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Impacts of hand sanitizer on human health and environment: a review

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ABSTRACT

Although the use of sanitizer starts around the middle of twentieth century but it becomes popular in early twenty first century (second decade of twenty first century during COVID-19 pandemic). To prevent the spread of COVID-19, World Health Organisation (WHO) recommended the use of sanitizers made up with different combinations of isopropyl alcohols, ethanol and hydrogen peroxides. Literature suggests some toxic effect of use and misuse of these components of sanitizers. Therefore, in the present study an attempt has been made to investigate the use of available hand sanitizers and their adverseeffects on human body as well as to collect and correlate the gathered information with their occupation which may further trigger the adverse effect of sanitizer on human being. Out of the total respondents, 98% are using but very few (2%) are not using any type of sanitizer. Age group 2 (16-25 years) is the largest user of hand sanitizer which shows the maximum awareness of this age group related to sanitation and hygiene. Data obtained suggests that males (57.5%) are more aware to sanitization in comparison to female (41.8%). Among the total respondents, house wives were very few (0.8%) which shows lack of awareness among them may be due to their busy schedule and household works. The obtained data revealed that education plays a key role inthe spread of sanitation and hygiene awareness. Most of the peoples are using the sanitizers of established brands. The data also revealed that 88% of the respondents were observing the various impacts on the body (49% skin dryness, 16% skin allergy 12% skin irritation and itching while 12% respondents are not sure about the impacts). Only 12% peoples responded that they are not observing any impacts of sanitizer. Besides this, different components used in sanitizers pose threat to the different spheres of the environment. Based on the findings of the present study, we can conclude that sanitizer is impacting the human health and environment in various ways. Therefore, there is a need of mass awareness regarding the use and disposal of disinfectants.

Introduction

COVID-19 virus was first identified as a human corona virus in 1965 which caused a common cold (Du *et al.,* 2020). The virus belongs to the same genus as severe acute respiratory syndrome corona virus (SARS-CoV) and Middle East respiratory syndrome (MERS)-CoV, and was thus named SARS-CoV-2 by the International Committee on Taxonomy of Viruses, in 2020.

SARS-CoV-2, the novel corona virus that causes COVID-19, was first detected in Wuhan, China, in late 2019 (Huang *et al.,* 2020). The persistent study of SARS-CoV-2 suggest that this virus was more stable on plastic and stainless steel than on copper and cardboard, and was detected up to 72 hours after application to these surfaces. The study carried out by Van Doremalen *et al.* (2020)

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highlighted that aerosol and fomite transmission of SARS-CoV-2 is possible, since the virus can remain sustainable and infectious in aerosols forhours and on surfaces up to days.Therefore, hand hygiene is very important as it maybe easily contaminated from direct contact with airborne microorganism such as SARS-CoV-2 droplets which may originate from coughs and sneezes. Predominantly in pandemic situations, it isessentially important to interrupt the transmission of the virus by the strict practice of proper hand sanitization. This can be accomplished by strict good hand hygiene and contact isolation (WHO,2020). The success of the hand sanitization simply depends on the use of effective hand disinfecting agents as sanitizer (Jing *et al.,* 2020). During the pandemic, using sanitizer was the basic necessities as with other basic daily needs. Therefore, it is vitalto know the effect of sanitizer on the human being as it was one of the basic requirement of human lifeduring this period. Yet to our knowledge, there has never been a comparison of the formulation and theadverse effect of a large number of brands of hand sanitizers. Therefore, the aim of the present study was to investigate the range of available hand sanitizers used by the society and the adverse effects on human body and environment. Attempt was also made to collect and correlate the gathered information with their occupation which mayfurther trigger the adverse effect of sanitizer onhuman being. The collected data can also be usedas reference for the further study.

WHO recommendation/guidelines for the formulations of hand rub (Hand Sanitizer)

Glycerol is one of the main ingredient used as humectant which reduce the loss of moisture, is cheap, easily available and miscible in water. Alcohol is non-toxic and do not promote allergy. Hydrogen peroxide is used as an antiseptic to eliminate the microorganisms that cause disease. Ingredients should be non-toxic in caseof accidental ingestion. A colorant may be allowed to add to the solution for differentiation it from other fluids, but it should not add toxicity, promote allergy, or interfere with antimicrobial properties. The addition of perfumes or dyes is not recommended due to safety as it may create allergic reactions (WHO, 2010). Except alcohols (96% ethanol or 99.8% isopropyl alcohol) WHO also recommended other ingredients including benzalkonium chloride as the active principal ingredient displayed excellent antibacterial activity, whereas others exhibited modest or poor activity in the assays performed (Chojnacki *et al.,* 2021; Aodah *et al.,* 2021).

Classification of Hand sanitizers

Specifically hand sanitizers can be categorized into three main classes: (1) Alcohol-based, (2) Alcohol-based supplemented = alcohol plus other antimicrobial agents and (3) Non-alcohol-based = majority of the product is water plus surfactant and antimicrobial agent (Jing *et al.,* 2020; Kumar and Das, 2021). Hand sanitizers containing 60–95% alcohol are most effective, other than this either lower or even higher concentrations are less effective, because water is essential to denature the proteins of virus. Further, pure alcohol or higher concentrations would evaporate too quickly to exert any germicidal effect (Meyers *et al.,* 2021). Therefore, mostly 60% to 80% concentrations are used for hand rubs. Alcohol-based hand rubs are available in the form of solutions (with low viscosity), gels and foams. However, most studies have suggested that gel-based formulations are rather less effective than solutions (Dharan *et al.,* 2003). It has also been emphasized that if a gel with lower activity is more frequently used, the overall outcome is expected to be better (Traore *et al.,*2007). Non-alcoholic hand sanitizers are safe in comparison to alcoholic due to use in very lowconcentrations (Jing *et al.,* 2020). In accord to the available literature and evidences on efficacy,tolerability and cost effectiveness, WHO recommends using an alcohol-based hand rub for routine hand antisepsis in most clinical and non- clinical situations. WHO also recommends the localproduction of the above given formulations as an alternative when suitable commercial products are either unavailable or too costly to afford (WHO, 2010).

Use of sanitizer and soap

Centres for Disease Control and Prevention (CDC) and WHO recommends the washing of hands with soap and water for at least 20 to 30 seconds or by alcoholic hand sanitizers (AHS) (comprised of either 80% ethanol or 75% isopropyl alcohol) frequently to reduce microbes (WHO 2020). Both CDC and WHO gives preference to AHS over soap and water due to its easy accessibility (Aodah *et al.,* 2021). People prefer to wash their hand frequently with sanitizers instead of soap and water due to easy availability, lack of water and time (Singh *et al.,* 2020).

Although in a study, Singh *et al.* (2020) concluded that use of sanitizer in conjunction with soap and water is much more effective. Emami *et al.* (2020) and Saha *et al.* (2021) also recommended hand washing with soap and water instead of AHS. AHS have proven to deliver rapid bactericidal activity towards bacterial pathogens as well as excellent virucidal activity toward both enveloped and non-enveloped viruses. AHS are active against influenza virus, severe acute respiratory syndrome corona virus (SARSCoV), middle eastern respiratory syndrome (MERS) virus, Zika virus, Ebola virus, and SARS corona virus 2 (SARS-CoV-2) (Kratzel *et al.,* 2020). In comparison to soap, sanitizers are not effective against all types of germs (ex- against non virus agents and *Clostridiumdifficile*) and in case of dirty and greasy hands (Vermeil *et al.,* 2019). A comparative life cycle assessment (LCA) of hand washing with soap (soap+water) and hand sanitizer (both ethanol and isopropanol based sanitizers) was carried out in UKto compare the environmental impact of increased levels of hand hygiene during the COVID-19 pandemic (Duane *et al.,* 2022). The isopropanol-based hand sanitizer had the lowest environmental impact in 14 out of the 16 impact categories used inthis study. It has been observed that all forms of hand hygiene have an environmental cost, and this needs to be weighed up against the health benefitsof preventing disease transmission. Whencomparing hand sanitizers to hand washing withsoap and water, this study found that using isopropanol based hand sanitizer is better for planetary health. However, no method of hand hygiene was ideal; isopropanol had a greater fossil fuel resource use than ethanol based hand sanitizer (Ghafoor *et al.,* 2021; Duane *et al.,* 2022).

Toxicity of Sanitizer ingredient

The ingredients and their possible impacts are presented in Table 1.

Table 1: Toxicity of sanitizer ingredient

SN	Component	Impacts
1	**Isopropyl alcohol**	Impacts on central nervous system, liver and kidney, drowsiness, ataxia, respiratory depression, irritation of mucous membranes and eyes, vomiting, pancreatitis, cold clammy skin, and hypothermia (Ghafoor *et al.,* 2021; Olson *et al.,* 2021).
2	**Propylene glycol**	Hyperosmolality, acute kidney injury, and sepsis-like syndrome (Zar *et al.,* 2007).
3	**Aminomethyl propanol**	Depends of quantity used. In excess concentration (more than 2% in mascara or any other cosmetic product) causes dermal irritation or allergic contact sensitization (Burnett *et al.,* 2007).
4	**EDTA (ethylene diamine tetra acetic acid)**	Depends of quantity used. Cytotoxic and weakly genotoxic, but not carcinogenic when used as chelating agent. Reproductive or developmental toxicity when used as an aerosolized cosmetic formulation (Lanigan and Yamarik 2002).
5	**Sodium Benzoate**	Oral, dermal or inhalation causes urticaria, asthma, rhinitis, or anaphylactic shock. The symptoms appear shortly after exposure and disappear within a few hours, even at low doses (Wibbertmann *et al.,* 2005).
6	**Octenidine dihydrochloride or triclosan (TCS)**	Immune disorders, ROS production, cardiovascular functions, reproductive and developmental defects in infants (Weatherly and Gosse, 2017), and skin allergy when used in dermal cream (Ridzwan and Zainudin 2017).
7	**Hydrogen peroxide (H_2O_2)**	Acute inhalation causes irritation to the nose, throat and respiratory tract. Dermal exposure to dilute solutions may cause whitening of the skin, slight gastrointestinal irritation (Moon *et al.,* 2006), portal vein thrombosis (Sung *et al.,* 2018), minor mucosal irritation, and vomiting, whilst more concentrated solutions can cause severe irritation and corrosion, severe burns, blisters, ulcers and permanent scarring (Colares *et al.,* 2019).
8	**Benzolkonium chloride**	Cytotoxic effect when used to sterilize soft contact lenses also decreases the vision tremendously (Gasset 1977).
9	**Ethanol**	Respiratory arrest, arrhythmia, hypothermia, hypotension, hypoglycemia, ketoacidosis (Wilson *et al.,* 2015), and skin irritation or contact dermatitis (Lachenmeier 2008).

Most of the ingredients have impacts on humanbody. Only very few ingredients show quantitative impacts. Toxicity of ingredients also depends on formulations and combinations (Mahmood *et al.,* 2020). Hand sanitizer containing the impurities of benzene, acetal and acetaldehyde cause differenttype of disease in human beings such as eye and skin irritation, cancer, and irritation in upperrespiratory tract (FDA, 2021; Cohen *et al.,* 2021). Dermal contact with ethanol is responsible for skin irritation and allergic reaction especially who are sensitive to ethanol and those are with skindisorders including fissures (Mahmood *et al.,*2020). Higher number of hand-skin problems were particularly reported among health care workers during the COVID-19 pandemic, which was associated with the increased frequency of hand sanitizer use (Altunisik *et al.,* 2020). Such incidences of hand-skin problems included mainly the dryness of the skin and other conditions such as redness, burning pain and itching. Moreover, alcohol is highly flammable and can result in fire hazards if used near fire or exposed to high temperatures. Hydrogen peroxide toxicity depends on its concentration used in the AHS. A low concentration (3%) of hydrogen peroxide may cause mild irritation of the eyes and skin when used externally and when ingested, may result in irritation of the mouth and the gastrointestinal tract,and may also result in air embolism in rare cases (Watt *et al.,* 2004; Ghannoum *et al.,* 2014). Excessive use of AHS may result in a rise of other viral diseases and antimicrobial resistance due to the selection of resistant strains, particularly for bacteria.

Materials and Methods

Data was collected via online mode using google form as it was contactless method of data collection during the pandemic. Different age groups, gender and occupational peoples such as students including research scholars, teaching faculties, health workers and house wives were targeted for the study. Collected data was based on the Questionnaire which was answered by each group of peoples (Table 2). Previous studies for literature survey purpose was searched on various research platforms such as Research gate, Google scholar, Sci hub and in the archive section of various journals using different keywords. The data obtained was segregated as per the age and divided into five age groups (5-15, 16-25, 26-35, 36-45, 46 above). The data of brands of sanitizer was divided into six brand such as brand A(Dettol), brand B (Lifebuoy), brand C (Himalaya), brand D (Savlon), brand E (Mix use), and brand E (others).

Table 2: Questionnaire used during the study

SN	Questions
1	Have you used sanitizer?
2	What is your age?
3	Mention your gender?
4	Mention your occupation?
5	Mention the brand of sanitizer used
6	Mention the quantity (Approximate) of sanitizer used per month?
7	Mention the bad impact observed on the Body?

Results and Discussion

Impacts on human health

The study was performed on the peoples of age group from 5 years to above 45 years, ignoring the genders and occupations. The results obtained during the study period are given in Table 3 and Figure 1 to 4.

Table 3: Number of respondent as per their age group and sex (n=129)

Age group	Number of respondent	%	Sex	Number of respondent	%
5 to 15	1	0.8	Male	0	0.0
			Female	1	0.8
16 to 25	86	66.7	Male	46	35.7
			Female	40	31.0
26 to 35	32	24.8	Male	25	19.4
			Female	7	5.4
36 to 45	5	3.9	Male	1	0.8
			Female	4	3.1
46 above	5	3.9	Male	2	1.6
			Female	3	2.3

It is come out in the study that 98% peoples frequently used sanitizer in total; only 2% never used it as shown in the graph. From the age group 5to 15 years only 0.8% respondents are using the sanitizer. The respondent belongs to age group 16- 25 years are the key users of sanitizers which is 66.7%. The second large percentile (24.8%) from 26-35 years, further decrement is continuing as 3.9% for 36-45 years and above 46 years respectively (Figure 1). This has been shown in the graph that the male users of sanitizers are maximum to age group 16-25 and 26-35 years' as 35.7% and 19.4% respectively, rest

male respondent do not have significant contribution as 1.6% (45 above years) 0.8% (between 35-45 years) and 0.0% (5-15 years). In female category, the highest respondents are age group 16-25 years (31%) and the second highest 26-35 years (5.4%). Similarly, with male trends, the female related to 36-45 (3.1%), above 46 years (2.3%) and below 15 years is 0.8%. It is clear from the data (Table 3) that the smallest percentage (0.0% and 0.8%) belong to 5-15 years age group in both male and female and slightly above (3.1% and 2.3%) in both male and female of age group of 36-45 years and above 46 years respectively.

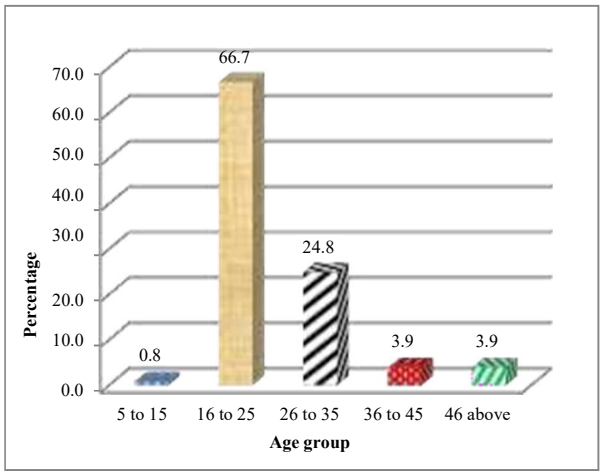

Figure 1: Percentage of respondent using the sanitizer as per their age group

By profession maximum users of sanitizers are students (71.3%) and minimum are house wives (0.8%). Nearly similar percentage as 11.6% and 10.9% correspond to teaching profession and private job respectively, rest (5.4 %) belong to the professions other than teaching and private jobs (Figure 2). It has been find out in the study that among the various brands of sanitizer brand A was more popular and has been used extensively by48% respondents. Other brands such as brand B, brand C, brand D were used by 12.6%, 6.3% and 6.3% respondents respectively. Some respondents (11%) used more than one brands as per the availability labelled as mix in this study. Other thanthese known brands, 17.3% respondents used other brands of sanitizer which may not be very popular or local brands as shown in Figure 3.

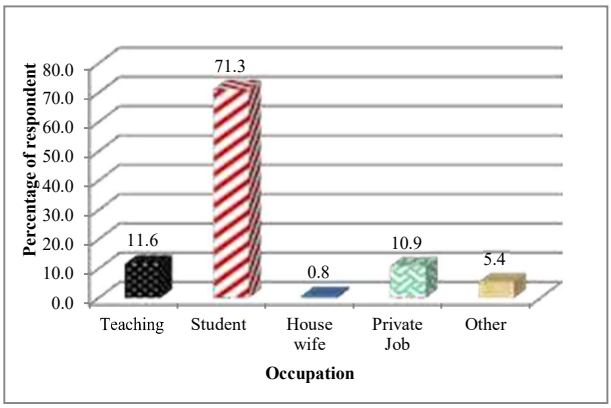

Figure 2: Percentage of different occupation of respondent

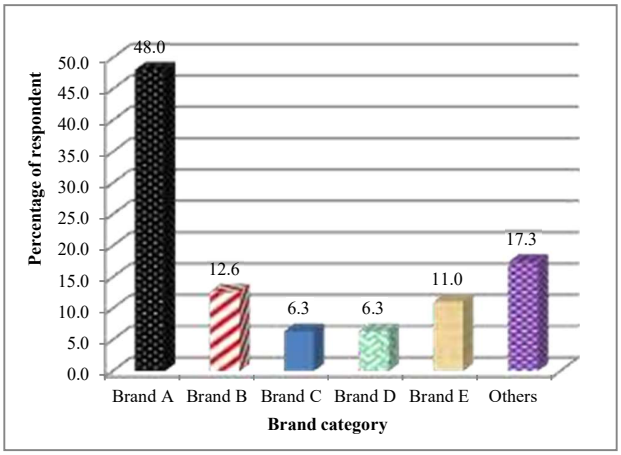

Figure 3: Percentage of different brand user among the respondent

Although, frequent use of hand sanitizer is necessary to maintain the hand hygiene and safety but some adverse effects were also observed by the number of peoples who were using hand sanitizer frequently. The data obtained shows that peoples are facing extreme hand dryness (49%), skinallergy (16%) and irritations or itching (12%). Ithas been find out in the study that 12% of therespondents were not aware of any direct visualimpact of sanitizer on their body. The rest numbers of peoples (12%) do not have any negative effecton their hand and other body parts (Figure 4).

It has been find out that awareness related to theuse of sanitizer increased as the age of respondents increased till the age of 35 years and above this age, a decrement is observed. It is summarised from the study that the respondent belongs to young age (under 15 years) are too young to understand the

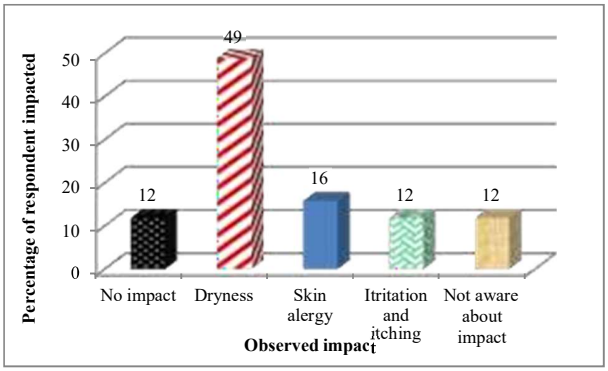

Figure 4: Different impact and their percentage in the respondent

importance of hygiene or may not have easy excess of sanitizer. On the other hand, the people belong to the age group between 16-25 years are more aware of hand hygiene and are maximum users. The moderate (24.8%) responses were received from age group 36-45 years. The people belong to 36 to 45 years and above are the least users of sanitizers may represent their indolence or ignorance. The male user of sanitizer is 57% in comparison to female (43%) which is 14% lesser than male users. Very less percentage of the older age male andfemale between 36-45 years and above 46 years uses hand sanitizers . It seems that either both male-female users in this category are not aware to sanitizer or cannot afford due to additional cost ofit.When the data obtained was analysed as per their professions, it was found that students are moreactive towards sanitisation and use the hand sanitizer more frequently. On the other hand, house wives are the least users of sanitizers they account too busy to perform house related responsibilities which results ignorance of hand hygiene or possiblyuse soap instead of sanitizer. This is also true that only few numbers of house wives were taking part in the study, therefore the given data cannot show the real picture of the society. It is also come out in the study that the peoples related to teaching profession and private jobs are nearby equally aware towards hand sanitization as it could be the result of their quality education. Only 5.4 % respondent relate to the jobs other than private job such as farmers, mechanical workers, shop holders and technicians etc. Again the low percentage indicate that hand hygiene is more promised in educated class of peoples and they used thesanitizer more frequently in comparison to non or less educated peoples.

Most of the respondents use the sanitizers of most popular brand such as Dettol, Savlon, Lifebuoy,and Himalaya. Some respondents use sanitizers ofmore than one brand may be due to lack of awareness regarding the composition and unavailability of the same brand in nearby market due the hike in the demand of sanitizers during COVID-19 pandemic. When the impacts of hand sanitizers were analysed, it was find out that the fragmented data does not seem very effective although, all together 88% peoples facing somekind of envisaged or non-envisaged problems after frequent use of sanitizer, only 12% do not have any significantly visual effect on them. Alcohol based sanitizers are responsible for skin dryness (cutaneous xerosis), hand dermatitis, irritant contact dermatitis (ICD), rarely allergic contact dermatitis (ACD) (Emami *et al.,* 2020; Beiu *et al.,* 2020; Aodah *et al.,* 2021), and elimination of helpful flora (Weaver, 2005) due to the impurities of acetaldehyde, acetal, benzene, and methanol (Cohen *et al.,* 2021). Now a day the use of orange extracts in perfumes and fragrances have been increased. However, it causes phytophotodermatitis on the exposure of sunlight (Lee *et al.,* 2022). Bakkar *et al.* (2021) and Abo-Zeid *et al.* (2022) worked on some lipid based sanitizers and concluded them as future alternative of AHS.

Impacts on Environment

The hand sanitizers which we considered and discussed in the present study are mainly based on ethanol, isopropyl alcohol and hydrogen peroxides. Sanitizers have different impacts on the environment based on their main components(Mahmood *et al.,* 2020). Ethanol is widely used in research and development laboratories, industries, academic laboratories and at home (Pendlington *et al.,* 2001). Bioaccumulation and bio concentration factor in fatty tissues for ethanol is very less due its high anticipated metabolic rate (HSDB, 2012). Aquatic organism are more likely to impacted by ethanol exposure due to its direct impact on dissolved oxygen concentration (NEIWPCC, 2001).Terrestrial organisms are less likely to be impacted by ethanol exposure because it either evaporates orpenetrates into the soil and water (Mahmood *et al.,* 2020). Ethanol spills on soil or in water impacts the invertebrates and microbial population (MassDEP, 2011).

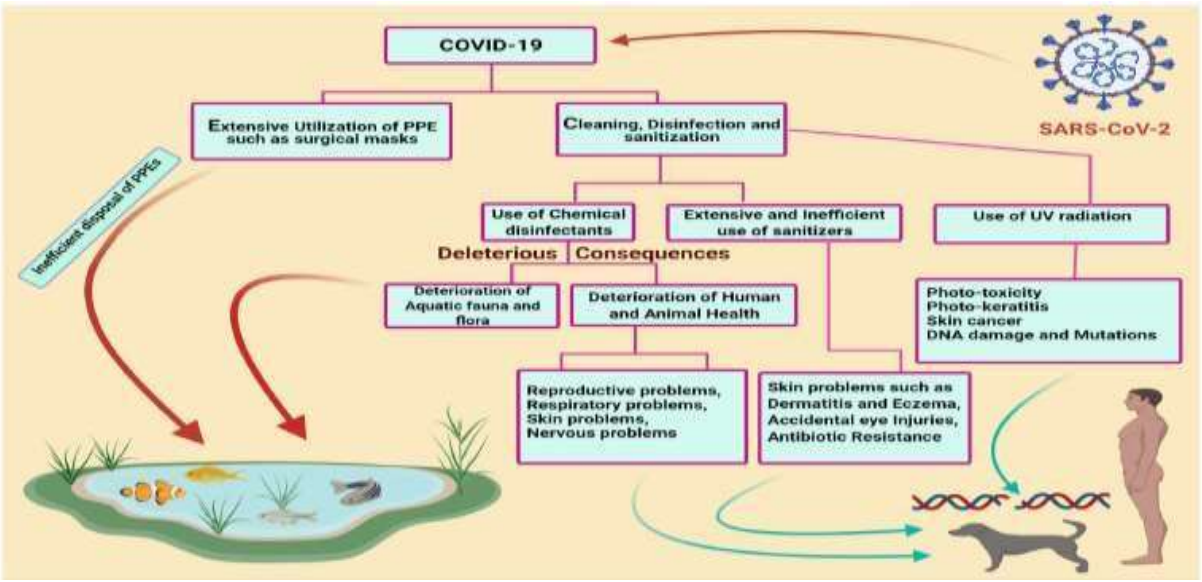

Figure 5a: Impacts of sanitizers on human health and Environment (adapted from Dhama *et al.*, 2021).

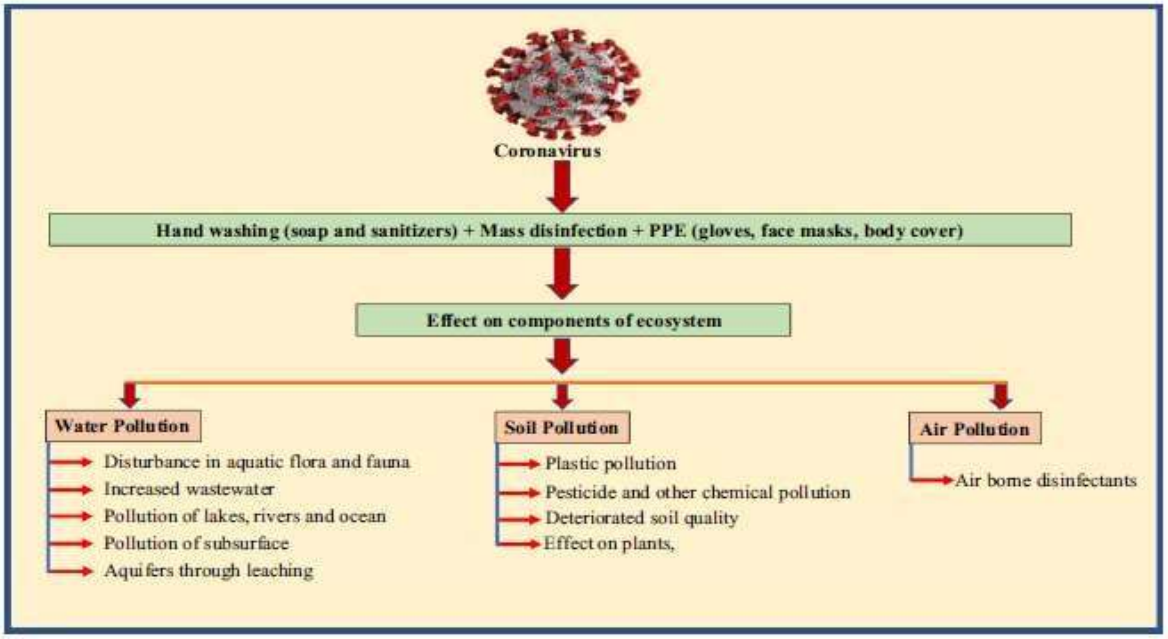

Figure 5b: Impacts of sanitizers on different components of Environment (adapted from Kumar *et al.*, 2021)

Wildlife shows different impacts on the exposure of different concentrations of ethanol USEPA ECOTOX Report, 2011; Nabi *et al.,* 2020).Minute quantities of isopropanol were reported in drinking water without any detectable limit (HSDB,2012) but larger spills of isopropanol on ground can contaminate ground water due infiltration through the upper strata of soil (Atolani *et al.,* 2020). Isopropanol is highly biodegradable and non-persistent in the atmosphere. Like ethanol, isopropanol also deplete the dissolved oxygen content of aquatic bodies and ultimately impacts theaquatic life (BABEC, 2001). In the formation of ground level ozone and photochemical smog, no role of isopropyl was reported in the literature. Hydrogen peroxide reacts with other compound with a very fast speed and therefore exists

in the environment for a short duration and therefore probabilities of impacts are very less (ATSDR, 2002). Due to fast degradation in soil and water, there are very less probability of accumulation in food chains (Mahmood *et al.,* 2020). Besides these, sodium hypochlorite, hypochlorous acids and other chlorine disinfectant pose threat to aquaticorganism (China Ministry of Ecology and Environment 2020; Sedlak, 2011; Subpiramaniyam, 2021). The disinfection practices such as washingof hospital, house, and laboratory floor, streets, and market places generated a huge amount of wastewater containing the sufficient quantity of disinfectant released directly or indirectly in rivers, lakes and ponds without any treatment (Geller *et al.,* 2012; Bashir *et al.,* 2020). Chlorine after reacting with organic matter produced organic chlorine which persists in the environment and posethreat to aquatic flora and fauna (Emmanuel *et al.,* 2004; Bhat *et al.,* 2021). Disinfectant when enters in wastewater impairs with the microbial life and therefore impacts the efficiency of wastewater treatment plant (Dhama *et al.,* 2021; Kumar *et al.,* 2021).

Conclusion

The present study was carried out to investigate the range of available hand sanitizers and the adverse effects on human body and environment. Attempt was also made to collect and correlate the gathered information with their occupation which may further trigger the adverse effect of sanitizer on human being. Most of the respondents were using the hand sanitizer and among them very few were aware about the composition of the sanitizer. Very few respondents of the age group 5-15years were using the sanitizer may be due to lack of awareness or reach of sanitizers. In comparison to males (57.5%), less awareness regarding the use of sanitizers were observed in females (41.8%) of different age groups. In females, only 0.8% of the house wives were using the sanitizers which maybe due to their busy schedule in household works. Maximum awareness level regarding sanitizer use was observed in age group 2 (16-25years) followed by 3 (26-35years) 4 (36-45y ears) 5 (46years) and above) and 1(0-15years). Sanitation and hygiene is more promised in educated class of respondents andthey used the sanitizer more frequently in compare to none or less educated respondents. 73.2% of the respondents were aware about the brands and using certain fixed brand while 11% of the respondents were using more than one brand simultaneously and 17.3% of the respondents were only using the sanitizer regardless of their brand. 76% of the respondents reported some sort of impacts on their body. Based on literature and the findings of the present study, we can conclude that the componentsof the sanitizer and other disinfectants are affecting the humans in various ways and also causing the disturbances in different components of the environment and therefore disturbing the natural functioning of the environment. Thus there is a need of strict regulations on the manufacturing units regarding the composition of sanitizers. Also, there is a need of spreading the awareness among the common peoples regarding the use of sanitizer and the impacts of their components on the body so that they can be more aware while selecting the sanitizers based on their components and impacts aswell as in disposal of various disinfectants.

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Conflict of interest

The authors declare that they have no conflict of interest.

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