CHAPTER

6

PREDICTING ACRYLIC FIRE EMISSIONS FOR CLEANER ENERGY APPLICATIONS

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6.1 INTRODUCTION

Unintentional fire-related deaths and injuries primarily result from the toxicity of fire emissions, including smoke containing harmful gases, vapours, and particles (Peeters et al., 2021). International Organization for Standardization (ISO) defines fire as a combustion process emitting heat and fire effluents (Dhabbah, 2015). Fire toxicity refers to materials' potential to produce harmful gases and smoke when burned. In United Kingdom (UK), 60% of fire-related deaths result from inhaling toxic smoke, highlighting the misconception that burns are the main cause (Giebułtowicz et al., 2017). Smoke-filled rooms hinder swift movement and reduce visibility, make it challenging for people to reach exits. In addition, the irritant and toxic gases found in smoke can cause eye irritation and impaired vision, as well as respiratory issues. Consequently, irritant gases may make escape more difficult, which raises the risk of a fatal exposure to asphyxiant gases such as carbon monoxide (CO), hydrogen cyanide (HCN), and ultimately results in the death of those who are attempting to flee (Mat Kiah, 2020).

The risk of death and damage to property posed by fire is not eliminated. This risk has been amplified as a result of the widespread use of synthetic polymers. Nowadays, most of the homes are filled with a wide variety of synthetic materials, it is undeniable, the use of synthetic materials facilitates every job in daily life. One of the most catastrophic events to occur in recent times in the United Kingdom was the fire that took place in Grenfell Tower in June of 2017. Within minutes, the fire had engulfed the exterior of the building and then spread to all four sides. Almost all the upper floors were ablaze. 72 persons died. Toxic gases and fine particulates emitted during the fire that involved the external wall cladding at an early stage were the primary cause of the shockingly high death toll in the Grenfell Towers fire in London (Stec et al., 2019). The cladding, composed of aluminium composite panels with a polyethylene core, proved highly combustible when exposed to high temperatures, contributing to the rapid spread of the fire. Similarly, in 2006, the Station Nightclub fire in which 100 people died, including eight firefighters, was triggered by highly flammable polyurethane foam ignited by pyrotechnics. Eight of firefighters (out of 28) were found to have elevated levels of cyanide and needed medical attention. HCN poisoning was treated for one of the firefighters who collapsed on the scene.

This project is mainly focused on the acrylic synthetic materials, one of many commercial products that are utilised extensively in building and construction industry. Acrylic polymers, including polymethyl methacrylate (PMMA) and polyacrylonitrile (PAN), have gained prominence in various industries. Thermoplastic acrylics find use in injection moulding, where they are used to manufacture a range of consumer goods, automotive components, and packaging materials (Ward et al., 2012). Acrylic fibres are fibres that have a chemical structure that consists of at least 85% Acrylonitrile (Johnston et al., 1988). Figure 6.1 depicts the structures of PMMA and acrylonitrile.

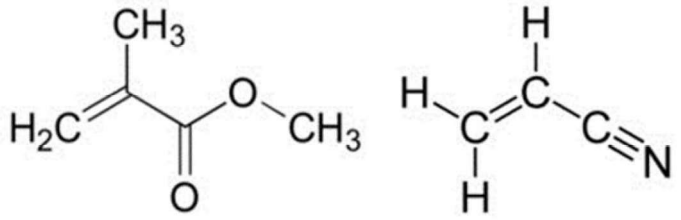

Figure 6.1 Structure of polymethyl methacrylate and acrylonitrile (Source: Tokyo Chemical Industry Co., 2024)

The study of proximate and ultimate analysis was implemented on acrylic-based materials and other types of material. Recently, the widespread use of acrylic-based commercial products across industries has improved convenience and aesthetics for consumers. However, products labeled as "100% acrylic" often contain chemical blends beyond acrylic alone due to modifications aimed at enhancing specific properties. While originating from acrylic polymers, these commercial items are no longer purely acrylic after such alterations. Even though PMMA has lower toxicity among other materials, it still produces toxic gases that can cause death in the event of a fire, which is why this study is conducted.

The characteristics and elemental composition of various materials will identify and evaluate the purity of acrylic material based on its composition and chemical formula. Other compositions found in acrylic materials other than carbon (C), oxygen (O), and hydrogen (H) indicate that the material has been modified for a specific function. In addition, the presence of foreign elements of modified material, for example, nitrogen, will lead to the formation of toxic gases or smoke containing HCN. Oxides are the most common by-products of burning elements where C, nitrogen (N), and sulphur (S) will produce dioxins (Speight, 2020). Besides, smoke particle analysis is also vital for observing the particulate size and emission from fires to understand its health effects on humans, especially those exposed directly. Acrylic, a thermoplastic polymer, is prone to melting and producing fire droplets during a fire