmail.com

Anna Shalimova
anna.shalimova83@gmail.com

Howieda Fouly
hoida.elfouly2@aun.edu.eg

Anna Suraya
Anna.suraya@binawan.ac.id

Juliana Pereira da Silva Faquim
julianafaquim@ufu.br

Bouadil Oumayma
Bouadiloumayma94@gmail.com

Maria Antonieta Annunziato
annunziato.maria@gmail.com

Rezarta Lalo
rezarta_lalo@yahoo.com

Evridiki Papastavrou
e.papastavrou@cut.ac.cy

Anju D. Ade
anju.ade@gmail.com

Susanna Caminada
susanna.caminada@uniroma1.it

Svetlana Stojkov
svetlanastojkov22@gmail.com

Carmen Gloria Narvaez
cgnarvaez@udd.cl

Lutendo Sylvia Mudau
mudauls72@gmail.com

Ines Rassas
inesrassas@yahoo.fr

Daphnee Michel
daphnee.michel@uniq.edu

Nur Sema Kaynar
nursemakaynar1@gmail.com

Sehar Iqbal
Sehar.iqbal@aau.ac.ae

Halla Elshwekh
Halla.h.m@btc.org.ly

Irin Hossain
Irin.hossain@gmail.com

Sadeq AL-Fayyadh
s.al-fayyadh@conursing.uobaghdad.edu.iq

Aniuta Sydorchuk
sidorchuk@bsmu.edu.ua; aniuta.sydorchuk@gmail.com

Dua'a M. H. Alnusairat
duaalnusairat@gmail.com

Asli Mohamed Abdullahi
aslimaxamed10@gmail.com

Apsara Pandey
apsara.pandey@mnc.tu.edu.np

Brenda Gómez-Gómez
bred_gomez@hotmail.com

Aysenur Gunaydin Akyildiz
gunaydinaysenur@gmail.com

Daniella Dwarica
Danielladwarica@gmail.com

Gantuya Dorj
gantuya.d@mnums.edu.mn

Sumaya Yusuf Hasan
sumayayousif@agu.edu.bh

Noha M. Al-Shdayfat
dr.nuhash@aabu.edu.jo

Bojana Knezevic
bojana.knezevic@kbc-zagreb.hr

Wendy Valladares
Wendy.valladares@unah.edu.hn

Cecilia Severi
severi.cecilia@gmail.com

Sofia Cuba Fuentes
maria.cuba@upch.pe

Sofia Augusto
s.augusto@fc.ul.pt

Elizaveta Sidorova
elizavsid@gmail.com

Anita Dewi Moelyaningrum
anitamoelyani@gmail.com; anitadm@unej.ac.id

Tafaul Alawad
tafaulalawad@gmail.com

Atiqa Khalid
atiqakkhalid@gmail.com

Nafisa M. K. Elehamer
elehamer.nafisa@med.unideb.hu

Anna Mihaylova
annamihaylova@abv.bg

Oxana Tsigengagel
tsigengagel.o@gmail.com

Aziza Menouni
aziza.menouni@kuleuven.be

Agnieszka Wojtecka
awojtecka@gumed.edu.pl

Rozita Hod
rozita.hod@ppukm.ukm.edu.my

Yusuf Banke Idayat
bitab19@yahoo.com

Khadija Othman
khadijaothman1993@gmail.com

Rim M. Harfouch
r.h.foph.LAT@aspu.edu.sy

Meruyert Omar
Meruyertomar92@gmail.com

Nana Christine Benderli
christinenana@yahoo.fr

Globila Nurika
nurikaglobila@unej.ac.id

Sana Amjad
sana@ualberta.ca

Salma Elnoamany
salmaalnomany6@gmail.com

Fatma Elesrigy
Fatma.abdalgawad.12@med.menofia.edu.eg

Marwa Mamdouh Shaban
Marwamamdouh.mamdouh70@gmail.com

Doménica Acevedo-López
domeacevedo@gmail.com

Maria Kartashova
kmk8963@gmail.com

Atika Khalaf
atika.khalaf@hkr.se; a.khalaf@squ.edu.om

Sabah Abdullah Jaafar
sabah.abd@mu.edu.iq

Taisir A. Kadhim
taisirak14@mu.edu.iq; taiseer.alhussainy@gmail.com

Nada Ab Hweissa
n.hweissa@zu.edu.ly

Yulong Teng
yulongteng@yonsei.ac.kr

Fatima E. Mohammed
fatima.abuelgasim12@gmail.com

Thayahlini Sasikumar
thaya.viswa@gmail.com

Christabel Nangandu Hikaambo
xbellhikaambo@gmail.com; Christabel.hikaambo@unza.zm

Aditi Kharat
aditi.kharat@utah.edu

Ulyana Lyamtseva
ulyamtseva@gmail.com

Maya Arfan Aldeeb
maldeeb@hamad.qa; mayaldeeb@yahoo.com

Natalia Pawlas
natalia.pawlas@sum.edu.pl

Lkhagvasuren Khorolsuren
khorolsuren.l@mnums.edu.mn

Roopeshwaree Pallavi Koonjul
pallavikoonjul1234@gmail.com

Halima Boubacar Maïnassara
amhalima@gmail.com

Priyanka Chahal
drchahal10@gmail.com

Rose W. Wangeci
rwanjohi40@gmail.com

Ainur B. Kumar
a.kumar@kaznmu.kz

Irina Zamora-Corrales
irigaz87@gmail.com

Stella Gracy
gracystella1985@gmail.com

Maimouna Mahamat
m_mahamat@yahoo.fr

Jakub Adamczyk
j.adamczyk@ujd.edu.pl

Haliza Abdul Rahman
dr.haliza@upm.edu.my

Lolita Matiashova
lota94s@gmail.com

Omneya Ezzat Elsherif
oelsherif@hotmail.com

Nazdar E. Alkhateeb
nazdar.alkhateeb@hmu.edu.krd

Yamilé Aleaga
Yamile.aleaga@ipk.sld.cu

Shima Bahrami
bahramishima31@gmail.com

Shaimaa Rahem Al-salihy
Sh.r802011@gmail.com

Paula Cabrera-Galeana
draPaulacabrera@gmail.com

Mladena Lalic-Popovic
mladena.lalic-popovic@mf.uns.ac.rs

Eugenie Brown-Myrie
ebrown@utech.edu.jm

Divya Bhandari
rayordeal3@gamil.com

Cinderella Akbar Mayaboti
cinderellamaya18@gmail.com

Svetlana Stanišić
sstanisic@singidunum.ac.rs

Sanda Kreitmayer Pestic
kreitmayersanda@gmail.com

Muhammed Yunus Bektay
yunusbektay@gmail.com

Haleama Al Sabbah
haleemah.alsabah@zu.ac.ae

Saber Hashemi
hashemisaber04@gmail.com

Bouchetara Assia
bouchetaraa@gmail.com

Anne-Sophie Merritt
anne-sophie.merritt@ki.se

Zhian Ramzi
zean.ramzi@univsul.edu.iq

Himawatee Baboolal
himawatee.baboolal475@we.utt.edu.tt

Juman Isstaif
j.isstaif@gmail.com

Rula Shami
ra1704753@qu.edu.qa

Rahma Saad
Rahmasaad63@gmail.com

Temwanani Nyirongo
temsnyirongo@gmail.com

[1] Department of Environmental Health Engineering, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran

[2] Department of Environmental and Occupational Health Sciences, School of Public Health, SUNY Downstate Health Sciences Center, Brooklyn, NY, USA

[3] Department of Medicine, O.O. Bogomolets National Medical University, Kyiv, Ukraine

[4] Department of Medicine, Tehran University of Medical Sciences, Tehran, Iran

[5] Center for Public Health, Department for Environmental Medicine, Medical University of Vienna, Kinderspitalgasse 15, 1090 Vienna, Austria

[6] Department of Biostatistics and Epidemiology, Faculty of Health and Nutrition, Bushehr University of Medical Sciences, Bushehr, Iran

[7] Faculty of Pharmacy, University of Sarajevo, Sarajevo, Bosnia and Herzegovina

[8] Department of Medical Laboratory Technology, College of Health and Medical Technology Shekhan, Duhok Polytechnic University, Duhok, Kurdistan Region, Iraq

[9] Family and Community Medicine Department, College of Medicine, University of Wasit, Kut, Wasit, Iraq

[10] Department of Environmental Health, Faculty of Public Health, University of Indonesia, Jakarta, Indonesia

[11] Department of Medical-Surgical Nursing, Faculty of Nursing, King Abdulaziz University, Jeddah, Saudi Arabia

[12] Faculty of Medicine, Hacettepe University, Ankara, Turkey

[13] Midwifery Department, Üsküdar Universty, Istanbul, Turkey

[14] Department of Health Administration, Graduate School, Yonsei University, 1 Yonseidae-Gicl, Wonju, Gangwon-do 26493, South Korea

[15] Department of Clinical Immunology and Allergology, Yerevan State Medical University, Yerevan, Armenia

[16] Department of Urban Planning and Design, The University of Hong Kong, Hong Kong, China

[17] Division of Epidemiology, Public Health Center of Valencia, Valencia, Spain

[18] Department of Clinical Laboratory and Food Safety, Faculty of Pharmacy, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania

[19] Department of Medicine, University of Granada, Granada, Spain

[20] School of Social Sciences, Hellenic Open University, Patras, Greece

[21] Department of Pathology, School of Medicine, University of Health and Allied Sciences, Ho, Ghana

[22] Department of Medical Laboratory Science, School of Allied Health Sciences, University of Health and Allied Sciences, Ho, Ghana

[23] Department of Nursing, School of Nursing & Midwifery, College of Health Sciences, Addis Ababa University, Addis Ababa, Ethiopia

[24] General and Toxicological Chemistry Department, Azerbaijan Medical University, Baku, Azerbaijan

[25] Institute of Sociology, University of Education Freiburg, Freiburg, Germany

[26] Department of Health Policy, School of Public Health, Mongolian National University of Medical Sciences, Ulan Bator, Mongolia

[27] Public Health Management Program, Faculty of Graduate Studies, An-Najah University, Nablus, State of Palestine

[28] Nursing Department Limassol, Cyprus University of Technology, Limassol, Cyprus

[29] Faculty of Public Health, Medical University Varna, 55 Marin Drinov Street, 9002 Varna, Bulgaria

[30] Department of Hygiene and Epidemiology, Faculty of Public Health, Medical University of Varna, Varna, Bulgaria

[31] Internal Medicine N1, Kharkiv National Medical University, Kharkiv, Ukraine

[32] Reproductive Health Nursing (Gynecology and Obstetrics Nursing), Faculty of Nursing, Assiut University, Asyut, Egypt

[33] CIHLMU Center for International Health, University Hospital, LMU, Munich, Germany

[34] Occupational Safety and Health Department, Binawan University, East Jakarta, Indonesia

[35] Technical School of Health, Federal University of Uberlândia (UFU), Uberlândia, MG, Brazil

[36] National School of Applied Sciences of Al Hoceima, Abdelmalek Essaadi University, Tetouan, Morocco

[37] Venezuelan and Latin American Association of Clinical Nanomedicine, Caracas, Venezuela

[38] Department of Health Care, Faculty of Public Health, The University of Vlore "Ismail Qemali", Vlore, Albania

[39] Cyprus University of Technology, Limassol, Cyprus

[40] Department of Community Medicine, SVIMS, Sri Padamavathi Medical College, Tirupati, Andhra Pradesh, India

[41] Department of Public Health and Infectious Diseases, Sapienza University, Rome, Italy

[42] Department of Social Pharmacy, Faculty of Pharmacy, University Business Academy in Novi Sad, Novi Sad, Serbia

[43] Facultad de Ciencias de la Salud, Universidad del Desarrollo, Concepción, Chile

[44] Department of Environmental Health, Faculty of Science, Tshwane University of Technology, Pretoria, South Africa

[45] Department of Occupational Medicine and Ergonomics, Faculty of Medicine, University of Monastir, Monastir, Tunisia

[46] West Department, Quisqueya University, Port-au-Prince, Haiti

[47] Public Health Nursing Department, Florence Nightingale Faculty of Nursing, Istanbul University-Cerrahpasa, Istanbul, Turkey

[48] Department of Public Health and Nutrition, Al Ain University, Abu Dahbi, United Arab Emirates

[49] Department of Genetic Engineering, The Biotechnology Research Center, Tripoli, Libya

[50] Department of Occupational and Environmental Health (OEH), NIPSOM, Mohakhali, Dhaka, Bangladesh

[51] Adult Nursing Department, College of Nursing, University of Baghdad, Baghdad, Iraq

[52] Department of Infectious Diseases and Epidemiology, Bukovinian State Medical University, Chernivtsi, Ukraine

[53] Clinical Sciences Department, College of Medicine, University of Sharjah, Sharjah, United Arab Emirates

[54] School of Medicine and Health Science, Simad University, Mogadishu, Somalia

[55] Environmental Epidemiology Group, UK Health Security Agency, Chilton, Oxon, UK

[56] Maharajgunj Nursing Campus, Institute of Medicine, Tribhuvan University, Kathmandu, Nepal

[57] Department of Infectious Diseases, Centro Médico ABC, Mexico City, Mexico

[58] Department of Pharmaceutical Toxicology, Faculty of Pharmacy, Bezmialem Vakif University, Istanbul, Turkey

[59] Faculty of Medical Sciences, University of the West Indies, St. Augustine, Trinidad and Tobago

[60] Department of Epidemiology and Biostatistics, School of Public Health, Mongolian National University of Medical Sciences, Ulan Bator, Mongolia

[61] Department of Natural Resources and Environment, College of Graduate Studies, Arabian Gulf University, Manama, Bahrain

[62] Community and Mental Health Department, Al al-Bayt University, Mafraq, Jordan

[63] University Hospital Centre Zagreb, Zagreb, Croatia

[64] Microbiology Research Institute, National Autonomous University of Honduras, Tegucigalpa, Honduras

[65] Department of Preventive Medicine, Faculty of Medicine, University of the Republic, Montevideo, Uruguay

[66] Faculty of Medicine, Universidad Peruana Cayetano Heredia, Lima, Peru

[67] EPIUnit-Institute of Public Health, University of Porto, Porto, Portugal

[68] Moscow State Medical University, Sechenov University, Moscow, Russia

[69] Public Health Faculty, Environmental Health and Occupational Health and Savety Departement, University of Jember, Jember, Indonesia

[70] Faculty of Public and Environmental Health, University of Khartoum, Khartoum, Sudan

[71] Sahiwal Medical College, University of Health Sciences, Lahore, Pakistan

[72] Department of Health Education, University of Khartoum, Khartoum, Sudan

[73] Medical College, Medical University of Plovdiv, Plovdiv, Bulgaria

[74] Department of Public Health, NCJSC "Semey Medical University", Semey, Kazakhstan

[75] Environment and Health Unit, Department of Public Health and Primary Care, Katholieke Universiteit Leuven, Leuven, Belgium

[76] Department of Public Health and Social Medicine, Medical University of Gdansk, Gdansk, Poland

[77] Department of Community Health, Faculty of Medicine, University Kebangsaan Malaysia, Bangi, Malaysia

[78] Department of Environmental Health Sciences, University of Ibadan, Ibadan, Nigeria

[79] Ministry of Foreign Affairs and East African Cooperation, Dodoma, Tanzania

[80] Department of Microbiology and Biochemistry, Al Sham Private University, Latakia, Syria

[81] Department of Population Health and Social Sciences, Kazakhstan's Medical University School of Public Health, Almaty, Kazakhstan

[82] Biotechnology Center, University of Yaoundé I, Yaoundé, Cameroon

[83] Department of Animals Biology and Physiology, University of Yaoundé I, Yaoundé, Cameroon

[84] Department of Obstetrics and Gynaecology, University of Alberta, Edmonton, Canada

[85] Family Medicine Department, Faculty of Medicine, Menoufia University, Menoufia, Egypt

[86] Community Health Nursing Department, Faculty of Nursing, Cairo-University, Cairo, Egypt

[87] Faculty of Medicine, Fundación Universitaria Autónoma de las Américas, Pereira, Risaralda, Colombia

[88] Department of Human Pathology, Sechenov University, Moscow, Russia

[89] Faculty of Health Sciences, Kristianstad University, Kristianstad, Sweden

[90] College of Nursing, Sultan Qaboos University, Muscat, Oman

[91] College of Nursing, University of Al-Muthanna, Samawah, Iraq

[92] Department of Public Health, Faculty of Medical Technology, Zawia University, Zawia, Libya

[93] Department of Korean Language and Literature, Graduate School, Yonsei University, Gangwon-do, South Korea

[94] Faculty of Medicine, University of Khartoum, Khartoum, Sudan

[95] Institute of Medicine, University of Colombo, Colombo, Sri Lanka

[96] Department of Pharmacy, School of Health Sciences, University of Zambia, Lusaka, Zambia

[97] College of Pharmacy, University of Utah, Salt Lake City, UT, USA

[98] Department of Medicine of the Future, Sechenov University, Moscow, Russia

[99] Hamad Medical Corporation, Doha, Qatar

[100] Damascus University, Damascus, Syria

[101] Department of Pharmacology, Faculty of Medical Sciences in Zabrze, Medical University of Silesia, Katowice, Poland

[102] Institute of Public Health, Mongolian National University of Medical Sciences, Ulan Bator, Mongolia

[103] Department of Medicine, University of Mauritius, Moka, Mauritius

[104] Conseils Etudes Enquêtes Recherches Formation en Epidémiologie (CEERFE), Niamey, Niger

[105] S. Tentishev Asian Medical Institute, Kant, Kyrgyzstan

[106] Health Sciences, School of Public Health, University of Nairobi, Nairobi, Kenya

[107] Department of Health Policy and Management, School of Public Health, Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan

[108] School of Public Health, University of Costa Rica, San José, Costa Rica

[109] Department of Biomedical Sciences, University of Asmara, Asmara, Eritrea

[110] Department of Internal Medicine and Specialties, Faculty of Medicine and Biomedical Sciences, Yaounde General Hospital, Yaounde, Cameroon

[111] Faculty of Health Sciences, Jan Długosz University of Humanities and Life Sciences, Czestochowa, Poland

[112] Department of Environmental and Health Sciences, Faculty of Medicine & Health Sciences, Universiti Putra Malaysia, Selangor, Malaysia

[113] T Malaya Therapy National Institute, National Academy of Medical Sciences of Ukraine, Kharkiv, Ukraine

[114] Cairo University Hospitals, Cairo, Egypt

[115] Department of Medical Education, College of Medicine, Hawler Medical University, Erbil, Iraq

[116] Department of Clinical Microbiology, Institute of Tropical Medicine "Pedro Kouri", Havana, Cuba

[117] Shiraz University of Medical Sciences, Shiraz, Iran

[118] Microbiology Department, College of Medicine, University of Diyala, Diyala, Iraq

[119] Instituto Nacional de Cancerología, Mexico City, Mexico

[120] Department of Pharmacy, Faculty of Medicine, University of Novi Sad, Novi Sad, Serbia

[121] Department of Pharmaceutics, School of Pharmacy, College of Health Sciences, University of Technology, Kingston, Jamaica

[122] Medical Governance Research Institute, Tokyo, Japan

[123] University of Oslo, Oslo, Norway

[124] Singidunum University, Belgrade, Serbia

[125] Family Medicine Department, Medical School, University of Tuzla, Tuzla, Bosnia and Herzegovina

[126] Clinical Pharmacy Department, Faculty of Pharmacy, Marmara University, Istanbul, Turkey

[127] Department of Health Sciences, Zayed University, Dubai, United Arab Emirates

[128] Department of Chemical Engineering, Faculty of Engineering, University of Kurdistan, Sanandaj, Iran

[129] Peadiatric's Infectious diseases, Hospital of Canastel and Faculty of Medicine, Oran, Algeria

[130] Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden

[131] College of Nursing, University of Sulaimani, Kurdistan, Sulaimani, Iraq

[132] Faculty of Medical Sciences, University of the West Indies, St. Augustine, Trinidad and Tobago

[133] Department of Neurology, Faculty of Medicine, Damascus University, Damascus, Syria

[134] Department of Public Health, College of Health Sciences, Qatar University, Doha, Qatar

[135] Department of Public Health, Qatar University, Doha, Qatar

[136] Environmental Health, Rusangu University, Monze, Zambia

[137] Research Center for Health Sciences, Institute of Health, Shiraz, Iran

[138] Department of Environmental Health, School of Health, Shiraz University of Medical Sciences, Razi Blvd, Kuye-Zahra Ave, Shiraz 1417653861, Iran