Journal of Science and Technology, Vol. 40, No. 1 (2022), pp 51- 65

RESEARCH PAPER

EFFECT OF PREVENTIVE MEASURES AGAINST COVID-19 ON THE ENVIRONMENT

Temitope Monsurat Osobamiro[1*], Oluwafemi Awolesi[2], Ogundaini Rotimi Sina[3]

[1]Department of Chemical Sciences, Olabisi Onabanjo University, Nigeria
[2]Department of Chemistry, Mississippi State University, Mississippi State, U.S.A.
[3]Department of Chemistry, Federal College of Education, Akoka, Lagos, Nigeria.

***Corresponding Author:** osobamiro.temitope@oouagoiwoye.edu.ng

ABSTRACT

As COVID-19 becomes fast spread, safe disposal of infectious and hazardous COVID-19 waste that has mixed with municipal waste is now becoming a major environmental challenge. In many cities in Nigeria, such wastes are often disposed of in landfills or incinerated openly. Though, significant attention has been paid to policy and management of COVID-19 in the health sector, little has been done in managing COVID-19 waste. Effective handling and disposal techniques of these wastes must be harnessed in sustaining the environment and curbing the spread of this disease. This paper is aimed at evaluating the two major precautionary measures taken against the spread of COVID-19; face covering and hand sanitizer, their chemical composition, use, disposal and impacts of their improper disposal on the environment. Common medical and disposable face masks are made of non-biodegradable plastic materials containing toxic additives that are carcinogenic, mutagenic and contribute significantly to climate change. Prolong or misuse of commonly used hand sanitizers can cause oral and dermal toxicity especially in children. Safer, economical and reusable materials to replace hitherto toxic materials used in curbing the spread COVID-19 should be made available. Aside from frequent washing of hands with soap and water, this paper recommends that attention should also be focused on public awareness on proper handling and disposal of all waste. Hospitals and municipal waste management should adopt the art of autoclaving before incineration of waste.

Keywords: Facemask, Hand sanitizer, Waste disposal, Precautionary measures,

INTRODUCTION

The widespread of COVID-19 has affected the total wellbeing of human societies. The pandemic has led to major environmental challenges as new kinds of waste have been introduced into the environment. These include used face masks and hand gloves, empty hand sanitizer containers and other plastic materials generated as a result of bulk-buying in cities and states across the country (Ilechukwu, 2020). Safe disposal of infectious and hazardous waste due to COVID-19 that has mixed with municipal waste now becomes an environmental issue. Government in various countries has put different measures in place to curtail the virus and its further spread. The quarantine and lockdown policies established in most countries, have led to increase in municipal waste generated at homes and safe management of household waste has become critical (United Nations Environment Programme, 2020). Chemicals and disinfectants are now the new norm, some of which can be dangerous to human health and the environment (Guzman, 2020).

The precautionary measures put in place by the government may directly impact the environment negatively as well as improper disposal of waste generated by these measures. There has been an increase in waste from the use of Personal Protective Equipment (PPE) by individuals and frontline health workers and this requires critical wastes management in relation to COVID-19 (UN-Habitat 2020; Calma, 2020). Along this same line, the UN Environment Program has urged governments to treat waste management, including medical, domestic, and other waste, as an urgent and essential public service to minimize possible secondary health and environmental effects (ARCplus, 2020).

The outbreak of covid-19 has led to an increase in the use and disposal of plastic products, even for non-medical applications. Single-use plastics are seen by consumers as a safe alternative for many applications in household and restaurants. These materials including; plastic packaging materials, drinking bottles, and fast food containers have been identified as a significant source of plastics and plastic particle pollution in the environment (Fadare et al., 2020). Their disposal is indirectly accompanied by a wide range of environmental issues, such as soil erosion, deforestation, air, and water pollution (Mourad, 2016; Schanes et al., 2018).

As the number of infected people increases, so does the amount of infectious medical waste. Hospitals in Wuhan produced an average of 240 metric tons of medical waste per day during the outbreak, compared to their previous average of fewer than 50 metric tons (Calma, 2020). In many cities in Nigeria, medical waste are often mixed with municipal solid waste and disposed of in residential waste landfills or incinerated openly (Awodele et al., 2016). Although significant attention has been paid to policy and management of COVID-19 in the health sector, little attention has been paid to waste management under COVID-19 pandemic in spite of the clear connection between solid waste management, health and development (Gonzenbach and Coad 2007; UN-Habitat 2020). It has been noted that strategies to manage solid wastes, during and after the COVID-19 pandemic, are lacking in Nigeria (Nzediegwu and Chang, 2020).

This paper is aimed at evaluating the two major preventive measures; face covering and hand sanitizer; their chemical composition, use, means of disposal and impacts of their improper disposal on the environment.

Face Coverings: Types, Composition and Use

Medical and Disposable Facemasks

The science around the use of masks by the general public to prevent its transmission is

advancing rapidly (Howard et al., 2020). In spite of the widespread usage of face masks, there has been a great deal of anomalies in the handling and disposal (New Straits Times, 2020; The Conversation, 2020). Virtually all medical and disposable face masks (single use face masks) are derived from non-biodegradable substances produced from polymers, such as polypropylene, polyurethane, polyacrylonitrile, polystyrene, polycarbonate, polyethylene, or polyester (Potluri and Needham, 2005; Ecowatch, 2020). Plastic polymers are not considered as toxic, but the additives that are typically blended with the monomer are hazardous and toxic.

Additives, such as flame retardants, heat stabilizers, antioxidants, light stabilizers, lubricants and acid scavengers are added for polymerization to take place (Rosato, 1998). These additives are hazardous to the environment and human health because they are carcinogenic, mutagenic, toxic with long lasting effects. They are of low molecular weight and are either weakly bound or not bound at all to the polymeric macromolecules and so, can be emitted from the plastic products (Crompton, 2007; OECD, 2004) to air, water or other contact media, for example food. Some of these have been evaluated for the endocrine disrupting properties (Groshart and Okkerman, 2000).

Reputable scientific studies have revealed the possibility of widespread that may ensue if mishandling of the masks persists; the level of environmental pollution resulting from the poor disposal of face protective coverings may be alarming if not checked (New Straits Times, 2020; The Conversation, 2020). In as much as the Centre for Disease Control and Prevention (CDC) does not recommend the use of N95 mask for the general public (FDA, 2020), several people have resorted to it including government officials, politicians, though, to safeguard themselves against contacting the deadly COVID-19 disease but these protective wears are not properly disposed. A study estimated that a single use of face mask daily for a year by a person would amount to about 70,000 tonnes of contaminated wastes and 60,000 tonnes of plastic packaging (Weforum, 2020). It has been estimated that the number of plastic protective wear (PPW) such as face masks used daily in Africa is about seven hundred million (Nzediegwu and Chang, 2020).

Face shield

Face shield, which comes in various forms, provides a transparent plastic wall that guards the face. These shields are derived from common materials found in craft or office supply stores (Perencevich et al., 2020). As a result, they are not as scarce as medical masks. In addition to this, face shields are more durable, can be reused and sanitized with disinfectants, or soap and water (Perencevich et al., 2020). It requires no removal if one has to communicate coherently with another even through facial signals, in comparison to medical and fabric masks. It is worn with comfort and has strong shielding against viral entry, including COVID-19 and influenza viruses (Perencevich et al., 2020).

ECOLOGICAL AND ENVIRONMENTAL IMPLICATION OF IMPROPER DISPOSAL OF COVID-19 WASTES

A boomeranging problem associated with the use of face coverings is not only the sudden surge in the volume of plastic waste but also the issue of disposal (Earth.org, 2020b; Klemeš et al., 2020). Waterlogged masks and other wastes linked with COVID-19 are being identified on sea-beds, and eroded into other water bodies (see Fig. 1-3) adding to the daily

debris in the aquatic ecosystems (Weforum, 2020).

Fig 1: Mask Pollution

(Source: connexionfrance.com; accessed 25th Oct. 2020)

The environmental implication and the adverse effects of improper disposal of plastics and plastic particles include; threat to aquatic lives, which constitute a major part of the food web and support to human existence (Fadare et al., 2020), reduction in aesthetic and recreational worth which are vital to human social and mental stability.

The presence of plastics in the environment is contributing significantly to climate change due to carbon emission and a greater risk to the global food chain (Reid et al., 2020; Shen et al., 2019). Another implication of indiscriminate disposal of used plastic face masks or PPE in the environment is the possibility of acting as a medium for disease outbreak, as plastic particles are known to propagate microbes such as invasive pathogens (Reid et al., 2020). When these are remained discarded in an animal's natural habitat in both land and ocean this could cause animals to mistakenly eat this as food which may lead to death (Hellewell et al., 2020). There is currently no unified international regulation on plastics regulation and pollution management. Some inhabitants in developing countries drop their waste in run-off water during rain, thereby, clogging water ways leading to flooding.

Cleaners and waste-collectors amongst other groups of health workers in their quest to make a living among communities are more susceptible to the negative effects from exposure to these wastes (see Fig. 2) (Wilson et al., 2006; Samson 2020). Health workers and cleaners are not provided with adequate protective wears and this has exposed many of them to the disease. Usually, COVID-19 waste is usually mixed with general household waste, which may put waste collectors at risk of contracting disease (Nzeadibe and Ejike-Alieji, 2020; Chuks et al., 2013).

Fig. 2: Mask Waste from Hong Kong Beach

(Source: bangkokpost.com; accessed 25th Oct. 2020)

The mass retrieval of different types of nose masks in Hong Kong (see Fig. 2) in February, 2020 New South Wales beach (Fig. 3) and along an expressway and drainage in Ile-Ife, Nigeria in May, 2020 is a proof that facemasks are environmental litters on land and in water, and the pandemic is continuously increasing plastic pollution; thus, indicating a menace trend in the environment (Fadare and Okoffo, 2020; Ecowatch, 2020). These plastic wastes can be easily eroded into water bodies and if not controlled, may probably emerge as

new origin of microplastic fibres, due to their degradability and fragmentation under environmental conditions (Fadare and Okoffo, 2020).

Fig. 3: Mask Waste from New South Wales (NSW) Beach

(Source: au.news.yahoo.com; accessed 15th Nov., 2020)

Burning of plastics usually produces some noxious gases like furans and dioxins, which are dangerous greenhouse gases that play important role in ozone layer depletion (Verma et al., 2016). In fact, dioxins specifically disrupt the functioning of the human endocrine hormone and thus are major concern for the human health. Substances released from various plastic products include; phthalates (Tonning et al., 2010), brominated flame retardants (Kim et al., 2006), bisphenol A (Geens et al., 2010), lead, tin and cadmium (Al-Malack, 2001), formaldehyde and acetaldehyde (Özlem, 2008), 4-nonylphenol (Fernandes et al., 2008) and benzene (Skjevrak et al., 2003).

Green House Gases (GHG) is emitted during production and incineration of cotton and plastic face masks (Klemeš et al., 2020). Also, landfilling of plastic wastes may generate microplastics which are present in landfill leachates and may be released to the surrounding environment (Silva et al., 2021). Waste water from hand washing is not usually treated and when washed into water bodies can cause eutrophication, foaming, and altering water physicochemical parameters such as temperature, salinity, turbidity, and pH (Mousavi and Khodadoost 2019).

Most PPE including gloves, aprons, long sleeved gowns, goggles, fluid-repellent surgical masks, eye, nose and mouth protection, face visors and respirator masks used in healthcare and during the burial of deceased COVID-19 victim oftentimes are not properly disposed. A good example of this is a viral video clip which showed how one of the pall bearers after the burial of a prominent government official in Nigeria was seen carelessly disposing off his PPE in the open environment (Isine, 2020).

Handling regulations for Face Coverings

The World Health Organization (2020) stipulates guidelines for handling of face coverings, specifically medical masks. Used tissues and face masks must be disposed in closed litter receptacles while other medical equipment must be sterilized and incinerated at high temperatures (WHO, 2020). Many

hospitals do not have the ability to correctly tackle the abrupt surge in medical wastes engendered by the pandemic because most of them especially in developing nations are not equipped with the modern incinerators operating within 800 to 1200°C in line with international emission standards (Earth.org, 2020a).

Disposal of moist masks should not be delayed and should be replaced. Perhaps due to the availability and affordability of fabric masks to the general public, guidelines on its usage have been provided by different authorized health agencies across the world. The Nigeria Centre for Disease Control (NCDC, 2020) has recommended frequent washing of hands with soap under running water to prevent contamination, social distancing and mask wearing before leaving for essential services. Other regulations include not pulling down the mask to cough or sneeze as well as not leaving a used facemask on dirty surfaces or in the proximities of children. It also recommends the use of tissue or bent elbow over the mask until one is able to safely remove the mask for washing. Furthermore, washing or sanitizing the hands before removing the mask by the straps is advised. Fabric mask should be immediately washed with soap or detergent and sundried, followed by ironing before reuse.

It also emphasizes the use of three-layer fabric masks but should be avoided for below two years old. New masks purchased from vendors need not be immediately worn but after washing. Reuse of fabric mask must always come after sufficient washing and drying. Furthermore, washing or sanitizing the hands before removing the mask by the straps is advised.

Hand Sanitizers: Types, Composition and Use

After the outbreak of COVID-19 in December 2019 usage of hand sanitizer was suggested by WHO as a preventive measure to control this pandemic, which leads to exponentially increased usage of alcohol based hand sanitizers as hand hygiene. Adaptation of effective hand hygiene is vital, where one of the best advices by WHO is to wash hands frequently with soap and water or sanitize with >60% alcoholic hand sanitizer. Two compositions of hand sanitizer were suggested by WHO mainly made up from ethanol, isopropyl alcohols, hydrogen peroxides in different combinations (WHO, 2020), one with ethanol (96%) and the other with isopropyl alcohol (99.8%). Final product concentration suggested by WHO for household or local production is ethanol (80% v/v), hydrogen peroxide (0.125% v/v) and glycerol (1.45% v/v) for formulation A and isopropyl alcohol (75% v/v), hydrogen peroxide (0.125% v/v) and glycerol (1.45% v/v) for formulation B.

Prolong or wrong use of these chemicals can lead to toxicity and NCDC has even announced that many sanitizers in the market are fake (Premium Times, 2020). Information on the label of some hand sanitizer are usually incomplete, abbreviated while some only indicated that 'alcohol' is the main ingredient, without stating the specific alcohol used (Nyamweya and Abuga , 2020)

These preparations may become toxic to human health and environment when misused or when released by evaporation (Slaughter et al., 2014). Some hand sanitizers contain methanol which show oral and dermal toxicity and have been mandated not to be use in hand hygiene products (Chan and Chan, 2018).

Ethanol and Isopropyl alcohol Toxicity

Consistent use of ethanol based hand sanitizer have been associated with increase in concentration of urinary ethyl glucuronide (Salomone et al., 2018) and its responsible for skin and eyes irritation or contact dermatitis (Lachenmeier, 2008). Toxicity from the use of Isopropyl based is more intense compared to

ethanol due to its higher molecular weight (Wilson et al., 2015). Toxicity may be as a result of accidental (especially in children) or suicidal ingestion or absorption through dermal contact. About 90% of ingested ethanol metabolized to acetaldehyde and acetyl CO-A (Ellis-Caleo and Burstein, 2017). Ingestion of one ounce (oz) of isopropanol solution has been reported to result in serious clinical effects in children under age of six years (Stremski and Hennes, 2000). Possible lethal dose of isopropanol for adults is approximately 240 ml (Gosselin et al., 1984).

Common symptoms that appear after ingestion of ethanol based hand sanitizer are; nausea, vomiting, epigastria pain, and varying degrees of central nervous system depression (Archer et al., 2007). Ethanol toxicity has been linked with respiratory diseases such as; hypothermia, cardiac dysrhythmias with possible cardiac arrest, hypoglycemia, ketoacidosis and hypotension (Gormley et al., 2012). Isopropyl alcohol also irritates mucosal lining in gastrointestinal tract (Slaughter et al, 2014) and contributes to gastritis (Matteucci, 2011), associated to cause ketosis (Trummel et al., 1996), respiratory depression, and increase in the serum cretinine (Zaman et al., 2002).

Toxicity due to dermal absorption can result if ethanol or isopropanol-based hand sanitizer is continuously used for months and several times a day, as currently happening for COVID-19 prevention (Bouthoorn et al., 2011; Gormley et al., 2012; NJH, 2016; Salomone et al., 2018).

Triclosan Toxicity

Hand sanitizers void of alcohol may contain triclosan, a powerful antibacterial agent often used in the production of pesticides (Glaser, 2004). It is readily absorbed by the skin which can directly impact thyroid function and is deleterious to the liver and muscles when in contact (Glaser, 2004; Ley et al., 2017). Studies reveal that many individuals have transitioned from the use of soap and water to clean up the hands before picking up foods or fruits to the use of hand sanitizers. The implication of this is adverse on the body system, especially individuals with low immunity, as they not only consume the edibles but do that in conjunction with the ingestion of the harmful chemicals the sanitizers contain (Weatherly and Gosse, 2017). Triclosan, when ingested, reduces the effectiveness of the body's immunity, thereby making the victims more vulnerable to even genital dysfunction (Glaser, 2004; Weatherly and Gosse, 2017).

Hand Sanitizer: Risk Factor for Children

Most of the available hand sanitizers are available in brightly hued bottles and have appealing smell like candy or any food flavor which is very tempting to young children. Most scented hand sanitizers contain toxins and ingestion of small amount of sanitizer may pose no health risk but ingesting any more than a taste could lead to alcohol poisoning in children (AAPCC, 2020). Recent reports have recognized serious concerns, including apnea, acidosis, and coma in young children who ingested alcohol-based (alcohol) hand sanitizer (Santos et al., 2017). In early five months of 2020, American Association of Poison Control Center reported 9504 alcoholic hand sanitizer exposure cases in children under the age of 12 years and recognized that even a small amount of alcohol can cause alcohol poisoning in children that is responsible for confusion, vomiting and drowsiness, and in severe cases, respiratory arrest and death (AAPCC, 2020).

Increased Risk of Other Viral Diseases

Medical experts have started to warn that excessive use of alcohol based hand sanitizer as a preventive measure against coronavirus indirectly increase the risk of infection through skin disorders. Too much use of sanitizer against new corona virus is responsible for

skin damage and reduce its ability to work as a barrier against other harmful viruses (Tachikawa, 2020). Excessive use of alcohol based sanitizer increased permeability of skin (Schuster, 2014) and deprives oil and water from skin and leads to skin roughness and irritation. Dry and damaged skin is hotbed for many diseases causing bacteria with increased risk of virus entry into skin (Tachikawa, 2020). Research reports have indicated that overuse of sanitizers in some cases may increase risk of viral outbreaks (Vogel, 2011).

Flammability of Hand Sanitizers

Alcohol-based sanitizers are highly flammable; as such, individuals who put it on their hands are susceptible to serious burn if they are in close proximity to any fire (Jing at al., 2020). It is important therefore to have all hand sanitizer containers airtight to minimize or eliminate the risk for flammability.

Graphene Materials as Safe Precautionary Measures against SARS-CoV-2

Graphene oxide (GO), a 2D nanomaterial that is environmental friendly has shown strong inhibitory activity against many viruses including coronavirus. This is attributable to its unique physicochemical, electronic and biological properties (Palmieri and Papi, 2020; Raghav and Mohanty, 2020). It has high negative charge and through hydrogen bonding and electrostatic interactions can adsorbed positively charged lipid bilayer of feline coronavirus (Song et al., 2015) causing structural disruption and cytotoxic effects to the viral membrane (Frost et al., 2012; Rui et al., 2015). Based on technology, different precautionary materials against COVID-19 have been produced. An economical and reusable graphene mask was produced by Bonbouton (https://www.bonbouton.com/COVID-mask). Composite ink of GO and silver nanoparticles that effectively eradicates strains of coronavirus was proposed by Zen Graphene Solutions Ltd (Mining, 2020). The mist spray of this composite can be used as body spray to sanitize nasal or mouth by masking the S-protein of SARS-CoV-2 (Raghav and Mohanty, 2020).

Also, surface cleaner wipes coated with graphene or graphene-based nanomaterials have been used as disinfectant (Raghav and Mohanty, 2020). Graphene-based nano-drugs conjugated with antivirals are being postulated to be effective against SARS-CoV-2. Reusable PPE coated with modified nanomaterials with enhanced capacity to repel the SARS-CoV-2 has been postulated to prevent aerosol transmission in medical healthcare workers. Multiple layer nanomaterials with modified positive charge filters installed in the air purification and air-conditioning devices can prevent aerosol transmission of COVID-19 (Graphene-info, 2020; Raghav and Mohanty, 2020).

CONCLUSION AND RECOMMENDATIONS

Management of COVID-19 PPE waste is everybody's business, major stakeholders include; health workers, waste collectors, waste management companies and the general public at large. The potential implications of the negligence of Covid 19 control wastes can be deleterious if care is not taken promptly.

It is therefore recommended that washing of hands with soap and water regularly; keeping the sanitizer away from children; storing it in an airtight bottle in a cool dry place, non-usage in the kitchen or in an environment close to fire; and cleaning the face coverings with soap and water are adopted.

An eco-friendly and cost effective methods of plastic degradation by microbes or modification with natural polymers can be adopted. Plastic waste can also be recycled into new useful materials. For instance in

Bangalore, India, plastic asphalt produce from churned plastic waste blended with bitumen is used as an alternative road material (Khullar, 2009; Gulati, 2010).

Public awareness should be focus on proper disposal/sorting of all COVID-19 wastes from household waste. Training of local waste collectors on proper handling of COVID cum household waste should be encouraged. The art of autoclaving before incineration of waste should be adopted while all laboratories and hospitals should be mandated to have incinerators.

Technology should be geared towards the development of eco-friendly and affordable (and perhaps reusable) materials to curb the spread of the diseases coupled with the amelioration of recycling streams to guarantee suitable end-of-life for those products. In all, actions that support environmental sustainability should be put in place and communicated to the general public. Only if these and many more associated innovations are put into practice would we prevent the next probable pandemic from surfacing: Plastic pollution!

REFERENCES

American Association of Poison Control Centers (AAPCC). (2020). Hand Sanitizer. Retrieved from: https://aapcc.org/track/hand-sanitizer.

Al-Malack, M.H. (2001). "Migration of lead from unplasticized polyvinyl chloride pipes". J.Haz. Mat. B82, 263-274.

Archer, J.R., Wood, D.M., Tizzard, Z., Jones, A.L. and Dargan, P.I. (2007). "Alcohol hand rubs: hygiene and hazard". BMJ. 335 (7630):1154-1155.

ARCplus. (2020). Indirect effects of COVID-19 on the environment. Retrieved from https://www.acrplus.org/en/municipal-waste-management-covid-19, Accessed April 5, 2020

Awodele,O., Adewoye, A.A. and Oparah, A.C. (2016). "Assessment of medical waste management in seven hospitals in Lagos, Nigeria". BMC Public Health 16:269

Bouthoorn, S.H., van der Ploeg, T., van Erkel, N.E. and van der Lely, N. (2011). "Alcohol intoxication among Dutch adolescents: acute medical complications in the years 2000-2010". Clin Pediatr (Phila) 50, 244-251.

Calma, J. (2020). https://www.theverge.com/2020/3/26/21194647/the-covid-19-pandemic-is-generating-tons-of-medical-waste Accessed date: 6th Nov., 2020.

CDC. (2020). Use of Cloth Face Coverings to Help Slow the Spread of COVID-19. Retrieved from https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/diy-cloth-face-coverings.html

Chan, A.P.L. and Chan, T.Y.K. (2018). "Methanol as an Unlisted Ingredient in Supposedly Alcohol-Based Hand Rub Can Pose Serious Health Risk". Int. J. Environ. Res. Public Health 15, 1440 doi:10.3390/ijerph15071440. www.mdpi.com/journal/ijerph

Chuks, N., Anayo, F. and Ugbogu, O. C. (2013). "Health Care Waste Management – Public Health Benefits, and the Need for Effective Environmental Regulatory Surveillance in Federal Republic of Nigeria". Current Topics in Public Health doi:10.5772/53196

Crompton, T.R. (2007). "Additive migration from plastics into foods. A guide for the analytical chemist". Ismithers Rapra Publishing, Shrewsbury.

Earth.org. (2020a). COVID-19:Unmasking the Environmental Impact. Retrieved from https://earth.org/covid-19-unmasking-the-environmental-impact/

Earth.org. (2020b). Another Side Effect of COVID-19: The Surge in Plastic Pollution. Retrieved from https://earth.org/covid-19-surge-in-plastic-pollution/

Ecowatch. (2020). COVID19 Masks Are Polluting Beaches and Oceans. Retrieved fromhttps://www.ecowatch.com/covid-19-masks-beaches-oceans-2646165717.html?rebelltitem=3#rebelltitem3

Ellis-Caleo, T. and Burstein, S. (2017). A Case of Hand Sanitizer Intoxication. Proceedings of UCLA Healthcare 21. Retrieved from: https://www.proceedings.med.ucla.edu/wpcontent/uploads/2017/11/A-Case-of-Hand-Sanitizer-Intoxication.pdf

Fadare, O.O., Wan, B., Guo, L. and Zhao, L. (2020). "Microplastics from consumer plastic food containers: are we consuming it?" Chemosphere 253:126787.

Fadare, O. O. and Okoffo, E. D. (2020). "Covid-19 face masks: A potential source of micro-plasticfibers in the environment". The Science of the total environment 737: 140279.

Food and drug administration (FDA). (2020). Retrieved from https://www.fda.gov/medicaldevices/personal-protective-equipment-infection-control/n95-respirators-surgical-masks-and-face-masks

Fernandes, A.R., Rose, M. and Charlton, C. (2008). "4-Nonylphenol in food-contact material Analytical methodology and occurrence". Food. Addit. Contam. 25:364-372.

Frost, R., Jonsson, G.E, Chakarov, D., Svedhem, S. and Kasemo, B. (2012). "Graphene oxide and lipid membranes: Interactions and nanocomposite structures. Nano Lett 2012.

Geens, T., Apelbaum, T.Z., Goeyens, L., Neels, H. and Covaci, A. (2010). "Intake of bisphenol A from canned beverages and foods on the Belgian market". Food Addit. Contam.Part A, 27: 1627-1637.

Glacier, A. (2004). "Beyond Pesticides/National Coalition against the Misuse of Pesticides". Pesticides and You 24(3): 12-17.

Gonzenbach, B., and Coad, A. (2007). "Solid Waste, Health and the Millennium Development Goals: Links that Inspire Action." Collaborative Working Group on Solid Waste Management in Low- and Middle-income Countries. CWG Publication Series No 3.

Gormley, N.J., Bronstein, A.C., Rasimas, J.J., Pao, M., Wratney, A.T. and Sun, J. (2012). "The rising incidence of intentional ingestion of ethanol-containing hand sanitizers". Crit Care Med. 40 (1): 290-294.

Gosselin, R.E., Smith, R.P. and Hodge, H.C. (1984). Clinical Toxicology of Commercial Products. 5th ed. Baltimore: Williams & Wilkins

Graphene-info (2020). Graphene. [online] Available at: https://www.graphene-info.com/ [Accessed 14 Jan. 2021].

Groshart, C.P. and Okkerman, P.C. (2000). "Towards the establishment of a priority list of substances for further evaluation of their role in endocrine disruption preparation of a candidate list of substances as a basis for priority setting:. Final Report, Annex 15 List of 66 substances with categorization high, medium or low exposure concern.

Gulati, V. (2010). Indian state uses plastic waste for road construction. One World South Asia. (News article) http://southasia.oneworld.net/todaysheadlines/indian-state-uses-plastic-waste-for-road-construction (Accessed 23 January 2011)

Guzman, M.I. (2020). "Bioaerosol Side Effect in COVID-19 Transmission". Preprints. doi:10.20944/preprints202004.0093.v2

Earth.org. (2020b). Another Side Effect of COVID-19: The Surge in Plastic Pollution. Retrieved from https://earth.org/covid-19-surge-in-plastic-pollution/

Ecowatch. (2020). COVID19 Masks Are Polluting Beaches and Oceans. Retrieved from https://www.ecowatch.com/covid-19-masks-beaches-oceans- 2646165717. html?rebelltitem= 3#rebelltitem3

Ellis-Caleo, T. and Burstein, S. (2017). A Case of Hand Sanitizer Intoxication. Proceedings of UCLA Healthcare 21. Retrieved from: https://www.proceedings.med.ucla.edu/wpcontent/uploads/2017/11/A-Case-of-Hand-Sanitizer-Intoxication.pdf

Fadare, O.O., Wan, B., Guo, L. and Zhao, L. (2020). "Microplastics from consumer plastic food containers: are we consuming it?" Chemosphere 253:126787.

Fadare, O. O. and Okoffo, E. D. (2020). "Covid-19 face masks: A potential source of micro-plasticfibers in the environment". The Science of the total environment 737: 140279.

Food and drug administration (FDA). (2020). Retrieved from https://www.fda.gov/medicaldevices/personal-protective-equipment-infection-control/n95-respirators-surgical-masks-and-face-masks

Fernandes, A.R., Rose, M. and Charlton, C. (2008). "4-Nonylphenol in food-contact material Analytical methodology and occurrence". Food. Addit. Contam. 25:364-372.

Frost, R., Jonsson, G.E, Chakarov, D., Svedhem, S. and Kasemo, B. (2012). "Graphene oxide and lipid membranes: Interactions and nanocomposite structures. Nano Lett 2012.

Geens, T., Apelbaum, T.Z., Goeyens, L., Neels, H. and Covaci, A. (2010). "Intake of bisphenol A from canned beverages and foods on the Belgian market". Food Addit. Contam.Part A, 27: 1627-1637.

Glacier, A. (2004). "Beyond Pesticides/National Coalition against the Misuse of Pesticides". Pesticides and You 24(3): 12-17.

Gonzenbach, B., and Coad, A. (2007). "Solid Waste, Health and the Millennium Development Goals: Links that Inspire Action." Collaborative Working Group on Solid Waste Management in Low- and Middle-income Countries. CWG Publication Series No 3.

Gormley, N.J., Bronstein, A.C., Rasimas, J.J., Pao, M., Wratney, A.T. and Sun, J. (2012). "The rising incidence of intentional ingestion of ethanol-containing hand sanitizers". Crit Care Med. 40 (1): 290-294.

Gosselin, R.E., Smith, R.P. and Hodge, H.C. (1984). Clinical Toxicology of Commercial Products. 5th ed. Baltimore: Williams & Wilkins

Graphene-info (2020). Graphene. [online] Available at: https://www.graphene-info.com/ [Accessed 14 Jan. 2021].

Groshart, C.P. and Okkerman, P.C. (2000). "Towards the establishment of a priority list of substances for further evaluation of their role in endocrine disruption preparation of a candidate list of substances as a basis for priority setting:. Final Report, Annex 15 List of 66 substances with categorization high, medium or low exposure concern.

Gulati, V. (2010). Indian state uses plastic waste for road construction. One World South Asia. (News article) http://southasia.oneworld.net/todaysheadlines/indian-state-uses-plastic-waste-for-road-construction (Accessed 23 January 2011)

Guzman, M.I. (2020). "Bioaerosol Side Effect in COVID-19 Transmission". Preprints. doi:10.20944/preprints202004.0093.v2

Hellewell, J., Abbott, S., Gimma, A., Bosse, N.I., Jarvis, C.I., Russell, T.W., Munday, J.D., Kucharski, A.J., Edmunds, W.J. and Sun, F. J. (2020). "Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts". Lancet Glob. Health 8 (4): 488–496. https://doi.org/10.1016/S2214-109X(20)30074-7.

Howard, J., Huang, A., Li, Z., Tufekci, Z., Zdimal, V., van der Westhuizen, H., von Delft, A., Price, A., Fridman, L., Tang, L., Tang, V., Watson, G.L., Bax, C.E., Shaikh, R., Questier, F., Hernandez, D., Chu, L.F., Ramirez, C.M. and Rimoin, A.W. (2020). "Face Masks against COVID-19: An Evidence Review". Preprints. doi: 10.20944/preprints202004.0203.v2

Ilechukwu, I. (2020). "COVID-19 Wastes." April 9. Accessed June 13, 2020. https://www.thecable.ng/covid-19-wastes.

Isine, I (2020) SCARY: Amateur Video Shows Man Disposing PPE Outside Abuja Cemetery after Abba Kyari's Burial. In: Next Ed. https:// www. next edition. com. ng/ scary- amateur- video- shows- man-disposing- ppe- outside- abuja- cemetery-after- abba- kyaris- burial. Accessed on 14 July, 2021

Jing, J., Pei Yi, T., Bose, R., McCarthy, J. R., Tharmalingam, N. and Madheswaran, T. (2020). "Hand Sanitizers: A Review on Formulation Aspects, Adverse Effects, and Regulations". International journal of environmental research and public health, 17(9): 3326. https://doi.org/10.3390/ijerph17093326

Khullar, M. (2009). "Plastic roads offer greener way to travel in India". The New York Times, 13 November 2009.

Kim, Y.J., Osako, M. and Sakai, S. (2006). "Leaching characteristics of polybrominated diphenyl ethers (PBDEs) from flame-retardant plastics". Chemosphere. 65:506-513.

Klemeš, J. J., Fan, Y. V., Tan, R. R. and Jiang, P. (2020). "Minimizing the present and future plastic waste, energy and environmental footprints related to COVID-19". Renewable and Sustainable Energy Reviews, 127. https://doi.org/10.1016/j.rser.2020.109883.

Lachenmeier, D.W. (2008). "Safety evaluation of topical applications of ethanol on the skin and inside the oral cavity". J Occup Med Toxicol 3 (26). doi:10.1186/1745-6673-3-26.

Ley, C., Pischel, L. and Parsonnet, J. (2017). "Triclosan and triclocarban exposure and thyroid function during pregnancy-A randomized intervention". Reproductive toxicology (Elmsford, N.Y.), 74: 143–149. https://doi.org/10.1016/j.reprotox.2017.09.005

Matteucci, M.J. (2011). Isopropyl Alcohol. Poisoning and Drug Overdose. Retrieved from: https://accessmedicine.mhmedical.com/book.aspx?bookid=391

Mining. (2020). Graphene Ink may be used to Fight Novel Coronavirus [online] Available at: https://www.mining.com/graphene-ink-may-be-used-to-fight-novel-coronavirus/ [Accessed 14 Jan. 2021].

Mousavi SA., Khodadoost F. (2019). Effects of detergents on natural ecosystems and wastewater treatment processes: a review. Environ Sci Pollut Res 26, 26439–26448 https://doi.org/10.1007/s11356-019-05802-x

Mourad, M. (2016). "Recycling, recovering and preventing food waste: competing solutions for food systems sustainability in the United States and France". J. Clean. Prod. 126: 461–477.

New Straits Times. (2020). Improper disposal of used face masks could lead toCovid-19 resurgence. Retrieved from https://www.nst.com.my/news/nation/2020/05/594843/improper-disposal-used-face-masks-could-lead-covid-19-resurgence

New Jersey Department of Health (NJH). (2016). Hazardous substance fact sheet (isopropyl alcohol) Retrieved from: https://www.nj.gov/health/eoh/rtkweb/documents/fs/1076.pdf

Nyamweya, N.N and Abuga, K. O. (2020). "A Survey of Alcohol-Based Hand Sanitizers in Nairobi: Packaging, Labeling and Regulatory Compliance". East and Central African Journal of Pharmaceutical Sciences. 23: 72-76

Nzeadibe, T.C. and Ejike-Alieji, A.U.P. (2020). "Solid waste management during Covid-19 pandemic: policy gaps and prospects for inclusive waste governance in Nigeria". Local Environment DOI: 10.1080/13549839.2020.1782357

Nzediegwu, C., and Chang, S. X. (2020). "Improper Solid Waste Management Increases Potential for COVID-19 Spread in Developing Countries." Resources, Conservation & Recycling. doi:10.1016/j.resconrec.2020.104947.

OECD. (2004). Emission scenario document on plastic additives. Series on Emission Scenario documents, No. 3. Paris, Environmental directorate, OECD Environmental Health and Safety Publications.

Özlem, K.E. (2008). "Acetaldehyde migration from polyethylene terephthalate bottles into carbonated beverage in Türkiye". Int. J. Food Sci. Tech. 43:333-338.

Palmieri, V. and Papi, M. (2020). "Can graphene take part in the fight against COVID-19?" Nano Today 2020. https://doi.org/10.1016/j.nantod.2020.100883.

Perencevich, E. N., Diekema, D. J. and Edmond, M. B. (2020). "Moving Personal Protective Equipment into the Community: Face Shields and Containment

of COVID-19". JAMA, 323(22):2252–2253. doi:10.1001/jama.2020.7477

PremiumTimes(2020).Accessedfromhttps://www.premiumtimesng.com/coronavirus/403383-covid-19-63-per-cent-hand-sanitisers-in-abuja-not-registered-by-nafdac-ptf.html

Potluri, P. and Needham, P. (2005). Technical textiles for protection. In: Scott, R.A. (Ed.), Technical, 2005.

Raghav, P.K. and Mohanty S. (2020). "Are graphene and graphene-derived products capable of preventing COVID-19 infection?" Medical Hypotheses 144: 110031. https://doi.org/10.1016/j.mehy.2020.110031

Reid, A.J., Carlson, A.K., Creed, I.F., Eliason, E.J., Gell, P.A., Johnson, P.T.J., Kidd, K.A., MacCormack, T.J., Olden, J.D., Ormerod, S.J., Smol, J.P., Taylor, W.W. and Tockner, K. (2020). Retrieved from https://www.euronews.com/2020/07/14/coronavirus-how-the-wearing-of-face-masks-has-exposed-a-divided-europe

Rosato, D.V. (1998). Extruding plastics. Practical processing handbook. Kluwer Academic Publishers, Norwell.

Rui, L., Liu, J., Li, J., Weng, Y., Dou, Y. and Yuan, B. (2015). "Reduced graphene oxide directed self-assembly of phospholipid monolayers in liquid and gel phases". Biochim Biophys Acta – Biomembr 2015. https://doi.org/10.1016/j.bbamem.2015.02.018.

Salomone, A. Bozzo, A., Di-Corcia, D., Gerace, E. and Vincenti, M. (2018). "Occupational Exposure to Alcohol-Based Hand Sanitizers: The Diagnostic Role of Alcohol Biomarkers

in Hair." Journal of Analytical Toxicology 42:157–162.

Samson, M. (2020). "South Africa's Response to COVID-19 Worsens the Plight of Waste Reclaimers." The Conversation, April 1. Accessed May 26, 2020. https://theconversation.com/south-africas-response-to-covid-19-worsens-the-plight-ofwaste-reclaimers-135072

Santos, C., Kieszak, S., Wang, A., Law, R., Schier, J. and Wolkin, A. (2017). "Reported Adverse Health Effects in Children from Ingestion of Alcohol-Based Hand Sanitizers - United States, 2011-2014". MMWR Morb Mortal Wkly Rep. 66 (8): 223-226.

Schanes, K., Dobernig, K. and Gözet, B. (2018). "Food waste matters-a systematic review of household food waste practices and their policy implications". J. Clean. Prod. 182: 978–991

Shen, M., Ye, S., Zeng, G., Zhang, Y., Xing, L., Tang, W., Wen, X. and Liu, S. (2019). "Can microplastics pose a threat to ocean carbon sequestration?" Mar. Pollut. Bull. 137

Silva, A.L.P., Prata, J.C., Duarte, A.C.. Soares, A.M.V.M.; Barceló, D.; Rocha-Santos, T. (2021). Microplastics in landfill leachates: The need for reconnaissance studies and remediation technologies. Case Stud. Chem. Environ. Eng. 2021, 3, 100072. [CrossRef]

Skjevrak, I., Due, A., Gjerstad, K.O and Herikstad, H. (2003). "Volatile organic components migrating from plastic pipes (HDPE, PEX and PVC) into drinking water". Water Res. 37: 1912-1920.

Slaughter, R.J., Mason, R.W., Beasley, D.M.G., Vale, J. A. and Schep, L.J. (2014). "Isopropanol poisoning". Clinical Toxicology 52: 470–478.

Song, Z., Wang, X., Zhu, G., Nian, Q., Zhou, H. and Yang, D. (2015). "Virus capture and destruction by label-free graphene oxide for detection and disinfection applications". Small 2015. https://doi.org/10.1002/smll.201401706.

Stremski, E. and Hennes, H. (2000). "Accidental isopropanol ingestion in children". Pediatr Emerg Care 16: 238–240.

Tachikawa, T., (2020). Overreliance on hand sanitizers may increase risk of coronavirus infection. Kyodo News. Retrieved from: https://english.kyodonews.net/news/2020/02/690b9e1c9b86-focus-overreliance-on-handsanitizers-may-increase-risk-of-virus-infection.html

The Conversation. (2020). Single-use masks could be a coronavirus hazard if we don't dispose of them properly. Retrieved from https://theconversation.com/single-use-masks-could-be-a-coronavirus-hazard-if-we-dont-dispose-of-them-properly-143007

Tonning, K., Jacobsen, E., Pedersen, E. and Nilsson, N.H. (2010). Phthalates in products that children are in direct contact with. Danish Technological Institute. Survey of chemical substances in consumer products. Danish Ministry of the Environment and EPA.

Trummel, J., Ford, M. and Austin, P. (1996). "Ingestion of an unknown alcohol". Ann Emerg Med. 27: 368–374.

UN-Habitat. 2020. "Strategy Guidance: Solid Waste Management Response to COVID-19." Accessed June 4, 2020. https://unhabitat.org/sites/default/files/2020/05/un-habitat_strategy_guidance_swm_reponse_to_covid19.pdf

United Nations Environment Programme 2020 United Nations Environment Programme. (2020). "Waste Management an Essential Public Service in the Fight

to Beat COVID-19." March 24. https://www.unenvironment.org/news-and-stories/press-release/waste-managementessential-public-service-fight-beat-covid-19

Verma, R., Vinoda, K. S., Papireddy, M. and Gowda, A.N.S. (2016)."Pollutants from Plastic Waste- A Review Procedia Environmental Sciences 35; 701 – 708

Vogel, L. (2011). "Hand sanitizers may increase norovirus risk. CMAJ, 183 (12), E799-E800.

Weatherly, L.M. and Gosse, J.A. (2017). Triclosan exposure, transformation, and human health effects. Journal of toxicology and environmental health. Part B,Criticalreviews, 20(8):447469. https://doi.org/10.1080/10937404.2017.1399306

Weforum (2020). Retrieved from https://www.weforum.org/agenda/2020/06/ppe-masks-gloves-coronavirus-ocean-pollution/

Wilson, M.E., Guru, P.K. and Park, J.G. (2015). "Recurrent lactic acidosis secondary to hand sanitizer ingestion". Indian Journal of Nephrology 25 (1): 57-59.

Wilson, D. C., Velis, C. and Cheeseman,C. (2006). "Role of Informal Sector Recycling in Waste Management in Developing Countries." Habitat International 30(4): 797–808.

World Health Organization (2020). World Health Organization and the United Nations Children's Fund. 2020. "Water, Sanitation, Hygiene, and Waste Management for the COVID-19 Virus." Interim Guidance, April 23. WHO/2019-nCoV/IPC_WASH/2020.3. https://www.who.int/publications-detail/water-sanitation-hygiene-and-waste-management-for-covid-19

Zaman, F., Pervez, A. and Abreo, K. (2002). "Isopropyl alcohol intoxication: A diagnostic challenge". American Journal of Kidney Diseases 40 (3): 1-4.