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Understanding disposable plastics effects generated from the PCR testing labs during the COVID-19 pandemic

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A B S T R A C T

In medical labs, especially in polymerase chain reaction (PCR) testing labs, plastic residues (PCR tubes, pipet tips, falcon tubes, buffer bottles, medical globes, and others) wastes are potential sources of plastic waste. Evidence showed that a single PCR test for COVID-19 diagnosis used 37 g of disposable plastic per sample. Globally, an estimated amount of above 15,000 tons of plastic residue have been generated from the PCRs tests during the COVID-19 pandemic. These plastic residues are mismanaged and dumped with other solid wastes, especially in molecular testing labs (MTLs) from academic institutes such as universities thereby polluting the ecosystem. Plastic waste from PCR testing labs also contain hazardous chemicals and pathogenic microorganisms. Thus, plastic residues in PCR testing labs are an important add-on source to conventional plastic wastes. In this perspective, research questions on (1) type and characteristics of plastic, (2) quantity of plastic residues as an add-on source to the conventional plastic wastes, (3) prevalence of microplastics generated from PCR testing labs of plastic wastes, (4) handling, disinfection techniques, and management strategies of these plastic residues, (5) PCR test materials as a source of hazardous chemical pollutants, and (6) future environmental pollution threats imposed by genetic material determination were raised. It is suggested that this work will be used as the baseline information in addressing the knowledge gap for improving PCR testing labs plastic waste management, and regulation to control environmental pollution. Understanding these plastics’ impacts and risks is crucial for driving predictions and innovative technology processes towards sustainability.

1. Introduction

Plastic polymers have been manufactured and used as commercial goods since the 1950s. The global production of plastics increased exponentially in the 20th century (Anon 2020). Plastic pollution become a key environmental concern around the globe due to its massive disposal (Qahtani et al., 2021). Scientific laboratories use plastics for medical diagnosis and generated a huge amount of unsorted plastic residues. Currently, single-use plastics have been extensively used for coronavirus protection such as face masks, and to diagnose them in the molecular testing lab (MTLs). Particularly, PCR testing techniques used huge various plastic inputs, most of which are single-uses for COVID-19 confirmatory test (Tang et al., 2020).

During the pandemic era, these plastic inputs in the molecular testing lab (MTLs) have been extensively utilized and disposed of after the PCR confirmatory test. At the time of urgent COVID-19 transmission, the PCR confirmatory test has not been carried out at private and public hospitals and health institutes, but also in non-health-related institutes such as from scientific labs in academic institutes (universities and research institutes) having MTLs. Even though most hospitals and health institutes expected that they have been managing PCR testing plastic inputs as per the medical waste management standards, scientific labs from non-health-related institutes have not managed them in medical waste management protocols. As a result, these plastic residues impact generated from the PCR testing labs during the COVID-19 pandemic, and employing standard management practice is critical.

Therefore, plastic residues are produced in these labs, thus contributing to the worsening plastic pollution problem in the COVID-19 era. Previous studies showed that 79.07% of plastic residues were generated from real-time PCR (RT-PCR) testing labs during the COVID-19 pandemic (Celis et al., 2021). In addition to the plastic residues in PCR testing labs, the presence of microorganisms and toxic chemicals during genetic material extraction and PCR amplification, such as loading dyes, ethidium bromide, acrylamide, phenol, and chloroform on the plastic residues, are important hazardous contaminants (Wang et al., 2018). Moreover, the additives released from PCR testing plastic inputs, such as phthalates and bisphenol, are toxic to the environment and human health (Camacho et al., 2019).

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Improper management and disposal practice of plastic residues in the PCR testing labs could contribute to the increased generation of municipal solid wastes to the high pollution level in the nearby water environments (Smyth et al., 2010). Hence, a repercussion of plastic residue from the PCR testing lab can be repurposed for sustainable recovery options (Okoro and Faloye, 2020). For example, they can be repurposed as raw materials by recovering, recycling, and reusing them for various applications, as sustainable management and resource utilization strategies (Das and Tiwari, 2018; Mekonnen and Aragaw, 2021). Because most of these plastic inputs are made from polypropylene polymers (Aragaw and Mekonnen, 2021).

To the best of the authors’ knowledge, the environmental impacts of PCR testing plastics are unnoticed due to the knowledge gap on plastic residue pollution. Scholars have been extensively investigating personal protective equipment (PPE) prevalence, pollution, and impacts on the freshwater environment and coastal environment during COVID-19 pandemic (Mvovo and Magagula, 2022). Abundantly surveyed types of PPE are face masks, and analytical characterization confirmed that they are made of polypropylene and polyethylene polymers (Aragaw et al., 2022; De-la-Torre et al., 2022). One preliminary work on plastic residues produced with confirmatory testing for COVID-19: Classification, quantification, fate, and impacts on human health have highlighted the year later the beginning era of the pandemic (Celis et al., 2021). However, the impacts of plastic residue from the PCR testing lab, in particular, to be an important source of plastic pollution and emission are still poorly investigated. As a result, we focused to comment on PCR lab plastic inputs pollution threats during the COVID-19 confirmatory test and genome extraction procedures. We surveyed and observed several PCR testing labs, they have been using those plastic inputs in several COVID-19 testing centers, but not properly managed. This perspective aimed to draw attention to the knowledge gap on the impacts of plastic residue pollution from PCR testing labs on the land based environment, at the end to the aquatic ecosystem. Moreover, the present work will serve as baseline information in addressing the issues associated with PCR testing labs, plastic waste management, and plastic pollution control regulations during the COVID-19 pandemic. The present information can be a significant benchmark study to show a new aspect of the problem regarding the PCR testing labs plastic residue associated with COVID-19.

2. PCR testing labs as a source of plastic residues and their fate

Plastic residues from COVID-19 testing labs are polymers that emerge as important pollutants at the solid waste dumping area and natural environments during the confirmation of coronaviruses. The potential source of disposable plastics from the PCR testing labs are microcentrifuge tubes, PCR (Eppendorf) tubes, pipette tips, and medical gloves, as shown in Fig. 1 (A-C) discarded together with other wastes and are found near water bodies, as shown in Fig. 1 (D).

 Globally, disposable plastic inputs from life science labs litter academic institutes and solid waste dumping sites with no clear instructions and disposing protocols. Lately, microplastics are an add-on to top of plastic solid wastes. The plastic litter then fragmented into smaller pieces due to the presence of both chemical and mechanical weathering (Bond et al., 2018). Consequently, plastic residues undergo degradation/fragmentation and turn into mesoplastic or micro (nano)plastics (Su et al., 2019). This process followed by biotic degradation (mineralization) converts the carbon atoms into carbon dioxide (CO₂) and inorganic chemicals. In the end, macroplastics are released into the environment following land-based and ocean-based pathways (Letchhaler et al., 2020), contributing to marine pollution largely through storm-water runoff (Walker et al., 2018). Evidence proved that disposable plastic products represent a large proportion of the microplastic found in the environment, which is mostly due to their short service life and high production values (Letchhaler et al., 2020). This type of plastic pollution in the marine environment will be a potential threat in the coming era. Hence, scientists, environmentalists, lab janitors, assistants, policymakers, and governments are required to advance green solution strategies for integrated solid waste management systems (Memon, 2012).

Lab plastic wastes and other toxicants in the COVID-19 testing labs could have several fates. Like other plastics from common goods plastic wastes, medical residues in the lab are materials made of synthetic and non-degradable polymers (Isik and Demir, 2018). Hand gloves made of high-density polyvinyl chloride polymers used during COVID-19 testing, Eppendorf tubes, and micropipette tips made of less dense polypropylene polymers are critical sources of pollution. Plastic fates will vary due to their variability in the testing lab, their non-degradability, and their persistent nature in the environment. The PCR testing lab plastic pollutants are predicted to be persistent for many years and could be found inland and in the water environment.

3. Knowledge gaps and the need for research and policy

There are many studies about the impact of plastics on municipal solid wastes (Møggaard, 1995). Most recently, for example, landfill leachate is the source of microplastics in the marine environment (He et al., 2019), and soil amendments with municipal solid waste are a source of microplastics (Watteau et al., 2018). During the pandemic era, more than 15,000 tons of plastic residues have been generated globally from RT-PCR diagnostic testing labs. Reports confirm that 79.07% of plastic residues were generated with RT-PCR tests for coronavirus since August 2020 (Celis et al., 2021). This quantity of medical plastic residues generated from the PCR testing labs during the COVID-19 confirmatory test increasingly worried the scientific community because of the environmental impacts associated with the current pandemic. However, there is no documented evidence about the contributions and impact of plastic residues along with corresponding microplastics from PCR testing labs, on the sources, and in their destination at the end. There is an improper implementation of plastic waste collection among countries and regional states’ regulations and policies. In this sense, no clear state regulations and policies are not presented yet. However, several nations tried to apply cautionary measures for handling and discarding COVID-related wastes. For instance, the Portuguese Environmental Agency suggested the disposal of PPE mixed wastes in wrapped bins rather than recycling that will preferably go to incineration and/or landfilling (Di Martino et al., 2020). Similarly, the U.S.A has prioritized incineration and landfilling and stopped recycling strategies amid the threat of COVID-19 infection (Zambrano-monserrat and Alejandra, 2020). Currently, incineration and landfill have also been used for final disposal of plastic waste generated by the RT-PCR test for COVID-19 worldwide. Globally, 97% of plastic residues generated with RT-PCR tests are incinerated and 3% end up in landfills (Celis et al., 2021).

There are limitations in the knowledge of plastic waste pollution and possible impacts of the disposal technique on the environment owing to the lack of awareness. Yet, there are no adequate quantitative and qualitative studies on the impact of plastic residue pollution generated from PCR testing labs that mention, in addition to conventional solid wastes. Moreover, hazardous chemicals formed together with the plastics are not yet studied, and thus, the use of carcinogenic chemicals at these labs released along with plastic residues are not known or given attention. Thus, to understand the potential, fate, effect, and accumulation of plastics containing toxic chemicals in the PCR testing labs, one needs to know about the separation and collection of plastic debris, treatment and disinfection techniques, identification of the polymeric type, and fragmentation process of microplastics. Important and key research questions that should be studied on this basis are proposed hereafter:

**Question 1** What is the type of plastic polymer used at these labs and found with other plastic residues from solid wastes? How does it fragment into microplastics over time? How are these related to surface roughness and degradation in environmental weathering?
RT-PCR is the most widely used test technique for confirmation of COVID-19, and plastic inputs used are 100% single-use (Celis et al., 2021). The most common disposable plastic polymeric type used in PCR testing labs for coronaviruses confirmation are polypropylene, polyester, polyethylene, and polyvinyl chloride. Of all the plastics used in confirmatory testing for COVID-19, polypropylene accounted for 89.99%, polyester accounted for 8.22%, and polyethylene accounted for 1.78% (Celis et al., 2021).

There are no previous reports on the plastic residues generated from the PCR testing labs that will be a potential source of soil and/or marine pollution and microplastic generation. It is necessary to include this category of plastic wastes in monitoring plans, understand the occurrence of plastic wastes at scientific labs over time, and the degradation procedure with microbial, UV light, and mechanical weathering.

**Question 2**

*How many disposable plastic residues from PCR testing labs act as an add-on source to conventional plastic wastes? Are plastic wastes and microplastics generated from these labs a potential source of pollutants in the natural environment, and impact the environment and human health?*

Production of disposable plastics, utilization and generated plastic residues have extremely increased in the COVID-19 scenario. A single RT-PCR test for COVID-19 uses 37 g of disposable plastic per sample and generated the same quantity of plastic residues at the end. Globally, an estimated amount of more than 15,000 tons of plastic residue have been generated from the PCRs of COVID-19 until August 2020 (Celis et al., 2021). To take an action, research should be conducted on the quantification of plastic wastes released daily and annually. Besides, researchers are required to assess the percentage contribution of plastic residues in the solid wastes that enter the environment and their potential fate.

**Question 3**

*What are the characteristics and physicochemical properties of microplastics from PCR testing labs and how do they enter the ecosystem?*

It has been reported that plastic materials from heterogeneous solid matrices will degrade into microplastics at different rates depending on their physicochemical and mechanical characteristics (Ruggero et al., 2020). Due to the chemical and mechanical weathering followed by biotic degradation, the plastic residues gradually converted to smaller particles. Hence, it is essential to examine whether plastic debris from PCR testing labs is an important source of microplastics in the terrestrial and marine environment.

**Question 4**

*Is the plastic residue handling mechanism at PCR testing labs similar to the handling of other solid wastes in the lab? Do they require disinfection techniques and management strategies similar to medical wastes?*

Debris from these labs is well-known for the presence of hazardous chemicals. Various plastic materials are used for molecular tests and chemical analyses that may allow them to undergo disinfection techniques for repurposing them for safe handling and management strategies. PPE disinfection techniques such as incineration, thermal, and chemical treatment (chlorine and non-chlorine), vaporized hydrogen peroxide ($\text{H}_2\text{O}_2$), and UV-radiation of medical wastes were proposed by (Ilyas et al., 2020). However, the PCR testing lab residues are biohazardous and thus, their hazards level must be investigated.

**Question 5**

*Are PCR testing lab plastic residues a potential source of hazardous chemical pollutants and a threat to human health in addition to the pathogenic microbes in the environment?*
Plastic residues from the PCR testing lab contained hazardous chemicals and need to be neutralized and disinfected before disposal. Otherwise, it could be a source of add-on chemical contaminants in the environment and human health. COVID-19 test plastic residues are biohazardous and 99.2% of the global pandemic waste undergoes incineration (Celis et al., 2021). The burning of such biohazardous medical waste generated dioxygen which is extremely toxic chemical pollutant (Mandal, 2005). Non-biohazardous plastic residues usually go to landfills. Likewise, the leachate from landfills is the gateway of toxic chemicals into the marine environment. Hence, investigation of this hazardous chemical as a source of emerging contaminant is essential.

Question 6
Are plastic materials at the PCR testing labs, in general, genetic material determination labs, a future environmental threat?

Plastics for these labs are produced and used with microorganisms and toxic chemicals, especially in the emergency of molecular biology. The SARS-CoV-2 confirmatory procedure revealed by genetic identification uses plastic tubes, chemicals preservatives, loading dyes, ethidium bromide, acrylamide, phenol, and chloroform during genetic material extraction. Hence these materials from the PCR testing labs worldwide are important hazardous contaminants and future environmental threats. Therefore, generic materials used in the lab must be studied, including the number of scientists and/or technicians in the field.

4. Conclusion

The PCR testing labs during the COVID-19 pandemic brought additional plastic pollution loads to the conventional plastic waste management practices. Evidence assures that a high amount of plastic residues from the COVID-19 confirmatory testing inputs have been generated. These plastics have been observed that they are improperly disposed of together with conventional solid wastes. Consequently, these plastic residues in the PCR testing labs could reach the marine environment, and impacts the ecosystem. As a result, plastic residues in the MTLs, particularly the PCR testing lab are important sources, their impacts, and fates on the land and marine environment are discussed. Also, the knowledge gaps that those labs constitute a toxic chemicals are highlighted. In the present study, we suggested important key research questions, that must be addressed, associated with the plastic residue in the PCR testing labs, generally, molecular biology processes. To perform research on the proposed questions different approaches could be used. Because these plastic residues are hazardous, and may not follow similar approaches to the conventional plastic litter residues collection, handling, and sorting techniques. Thus, it could require special collection and management techniques. In addition, inappropriate disposal together with toxic chemicals may cause constraints during sampling and analysis. As a result, working together with scientists, janitors, and lab technicians is essential to fill these knowledge gaps—which will require tremendous effort, but is also a part of the research study. Finally, scholars can attempt data support a full-length research paper for detailed study, using as a benchmark of the present information.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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