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CASE REPORT

FORENSIC INVESTIGATION OF EXPLOSION IN A PLASTIC RECYCLING PLANT

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ABSTRACT

Introduction: Plastics have woven themselves intricately into the fabric of human existence, manifesting in myriad forms across daily life. From the convenience of single-use items like bags and bottles to the structural integrity of complex machinery components, plastics have no doubt revolutionized industries and consumer habits, rendering them indispensable in multiple sectors, especially routine household items, kid's toys, and healthcare, where they enable sterile packaging and life-saving medical devices. Their omnipresence has also generated environmental challenges; hence, reuse-recycling is encouraged. Plastic recycling plants have grown like mushrooms in the industrial belts of Delhi, the capital city of India, too. An accidental explosion in one such plant was life-threatening to three people and injured six. Cases of such demystifying explosions are rare, and therefore, forensic investigation into the incident is of utmost importance to understand the origin and cause of the explosion.

Case History: This case report details an atypical incident involving a sudden blast within a manufacturing facility in a plastic recycling unit. Forensic scene of crime examination, conducted meticulously and comprehensively, revealed no indications of external ignition sources or any incendiary materials. Chemical analysis of exhibits performed at a forensic laboratory confirmed the presence of butane, consistent with findings from cigarette lighter's fuel, using HS-GC-MS instrumentation.

Conclusion: The clear resolution of this enigmatic explosion was achieved by forensic investigators through a thorough scene of crime investigation, careful co-relation of all pertinent evidence, and applying the basic scientific principles of physics and chemistry. Instances of malpractice, lack of awareness, and negligence in recycling procedures have posed significant risks to individuals present in the vicinity of factory premises.

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INTRODUCTION

Accidental explosions are a cause of concern, especially resulting from the ignition of volatile flammable gases in industrial plants. The case becomes a serious hazard when it occurs in a small recycling industrial factory. The surrounding areas of Delhi, India, have a large number of small recycling units running in various designated industrial sectors. These incidents underscore the critical importance of understanding and effectively managing the risks associated with handling such hazardous materials, as often the explosions are sudden, providing very few opportunities to act on safety measures. The intersection of accidental explosions caused by the ignition of volatile inflammable gases always presents a compelling case study for forensic scientists to explore the intricate relationship between these unexplained explosions and the scientific methods employed for investigation and analysis. Understanding the dynamics and causes of such incidents is a crucial part for forensic investigators. While explosion injuries resulting from terrorist attacks or combat incidents or burns associated with inhalant abuse have been extensively documented, there is limited literature on sudden explosions due to volatile inflammable gases in industrial settings[1,2]. The investigation of volatile explosions is complex, necessitating a multidisciplinary approach, and requires a comprehensive analysis that encompasses various scientific principles and methodologies for understanding the mechanisms and consequences of such explosions. Explosion involves rapid chemical reactions that produce gases and heat, leading to a shockwave. Principles of physics help to explain the dynamics of shockwaves, while chemistry provides insights into the reactive materials and the specific reactions that occur during an explosion. In the aftermath of an explosion, forensic experts need to determine the cause where chemistry plays a key role in identifying residues and explosive compounds, while physics aids in reconstructing the event through blast wave analysis. This collaboration proves vital for understanding this phenomenon and helps law enforcement and regulatory bodies in their investigations. The authors, therefore, felt the need to write this article keeping in mind the forensic community.

CASE HISTORY

An explosion was reported at a plastic recycling facility situated in Delhi's Industrial Area, India, at approximately 5.10 pm. The blast transpired during the production phase involving the conversion of plastic scrap material, notably including plastic tubes, disposed of syringes and bottles, cannula, discarded cigarette lighters, etc., into small plastic granules. The explosion resulted in severe injury to six individuals, and three people succumbed to death. Notably, all individuals affected by the explosion were employed as daily wage labourers at the facility. Subsequent investigation disclosed that the factory obtained its raw materials from various sources, including hospital waste, general waste, and scrap materials, which were further processed to manufacture recycled plastic goods.

SCENE OF CRIME OBSERVATIONS

Information for the forensic scene of crime examination was received about the factory where the sudden blast took place, and explosion effects were visible when the team reached the spot approximately one hour after the incident (Fig. 1). The half portion of the metallic entrance gate was found broken and one meter apart from the entrance point which clearly depicted the intensity of the explosion (Fig. 1). It was a large plastic recycling factory with working units inside. The recyclable plastic items were segregated manually into different types and then subjected to the recycling process. Many plastic items like pipes, medical disposable bottles, syringes, cigarette lighters, etc., were observed lying in various places (Fig. 2). The walls, ceiling, and machines in the workshop had black shoot deposits on them (Fig. 3). The walls, fans, and other surrounding areas displayed burning and heat effects. The death of three persons working on the premises of the workshop was reported by investigating agencies. Initial inquiries by investigating authorities suspected the death was due to injuries from the sudden unexplained explosion as everyone in the factory was busy with their assigned duties and, therefore, did not pay attention to what had happened. It was also observed that the workshop lacked proper ventilation. Detailed investigation revealed that the explosion did not occur due to any added inflammable substance or electric short circuit. A thorough inspection of the area and waste garbage and raw material revealed some unused plastic bottles and some liquid inside mainly the broken used and unused cigarette lighters (Fig. 4). This raised some suspicion, and the samples were sent to the forensic science laboratory for detailed analysis. The autopsy samples of the three deceased, along with the scene of crime exhibits, were received at the Forensic Science Laboratory (FSL) for detailed chemical analysis.

Fig. 1: Photograph of the explosion at the scrap factory where the blast took place showing the broken metallic gate (arrow).

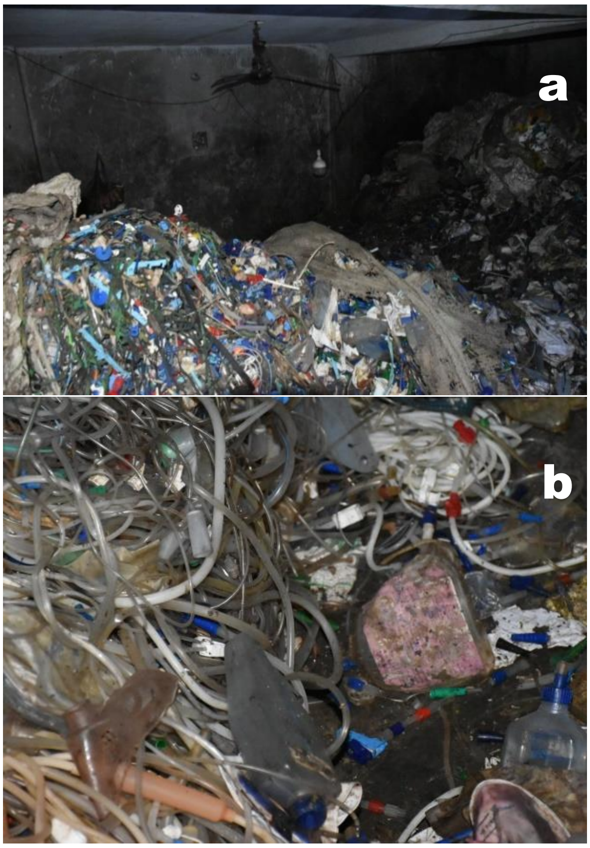

Fig. 2: Photograph showing various waste plastic items found inside the recycling factory (a) with a close-up view (b) showing different types of plastic waste.

Fig. 3: Photographs showing the cascading burnt impressions on walls in the factory.

Fig. 4: Photograph showing partly filled and empty lighters found at the scene of the crime (a) and a close-up view (b).

ANALYSIS METHODS

Samples: Scene of crime exhibits (six lighters with liquid inside), visceral samples, and fresh lighter (procured as working standard).

Instrument: Head Space Gas Chromatography Mass Spectrometry (HS-GC-MS)

Parameters: HS-GC-MS (make Thermofisher Scientific) was used in HS-GC-FID/MS configuration comprising of a GC (Trace 1610) fitted with a FID and MS detector (ISQ 7610) coupled to HS sampler (TriPlus RSH SMART). The split ratio was 1:1 for FID and MS using restrictors. Gas chromatography separation of analytes was carried out using TG Wax MS column (polyethylene glycol, 30m × 0.25 mm × 0.25 µm, make Thermofisher Scientific). The MSD was operated under EI mode. The HS parameters were as follows: oven temperature was maintained at 50°C, agitator speed 250 rpm, and sample drawn was 0.8µl. The sample vials were incubated for 10 min at 60 °C before injection of the sample. The injection port temperature was at 150 °C and operated in split mode with a split ratio of 20:1, a pressure of 9.7 psi, and a septum purge flow of 5 ml/min. The GC was programmed with an initial oven temperature of 45°C which was held for 6 min and then increased linearly to 100°C at a rate of 20°C/min with a 0.5 min hold time and then further increased to 220°C at a rate of 45°C/min. The FID detector temperature was at 250°C. The flow rates of hydrogen gas 35.0/min flow rate with Air 350.0 mL/min and makeup gas Nitrogen 25.0 mL/min for FID. The nitrogen flow rate was maintained at a constant 15 psi. Helium carrier gas (with purity 99.999%) was set to flow at a rate of 0.6 mL/min for MS. MSD temperature was at 300°C, ion source temperature was 280°C, the ionization energy in mass was 70 eV, and scanning was carried out from 14 to 200 amu at a rate of 3.0 scans/s. The total run time for HS-GC-FID/MS was 11.917 minutes per sample. Chromeleon Data Analysis software (Version 7.3.2.10759) was used for data analysis, record, and analysis, and NIST database 2020 was used to interpret the spectra. Identification of the compound was determined by the retention time.

RESULTS

HS-GC-MS is a powerful analytical technique used extensively in the identification of volatile substances. The combination of GC and MS allows for the separation and identification of complex mixtures, providing specific data on the molecular structure of each substance, making it highly sensitive even for detecting low concentrations of volatile compounds. Moreover, it enables rapid sample analysis with less or no sample preparation process, providing qualitative and quantitative analysis identification of volatile substances. A minimal sample preparation process reduces the risk of contamination and loss of volatile compounds, improving efficiency, which is particularly beneficial while analysing sensitive samples where preserving the integrity of the volatile components is critical. HS-GC-MS plays a crucial role in the identification of volatile substances across multiple sectors. Its sensitivity, speed, and versatility make it an indispensable tool for scientists and analysts working to ensure safety, compliance, and quality in their respective fields. HS-GC-MS analysis identified the presence of butane, and confirmation of ions of butane was detected with m/z values 43, 29, 27, and 57, respectively[3] in the liquid obtained from all the lighters collected from the scene of the crime (Fig. 4a and 4b) and Fig. 5a, 5b and 5c illustrates the result of only one lighter fluid sample along with the standard. All the samples gave similar results. A diagrammatic representation of the whole case is presented in Fig. 6.

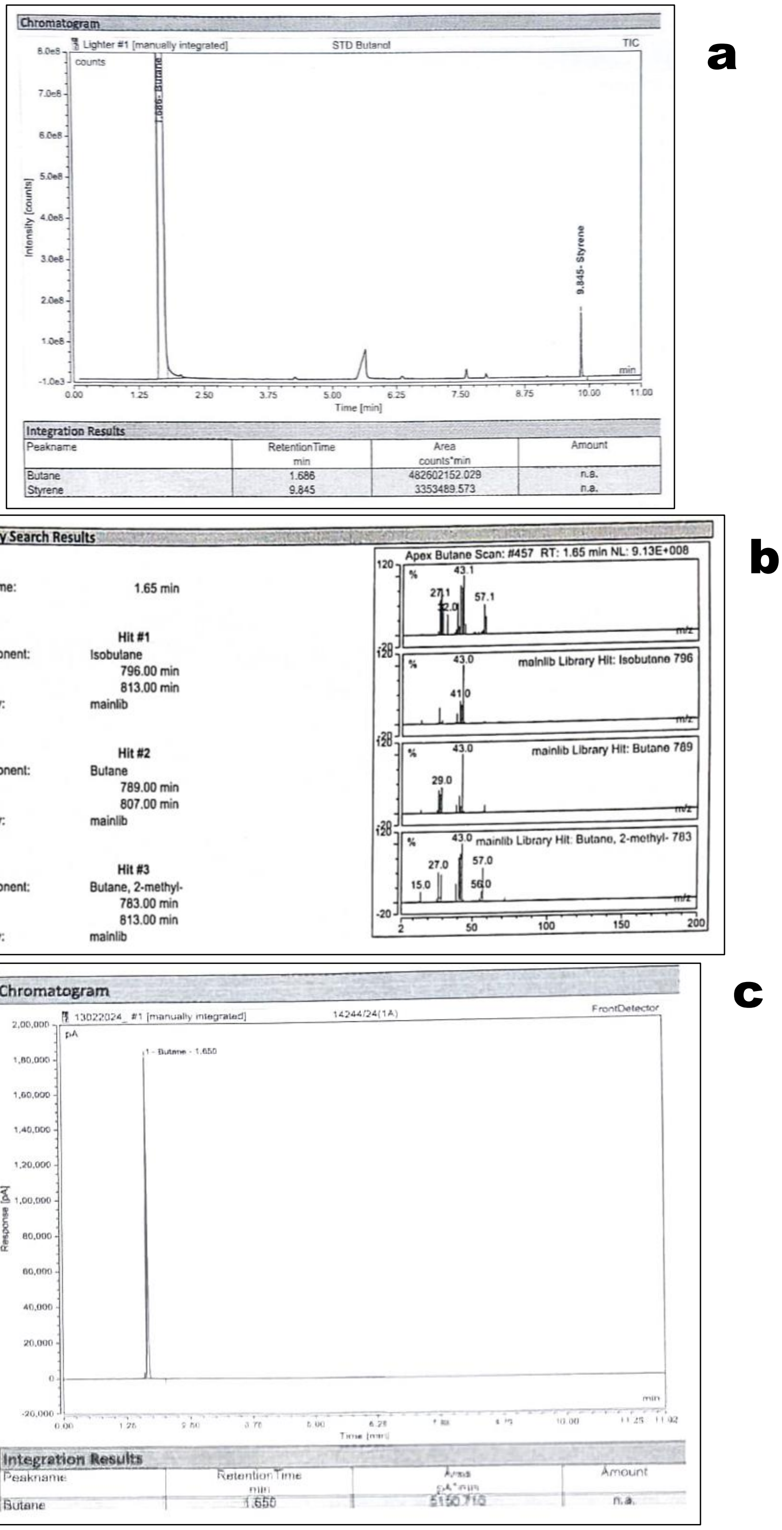

Fig. 5: Total Ion Chromatogram of Standard Liquid Butane (a), m/z values (b), and sample analysis liquid obtained from lighters in instrument GC-HC-MS (c).

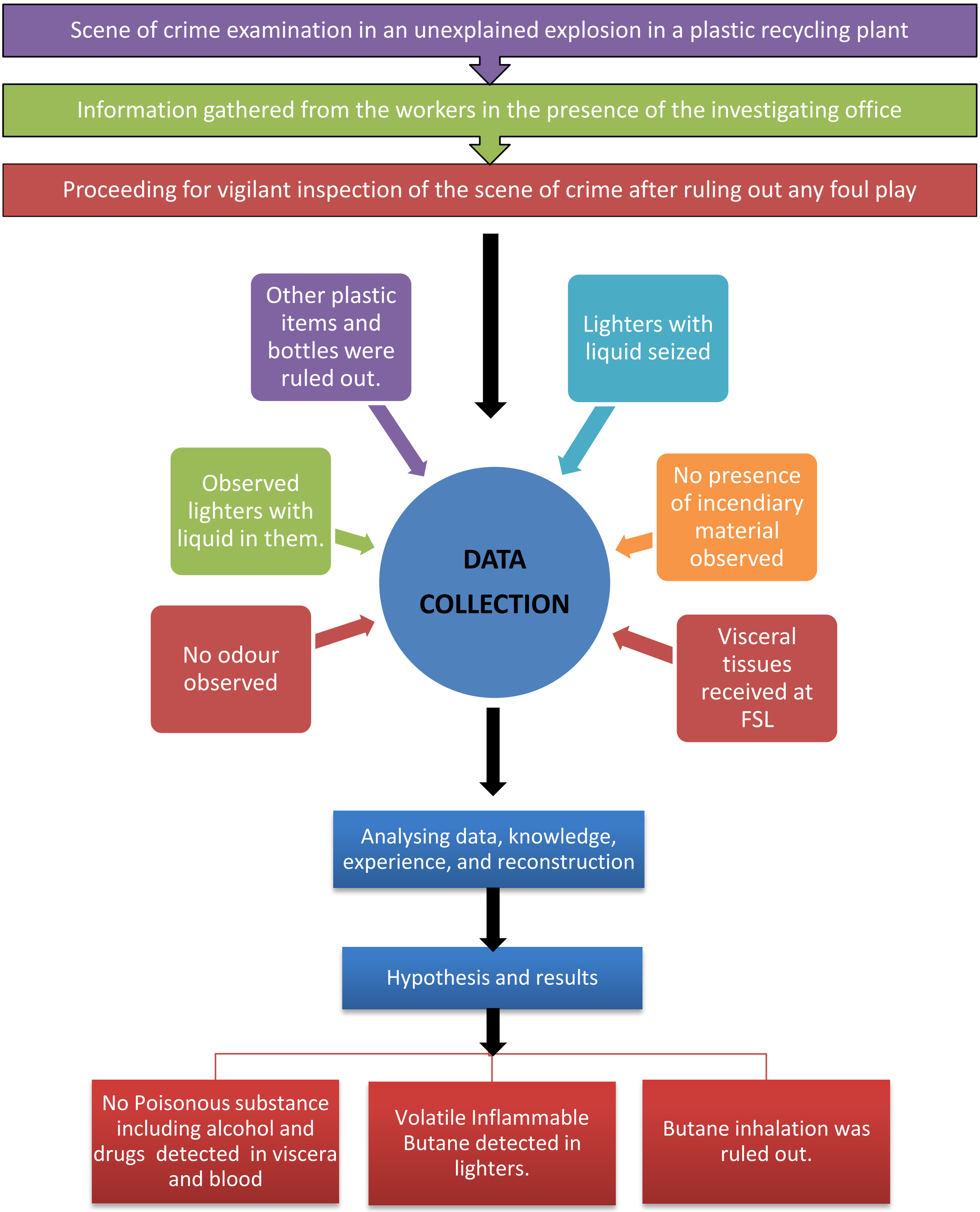

Fig. 6: Diagrammatic representation of the analysed case study

DISCUSSION

Accidental explosions attributed to butane gas are a rare phenomenon, although forensic reports on butane gas toxicity and inhalant abuse have been reported earlier. Butane is a highly flammable gas, which ignites quickly in the air if exposed to a static charge or a spark and is therefore used as a basic fuel in lighters. The presence of styrene was also detected in working standards, which is unexplained. Although styrene in gaseous form also has explosive and flammable properties, it was not identified in case exhibits, hence, it is not discussed here. During s, subsequent toxicological analysis, no other toxic chemicals, drugs, or any other pharmaceutical products were found to be present in the visceral tissues and blood of the three victims who died during the fatal accident. The post-mortem report suggested cranio-cerebral injuries as the cause of death. Thus, from the circumstantial evidence, autopsy findings, and results of the toxicological investigations, forensic scientists were clear that the cause of death of these victims was not remotely related to the presence of butane in the body tissues or blood sample.

Butane and isobutane are the primary volatile components of cigarette lighter fluid. Butane gas is used in many applications like fuel for cooking, lighter fluid, refrigerant, deodorant propellant, and industrial applications[1]. Butane, an aliphatic hydrocarbon derived from petroleum, is a highly flammable, odourless, colourless, non-halogenated gas[4]. Incidents involving butane gas typically stem from camping gas explosions, accidents during motor vehicle refuelling, or abusive inhalation[1]. While speaking to individuals in the factory, it was gathered that the collected lighters were first segregated based on their colours, and then their metal part was removed. Later, the lighters were broken into large pieces, and the inner liquid Butane was discarded carelessly or spilled into the nearby surroundings. Sometimes, the discarded plastic containers may be full or have some leftover contents in them. It is very important for individuals working in recycling units to know the contents that were stored in such containers and safely discard them before processing or breaking such containers. Butane, being an odourless gas, no foul smell must have been identified by individuals working on the premises, potentially leading to unnoticed accumulations. It is also important to mention here that there was no gas detector in the factory, which should be one of the prime requirements while establishing any factory. The boiling point of Butane gas is -0.5°C, suggesting its existence in gaseous form at normal temperature and pressure[5]. Low boiling point liquid Butane ensured rapid evaporation in the high summer temperature of Delhi and thus minimized workplace contamination where it was spilled during the recycling process. Therefore, no urgent need was felt by either the factory owner or the workers to make any appropriate arrangement for the proper removal of the discarded liquid. Delhi's warm summer climate gave enough time for the gas to accumulate in large volumes without getting noticed. However, the accumulation of inflammable butane vapours, imperceptible to smell, can pose significant risks. It is readily visible how butane gas settled in the routine process through heating effects observed on the ceiling, the fans, and the upper parts of the walls (Fig. 3) after the explosion in the recycling factory. In an enclosed space, these volatile, inflammable vapours become extremely explosive when an ignition source is introduced and is sufficient to create an explosion[1]. The ignition source may not be deliberate, but an invisible spark in the factory machine or at a plug point, which under normal conditions may not cause any harm, is, in fact, sufficient to cause an explosion. The investigation revealed that everyone was working during the incident, so the machines were in running condition. However, inquiries during the scene of crime investigation ruled out any possibility of intentional fire or observation of any spark in the premises. It is pertinent to mention here that the mere presence of an inflammable fuel in the vicinity of an ignition source will not in itself guarantee combustion, but the flammable range of that fuel must also be reached, above or below which combustion will not be sustained. Butane forms an explosive mixture with air when it is found in concentrations between 1.8 and 8.5%[5]. When such an inflammable mixture is ignited, a rapid, exothermic combustion reaction occurs. The resulting products of combustion, carbon dioxide, and water vapour, undergo a rapid increase in temperature, pressure, and volume. The destructive nature of this ignition will depend on two important factors. Firstly, the volume of the fugitive gas (here Butane) available for ignition will determine the amount of energy available for release. Secondly, the degree of confinement of the fugitive gas will determine the extent to which products of combustion will be able to expand, i.e., the force created. It is this destructive force of the gaseous explosion that caused the greatest damage in the plastic recycling plant but caused no fire because all the gaseous fuel was consumed in the explosion. Such explosions result in a short-term high-heat release that is too short in duration to ignite structural or other large components in the vicinity. The important point in any forensic analysis of such an unexplained explosion is the confinement of the inflammable mixture, its movement, and its spread. Upon re-analysis of the scene of the crime, it was evident that major prerequisites for combustion must have been fulfilled due to the very high possibility of the release of butane and its accumulation in sufficient quantity in the closed work area. Further, any ignition source or spark must have led to rapid combustion, creating a high pressure with subsequent explosion.

CONCLUSIONS

This interesting case of an accidental explosion is of forensic importance as the explosive potential of butane, a volatile and inflammable gas, is largely unknown. Plastic waste recycling is a specialized process including sorting, cleaning, and processing of plastic waste through methods like shredding and melting to produce raw materials suitable for manufacturing new plastic products. It is, therefore, pertinent to mention here that recycling plant owners and workers must have proper awareness regarding safe handling and accident prevention. While plastic scrap recycling significantly aids in mitigating environmental pollution and resource conservation by diverting waste from landfills and incinerators, any oversight or negligence can lead to tragic and inexplicable fatalities, as evidenced by the unfortunate loss of three lives in this instance.

LIST OF ABBREVIATIONS:

HS - Headspace
GC - Gas Chromatography
FID - Flame Ion Detector
MS - Mass Spectrometry
EI - Electron Impact Ionization

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CONFLICTS OF INTEREST

The author declared no conflicts of interest.

ETHICAL ISSUES

None.

SOURCES OF SUPPORT

None.

AUTHOR CONTRIBUTIONS

SS: Study conception and design, analysis, presentation, interpretation of data critical review of the draft; and final approval of the version to be published. **PP:** Scene of crime observation and final approval of the version to be published. **VK:** Data analysis and interpretation and final approval of the version to be published. **MK:** Instrumentation and interpretation; final approval of the version to be published. **YCP:** Critical review of draft and presentation and final approval of the version to be published.

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