REVIEW ARTICLE

A Case Study of Pasir Gudang Chemical Toxic Pollution: A Review on Health Symptoms, Psychological Manifestation and Biomarker Assessment

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ABSTRACT

Introduction: This paper provides an overview of chemical toxic pollution in Pasir Gudang industrial area Johor Malaysia. It discussed the health symptoms, argument of the psychology manifestation among children and the application of biomarkers and monitoring systems in chemical detection. **Methods:** The systematic search was conducted for four digital scientific journal databases: Science Direct, SCOPUS, PubMed and Google Scholar with a specified keyword. **Results:** Seven (7) chemicals were related to this incident namely; Methane, Hydrogen chloride, Acrylonitrile, Acrolein, Benzene, Xylene, and Methyl mercaptan. These chemicals are mainly generated from industrial activity and easily breakdown through interaction with other chemicals and sunlight. Inhalation is the major route of exposure and the major symptoms of these chemicals are headache, nausea, vomiting, breathing difficulties, eye irritation, chest tightness, and wheezing. There is no clear evidence to indicate that the victims in this incident are having a psychological manifestation since all chemicals involved are proven to cause the reported symptoms. **Conclusion:** Industrial chemicals are potential to produce toxic gas in the air through reaction with other substances or rays and causes acute health symptoms. Diagnose all post-emergency illnesses including mental and physical health is needed. Biomarker testing should consider a specified period after exposure occurs as the reactivity of some types of chemical and its short half-life, rendered limited for use as markers of exposure in the body.

Keywords: Toxic chemical, Industries, Biomarker, Health, Children

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INTRODUCTION

Industrial toxic chemicals mainly exhibit reactive characteristics, ignitability, corrosive and toxic. These toxic chemicals can be in a form of physical states such as gaseous, liquids or solids. It can be a byproduct of the manufacturing process or discarded commercial products such as cleaning fluids. Malaysia Environmental Quality Act 1974, Environmental Quality (Scheduled Wastes) Regulations 2005, has classified industrial toxic chemicals waste as scheduled waste. Five main types of scheduled wastes under this regulation, consist of metal and metal-bearing wastes (SW1), inorganic constituents (SW2), organic constituents (SW3), waste contain either inorganic or organic constituents (SW4) and other wastes (SW5). Unlike domestic waste, this type of waste required a specific method of pre-treatment before being disposed of.

Industrial toxic chemicals can pollute the environment and also harmful to human health especially to vulnerable groups such as children, elderly and pregnant mothers. Children are more susceptible to chemicals exposure through inhalation as compared to adults as their thin airways are more sensitive to the inflammation effects (1). Many research highlight the relationship between health and chemical poisoning. For example, industrial chemicals such as organochlorine compounds (OCs) in herbicides may accumulate in the food chain and mainly stored in the adipose tissue. When the fat tissues are metabolized, the chemical will become biologically available. Humans are exposed primarily through the food consumption of the high-fat animal goods from fish, meats, and poultry foods (2). Endocrine-disrupting chemicals of organochlorine compounds (OCs) such as Dioxin-like compounds (DLCs) and nondioxin-like PCBs (NDL-PCBs) may disrupt the hormonal process in the body and affect the development and reproductive systems (3, 4). This may increase diabetes and cardiac disease (5). Previous studies also indicated children who are exposed to organochlorines, are at greater risk for reducing in poor somatic growth, high BMI and neurobehavioral decrements (6, 7). This may increase the risk of behavioral disorders or cognitive deficits among children (8).

A significant episode of toxic chemical pollution incidents affecting thousands of people has been reported in the literature. Examples of chemical incidents occurring worldwide started in 1976 and among the two biggest incidents was in Seveso, Italy, and Bhopal tragedy in India (9). The incident in Seveso, Italy was related to the release of airborne dioxin in the manufacturing plant and the consequences were related to many thousands of animal deaths, however, no immediate human deaths were recorded. The incident that occurred in Bhopal was related to the release of methyl isocyanate which leaks from a tank at the Union Carbide factory which causes 3,800 immediate deaths, at least 15,000 premature deaths and caused chemical exposure to almost 500,000 people (9).

The incident of toxic chemical pollution in Pasir Gudang industrial area Johor Malaysia in 2019 has affected more than 5000 people, mainly children with respiratory symptoms such as breathing difficulties, nausea, and vomiting after breath in the poisonous gases. It was reported that these children were having a manifestation of psychology due to anxiety about chemical exposure (10). However, there is no clear evidence to prove this argument. Besides, the chemical exposure was unable to be detected in the children's urine and blood biomarkers (11). This paper aimed to study the characteristic of the chemicals related to this incident and the cause of health symptoms. This answers the argument about psychology manifestation among children as reported. The concept of a biomarker in chemical detection were also highlighted in this paper to answer of why the chemicals cannot be detected by the biomarker. The theory and facts discussed in this article might help us to understand the mechanism of toxic chemical pollution and its health effects.

MATERIALS AND METHODS

A systematic literature search was conducted to find the facts about the incident of toxic chemical pollution that has effects the population mainly young children. The systematic search was conducted for four digital scientific journal databases: Science Direct, SCOPUS, PubMed and Google Scholar. The literature search was conducted using the following terms; "toxic chemical pollution" OR "psychology manifestation" OR "industrial pollution Pasir Gudang" OR "biomarker" AND "children health" (Title, abstract, keywords). The logical OR operator and AND operator were used to combine the terms in the search. Only articles within the topic search of the toxic chemical pollution were defined for review in this article.

RESULTS

Description of the toxic chemical pollution incidents

Pasir Gudang is located in Mukim Plentong, Johor Bahru (Figure 1). It is an industrial area where heavy industries operated such as shipbuilding, petrochemicals manufacturing and other logistics and transportation. It was reported more than 2500 factories sited this area and 250 of them are chemical-based industries. Pasir Gudang has thrust into the spotlight after being reported with two incidents of toxic chemical pollution incidents in a row (12). The first incident was reported in March 2019, where toxic chemical waste was illegally dumped into the river near to the industrial area (i.e. Kim Kim river). More than 4,000 people mainly children were affected by this incident and rush for treatment after having breathing difficulties, nausea, and vomiting from the exposure to the toxic gases at schools (13). Methane and benzene are the toxic gases produced from the chemical waste known as marine oil that was dumped in the river. In total, 346 tonne metric of the chemical waste has been cleaned up along the 1.5 km river (13).

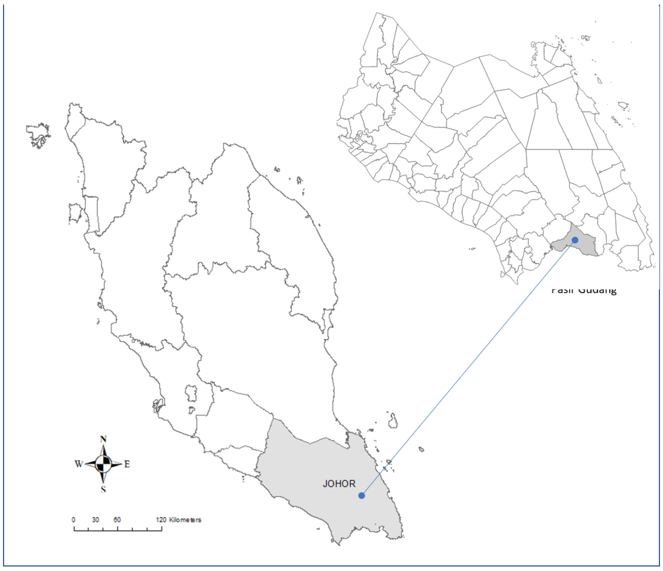


Figure 1 : The location of the case study area

The second incident was reported in June 2019 in Pasir Gudang industrial area causes more than 1000 children caught with similar symptoms of breathing difficulties, nausea, and vomiting. This incident was related to high concentration of methyl mercaptan in the industrial area. Three out of 257 chemical-based factories in the industrial area among the most likely sources of the toxic gas in this event (14). These factories are located within 3 km radius from the affected school. Several gases also were detected as abnormal in the ambient air.

There are few theories of the major causes of this incident highlighted by the media. The most relevant theory is the "heat island effects" that normally happen in the industrial area and has been reported by researchers across the globe. The "heat island effects" are caused by hot air in industrial areas produced from human activities such as fuel burning, the use of air conditioning, traffics etc. The building structures create roughness effects have slowed down the wind speed and have designed specific atmospheric dynamics in the area. The cold air outside the industrial area create the temperature differences and the contaminated substances were blocked and not be able to decompose. Besides, not much wind to push out contaminated material from the Pasir Gudang industrial area as during the incident, it is the monsoon transition period. Since Pasir Gudang lies next to the strait, the sea breeze in the morning pushes air in the industrial area to settlement areas. This theory is reinforced when most of the victims exposed are school students in the morning.

The chemicals characteristics and their association with health effects

From the literature search, seven (7) chemicals were related to this incident namely; Methane, Hydrogen chloride, Acrylonitrile, Acrolein, Benzene, Xylene, and Methyl mercaptan. Table I highlight the characteristic of these chemicals. In summary, all of the chemicals involved were generated from industrial activity such as in chemical production, plastic products industries, coal deposits during underground and surface mining, vehicle exhaust, oil and gas fields, coal-fired power plants, etc. All of these chemicals can be detected in the environmental medium such as air, water and soil. These chemicals can be released in the air when react with other chemicals and exposed to sunlight. Inhalation is the main route of exposure for these chemicals followed by ingestion and dermal absorption. The major symptoms are mainly headache, nausea, vomiting, breathing difficulties, eye irritation, chest tightness and wheezing, dizziness, diplopia, and a productive cough, etc. These were the symptoms reported by the victims in Pasir Gudang incident. The Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health's (NIOSH) have established the permissible exposure limit or safe recommended value for these chemicals.

Table II highlight the four routes of chemical exposure; through inhalation, dermal (or eye) absorption, ingestion, and injection. The chemical response through metabolism, storage, and excretion once enters the body. The response of chemical exposure is influenced by the environmental factor such as weather, workplace conditions, and living conditions. The mixed of some chemicals may create synergists, potentiation or antagonist effects. Synergists is when a chemical mixture produced a greater effect as compared to its additive. Potentiation is when the potentiator can increase the toxicity of other chemicals by the synergism effect. Antagonists are an effect of chemicals when combined, it lessens the predicted effect (15).

DISCUSSION

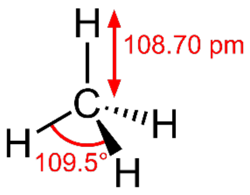
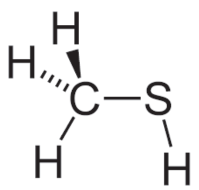
A manifestation of psychology among children

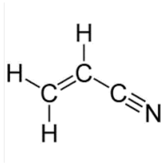
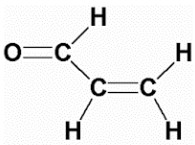
It was reported in the newspaper that the children in this incident were probably having a manifestation of psychology due to anxiety about chemical exposure. This was related to the pressure to get the latest information by the media, the lack of partial academics casts out an unpredictable view, the 'trends' of people are spreading issues associated with toxic pollution, prolonged with uncertain anxiety (16). Previous findings related to occupational or environmental emergency reported that most people who were exposed to such occurrences did not develop psychopathology (17). The most commonly reported post-disaster psychological problem was post-traumatic stress disorders (PTSD) which was estimated to be within the range of 30–40% among direct victims (18) which later resolved over time. Similar results were also found locally in Malaysia showing that majority of the flood victims experienced mild to moderate depression (29%) and PTSD (28%). Only 2% of them had severe depression and 9.3% had severe anxiety disorders (19).

These psychological problems are commonly believed to co-exist with physical symptoms also known as somatic distress or somatic symptom disorders (SSD). SSD is a form of mental illness that causes one or more physical symptoms including weakness, trembling, pain, or gastrointestinal distressed, which are triggered by the general adaptation syndrome (GAS) involving the autonomic nervous system (ANS) and hormonal-stress response (20). In several studies of post-emergency or post-disaster health consequences, mental health problems found to be correlated with physical health conditions (21). However, generally, these somatic symptoms were mostly identified by a checklist or a survey rather than through a structured diagnostic instrument. Hence, there is insufficient evidence showing that such symptoms are caused by the disaster or emergency events. A previous study involving 811 disaster survivors showed that only one case was identified as post-disaster SSD (22). Researchers argued that such somatic symptoms appear to merely represent endemic symptoms of the affected community rather than post-disaster illnesses. Therefore, we cannot conclude that post-disaster physical symptoms suffered by an affected community are merely psychological manifestations without any systematic diagnostic procedure being conducted especially when the sources of hazards exist and not merely a hearsay.

Common perception relates the somatic symptoms with psychological panic due to emergency occurrences. The population in an emergency is expected to breakdown and react and think irrationally perceiving unrealistic threats and consequences from the situation. However, this perception is rather exaggerated given

Table I : The characteristic of the chemicals reported related to the event

Chemicals	Properties	Sources	Health effects	PEL
Methane (CH4) (National Center for Biotechnology Information) 	• Methane is a colorless, odorless gas that can dissolve in water. Methane in water escapes quickly to the air as a gas. • Methane gas can build up in poorly ventilated areas, such as bathrooms, laundry rooms, and in the well itself. It can cause a fire or explosion.	• Major natural sources of methane - include emissions from wetlands and oceans, released from coal deposits during underground and surface mining, vehicle exhaust, oil and gas fields, coal-fired power plants, decomposition of waste and other human activities such as rice production, landfills, raising cattle and other ruminant animals (cow), and energy generation.	• Human get the exposure of methane through; inhalation (i.e. vehicle exhaust and emissions from farms, industries), skin contact (i.e. touching liquefied methane). • Skin contact can cause frostbite, skin and eye burns. Methane is considered an asphyxiant at extremely high concentrations and can displace oxygen in the blood. • Exposure to high levels of methane can cause, suffocation, loss of consciousness, headache and dizziness, nausea and vomiting, weakness, loss of coordination and increase breathing rate • Vapors may cause dizziness or asphyxiation without warning. Some may be irritating if inhaled at high concentrations.	• The Occupational Safety and Health Administration (OSHA) has no permissible exposure limit for methane. • The National Institute for Occupational Safety and Health's (NIOSH) maximum recommended safe methane concentration for workers during an 8-hour period is 1,000 ppm (0.1 percent).
Hydrogen chloride (HCl) (ATSDR, 2002) 	• Hydrogen chloride is a colorless to slightly yellow, corrosive, non-flammable gas that is heavier than air and has a strong irritating odor. • It forms hydrochloric acid when in contact with water. Both hydrogen chloride and hydrochloric acid are corrosive.	• Hydrogen chloride is used to produce other chemicals, or for applications such as a metal pickling, ore refining, food processing, manufacture of fertilizers and dyes, and in the rubber and textile industries. • Hydrogen chloride gas naturally-occurring through volcanic eruptions. • Hydrogen chloride can be formed during the burning of plastics.	• Exposure through inhalation or skin absorption. • Hydrogen chloride is irritating and corrosive to body tissue. Short term exposure to low levels causes throat irritation. • Exposure to high levels can result in rapid breathing, narrowing of the bronchioles, blue coloring of the skin, accumulation of fluid in the lungs, and even death. It also can cause swelling and spasm of the throat and suffocation. • Some people may develop an inflammatory reaction to hydrogen chloride, known as reactive airways dysfunction syndrome (RADS), a type of asthma. • HCL can produce from mild irritation to severe burns of the eyes and skin. • Ingestion concentrated hydrochloric acid will cause severe corrosive injury to the lips, mouth, throat, esophagus, and stomach.	• The U.S. Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health have established occupational exposure limits for hydrogen chloride at a ceiling of 5 ppm (7 mg/m^3).
Methyl mercaptan (CH_3SH) (ATSDR, 1999) 	• Vapors of liquified methyl mercaptan gas are heavier than air and spread along the ground.	• Methyl mercaptan is produced by the reaction of hydrogen sulfide with methanol. • It is used as a gas odorant; an intermediate in the production of pesticides, jet fuels, and plastics; in the synthesis of methionine; and as a catalyst. .	• May induce headache, nausea, vomiting, eye irritation, chest tightness and wheezing, dizziness, diplopia and a productive cough. • Inhalation is the major route of exposure. • Exposure in poorly ventilated, enclosed, or lowlying areas can result in asphyxiation. • Children exposed to the same levels as adults may receive a larger dose because they have a greater lung surface area. • Direct contact with liquid methyl mercaptan or the gas may cause frostbite injury or irritation of the eyes and skin. • Ingestion is unlikely to occur because methyl mercaptan is a gas at room temperature. • Methyl mercaptan gas is irritating to the eyes, skin, and respiratory tract. Edema of the airway and lungs can occur. • It is a central nervous system depressant that acts on the respiratory center to produce death by respiratory paralysis. • Individuals with pre-existing respiratory, cardiac, nervous system, or liver impairment may be more susceptible to the exposure.	• OSHA PEL = 10 ppm (20 mg/m^3) • NIOSH REL (recommended exposure limit) = 0.5 ppm • NIOSH IDLH (immediately dangerous to life or health) = 150 ppm

Acrylonitrile (ATSDR. 1999)  	• Acrylonitrile is a colorless, liquid, man-made chemical with a sharp, onion- or garlic-like odor. It can be dissolved in water and evaporates quickly. • Acrylonitrile is used to make other chemicals such as plastics, synthetic rubber, and acrylic fibers. • A mixture of acrylonitrile and carbon tetrachloride was used as a pesticide in the past.	• Acrylonitrile is released into the environment primarily from chemical production and plastic products industries (>95% in the sample country). There are no known natural sources. • Acrylonitrile may be found in the soil, water, or air near industrial sites where it is made, or at hazardous waste sites where it has been disposed of. • Acrylonitrile breaks down quickly in air (about half will disappear within 5 to 50 hours) by reacting with other chemicals and sunlight. • It can enter groundwater but not commonly found in groundwater. It is broken down by bacteria in surface water and soil. • Acrylonitrile does not build up in the food chain.	• Exposure through inhalation (i.e. breathing contaminated air near hazardous waste sites, working in, or living near, industries where it is manufactured or used) • Swallowing food and water that contains acrylonitrile. • Breathing high concentrations of acrylonitrile will cause nose and throat irritation, tightness in the chest, difficulty breathing, nausea, dizziness, weakness, headache, impaired judgment, and convulsions (symptoms usually disappear when exposure is stopped). • Acrylonitrile will burn the skin and produce redness and blisters. • Children are much more sensitive to acrylonitrile than adults. Children have died following exposure to acrylonitrile vapors that caused only minor nose and throat irritation in adults. • The Department of Health and Human Services (DHHS) has determined that acrylonitrile may reasonably be anticipated to cause cancer in people (animal studies have shown cancers of the brain and mammary glands).	• The EPA recommends that levels in lakes and streams should be limited to 0.058 ppb to prevent possible health effects • The Occupational Safety and Health Administration (OSHA) has set a limit of 2 ppm over an 8-hour workday, 40-hour workweek. • The National Institute of Occupational Safety and Health (NIOSH) recommends that average workplace air should not 1 ppm averaged over a 10-hour period.
Acrolein (ATSDR, 2007)  	• Acrolein is a colorless or yellow liquid with a disagreeable odor. • It dissolves in water easily and quickly changes to a vapor when heated. It also burns easily. • Small amounts of acrolein can be formed and can enter the air when trees, tobacco, other plants, gasoline, and oil are burned.	• Acrolein is used as a pesticide to control algae, weeds, bacteria, and mollusks. It is also used to make other chemicals. • It can be found in soil, water, or air. It breaks down fairly rapidly in the air (about half will disappear within 1 day) by reacting with other chemicals and sunlight.	• Inhaling vapors from overheated cooking oil or grease. It can causes irritation to the nasal cavity, lowered breathing rate, and damage to the lining of the lungs and could cause death. • Breathing lower amounts may cause eye watering and burning of the nose and throat and decreased breathing rate • Animals that swallowed acrolein had stomach irritation, vomiting, stomach ulcers and bleeding.	• The Food and Drug Administration (FDA) has determined that the amount of acrolein used to prepare modified food starch must not be more than 0.6% • The Occupational Safety and Health Administration (OSHA) has set a limit of 0.1 ppm for 8 hour shifts and 40 hour work weeks.

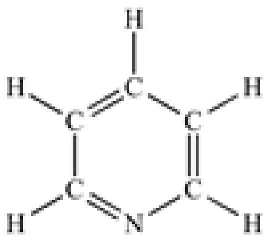
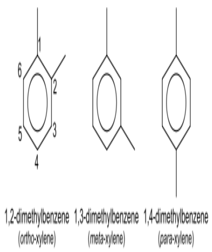
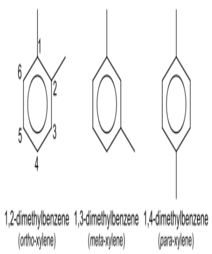
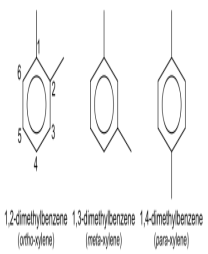
Benzene (ATSDR, 2007) 	• Benzene is a colorless liquid with a sweet odor. It evaporates into the air very quickly and dissolves slightly in water. • It is highly flammable and is formed from both natural processes and human activities.	• Industrial processes are the main source of benzene. It is use to make plastics, resins, and nylon and other synthetic fibers, rubbers, lubricants etc. • Natural sources of benzene include emissions from volcanoes and forest fires • Benzene can pass into the air from water and soil. It reacts with other chemicals in the air and breaks down within a few days. • Benzene does not build up in plants or animals. • Outdoor air contains low levels of benzene from tobacco smoke, automobile service stations, vehicles exhaust, and industrial emissions. • Vapors (or gases) from products that contain benzene, such as glues, paints, furniture wax, and detergents, can also be a source of exposure. • Air around hazardous waste sites or gas stations will contain higher levels of benzene.	• Breathing very high levels of benzene can result in death, while high levels can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, and unconsciousness. • Eating or drinking food containing high levels of benzene can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, and death. • The major effect of benzene from long-term exposure is on the blood. It causes harmful effects on the bone marrow and can cause a decrease in red blood cells - leading to anemia. • It can also cause excessive bleeding and can affect the immune system – increase the chance for infection. • Long-term exposure to high levels of benzene in the air can cause leukemia, particularly acute myelogenous leukemia (AML) - a cancer of the bloodforming organs. Benzene can pass from the mother's blood to a fetus. • According to the International Agency for Research on Cancer (IARC), benzene is carcinogenic to humans.	• The EPA has set the maximum permissible level of benzene in drinking water at 5 ppb. • The Occupational Safety and Health Administration (OSHA) has set limits of 1 ppm for 8 hour shifts and 40 hour work weeks.
Xylene (ATSDR 2007)   	• There are three forms of xylene in which are meta-xylene, ortho-xylene, and para-xylene (isomers). • Xylene is a colorless, sweet-smelling liquid that catches on fire easily. It occurs naturally in petroleum and coal tar.	• Xylene evaporates quickly from the soil and surface water • Xylene in the air broken down by sunlight into less harmful chemicals within couple of days. • It is broken down by microorganisms in soil and water. Only a small amount of it builds up in fish, shellfish, plants, and other animals. • Chemical industries produce xylene from petroleum. Xylene is used as a solvent and in the printing, rubber, and leather industries. • It is used as a cleaning agent, a thinner for paint, and in paints and varnishes. It is found in small amounts in airplane fuel and gasoline.	• Xylene can be absorbed through the respiratory tract and through the skin. • Ingesting xylene-contaminated food or water, are likely to be very low. • No health effects at the background levels that people are exposed to on a daily basis. • High levels of exposure for short or long periods can cause headaches, lack of muscle coordination, dizziness, confusion, and changes in sense of balance. • Exposure to high levels of xylene for short periods can cause irritation of the skin, eyes, nose, and throat; difficulty in breathing; problems with the lungs; delayed reaction time; memory difficulties; stomach discomfort; and effects the liver and kidneys. • It can cause unconsciousness and even death at very high levels.	• The EPA set a limit of 10 ppm in drinking water. • The Occupational Safety and Health Administration (OSHA) has set limits of 100 ppm at workplace air for 8 hour shifts and 40 hour work weeks.

Table II : The route of chemical exposure

Routes of entry	Description	Chemical processes in the body
Inhalation	• Most chemicals in the form of vapors, gases, mists, or particulates • Inhalation is the major route of entry. Chemicals are either exhaled or deposited in the respiratory tract. • Through direct contact with tissue or the chemical may diffuse into the blood through the lung-blood interface. Upon contact with tissue in the upper respiratory tract or lungs, chemicals may cause. • Health effects ranging from simple irritation to severe tissue destruction	• Metabolism Many chemicals are metabolized or transformed via chemical reactions in the body. • Storage In some cases, chemicals are distributed and stored in specific organs. Storage may reduce metabolism and therefore, increase the persistence of the chemicals in the body.
Skin (dermal)	• Contact can cause effects such as redness or mild dermatitis or severe effects such as destruction of skin tissue or other debilitating conditions. • Many chemicals can also cross the skin barrier and absorbed into the blood system. Once absorbed, they may produce systemic damage to internal organs.	• Excretion The various excretory mechanisms (exhaled breath, perspiration, urine, feces, or detoxification) rid the body, over a period of time, of the chemical. For some chemicals elimination may be a matter of days or months; for others, the elimination rate is so low that they may persist in the body for a lifetime and cause deleterious effects.
Eyes	• Short exposure can cause severe effects to the eyes or the substance can be absorbed through the eyes and be transported to other parts of the body causing harmful effects.	
Ingestion	• Chemicals that inadvertently get into the mouth and are swallowed do not generally harm the gastrointestinal tract itself unless they are irritating or corrosive. • Chemicals that are insoluble in the fluids of the gastrointestinal tract (stomach, small, and large intestines) are generally excreted. Others that are soluble are absorbed through the lining of the gastrointestinal tract. • They are then transported by the blood to internal organs where they can cause damage.	
Injection	• Substances may enter the body if the skin is penetrated or punctured by contaminated objects • Effects can then occur as the substance is circulated in the blood and deposited in the target organs.	

Source: UNL Environmental Health and Safety, (2002)

that from previous global occurrences mass psychology panic from the emergency event is uncommon (23). Psychology panic is influenced by many factors that lead to 'availability bias' a term used to describe the tendency of people to overweight or underweight consequences of an event based on previous frequencies and severity (24). Therefore, in the context of Malaysia, the occurrence of Pasir Gudang is a very rare event is contrary to the common beliefs, the affected community is more prone to underestimate the related health consequences and experiencing discounting panic rather than mass panic. This is because they have no memories of negative consequences from a similar event in local histories. Hence, if such an emergency event is not promptly investigated and the information obtained is not properly disseminated at a right time, any measures that should be taken to protect the affected community will be delayed putting them at high risk for any potential hazardous effect from such exposure. For instance, the 'availability bias' from the community in New Orleans was due to discounting panic, have failed to care for the evacuation warning before Hurricane Katrina because they underestimated the severity of such consequences based on previous occurrence (25). Follow-up health examination including mental health can be done as practiced by the Japan government after the Fukushima Daiichi Nuclear Power Plant accident (26) is reasonable to be implemented among victims in Pasir Gudang to ensure that they are free from any threats related to the occurrence.

Environmental monitoring system

The impacts arising from chemical disasters may exist for an extended period and is widespread and commonly depends on the exposure level (27). Exposure assessment is important because it sets forth the degree of effort required to mitigate the impacts arising from chemical exposures. It computes a numerical estimate or measurement for the exposure situation (9). In chemical disasters, first responders who are responsible during the rescue or clean-up phase is at risk for chemical exposures. These chemical exposures may occur at an acute level, meaning at concentrations or levels which are elevated and because of this, measurement during this phase is usually done with the main intent to protect workers. Exposure assessments are needed to help authorities obtain a greater understanding of the scale of morbidity and mortality which may or have occurred in the incident area.

For incidents involving chemical exposures occurring at a significant scale, routine environmental monitoring program needs to be established as part of the chemical incident management system. It is important to emphasize that such a program is crucial if chemical exposures occur in a densely populated area. Routine environmental monitoring program needs to include regular monitoring of chemical levels at selected intervals in several different exposure media which may consist of not only ambient air but also water, soil or food produced or sampled in the sites at risk for potential on-going chemical release. For chemical incidents, it may difficult to grab soil and water samples due to its proximity but air sampling is almost always possible to be done even at a distance, but workers that do these samplings needs to be trained and competent to ensure they do not expose themselves to unknown hazards.

The monitoring program needs to consist of on-going and systematic collection, analysis, and interpretation of the data from environmental samples collected. The monitoring program aims to produce available data on chemicals background concentration in the environment, to identify the deviation in the concentration, to act as a caution when a spike in chemical levels is observed, to compare the concentration if there are more incidents and to identify if background levels are reduced to what it was before.

Monitoring system to measure air pollution is abundant globally and in Malaysia, air quality monitoring systems provided by the funding of the government are available in many places both in peninsular and East Malaysia. Monitoring performed by these continuous air quality monitoring systems follows the existing Malaysia Ambient Air Quality Standards (2015) (28) which were recently established. It may not be suitable to depend on these monitoring systems to provide accurate data for locations or sites affected by chemical incidents. Furthermore, large monitoring systems are expensive, difficult to be installed, can be affected by restricted features such as roadblocks, rendering assessment to be unreliable of the air quality even at a short distance. As such, variety, small, low-cost, portable and profound air monitoring devices that are proficient for long-term, continuous and provide real-time monitoring is the best solution to be used to monitor outdoor air especially in the events of chemical incidents (29). With new technology and modifications, such instruments can be installed in selected representative areas which allow monitoring to be performed in an unhampered manner.

The application of biomarker in chemical detection

Chemicals concentration or metabolites excreted from body fluids or obtained from tissues in samples of the exposed population is called as biomarkers (9). Examples of a biomarker that widely used in testing include urine, blood, hair, fingernails, etc. Analysis of urine and blood from human samples can provide both qualitative and quantitative evidence of recent chemical exposures (30). Some assays are adequately sensitive and are replicable to identify the human body burden.

Even though a test was made to detect the chemicals through urine and blood among children who were affected by the incident, but the test was unable to detect any chemicals in the samples (10-11). This probably due to the consumption of biomarkers that have passed the exposure time frame causes chemicals to be no longer detectable in the human body. It must be emphasized that these assays (biomarkers) must be performed within a specified period after exposure occurs. This is because due to the reactivity of some types of chemical and its short half-life, it is rendered limited for use as markers of exposure in the body (30). It is reported by WHO, there are only a few biomarkers for the most common chemicals exposed to humans in environmental incidents and even chemical warfare agents (30) such as phosgene, cyanide, chlorine, asbestos, and particulates. Apart from short half-lives, several metabolites from hydrolysis are not appropriate as biomarkers of effects due to the existing background concentration in the human population. In other words, using biomarkers of effects is not a guarantee as there is an existing association between exposure and a chemical incident, and this is particularly true for chemicals that can be found in the natural surrounding at low concentrations (9). The report has also indicated that exposure to commercially available hydrolysis merchandises can cause the background levels in humans to increase (30). In these cases, more definitive biomarkers such as those derived from glutathione pathways or protein or DNA are more suitable as biomarkers.

WHO has also reported that it is a possibility to use physiological measurements such as enzyme inhibition to measure the health effects from the chemical exposure. These types of measurements are called biomarkers of effects. The changes that are measured rarely linked with environmental contaminants. However, it is suggested that reference groups or comparison groups are included in the measurement to help researchers assess whether abnormalities detected are linked with the exposure being studied. WHO also emphasizes the use of thorough batteries of tests to assess immune function, neuro behavioural and respiratory factors which are all commonly applied in an environmental investigation.

CONCLUSION

All of the chemicals involved in the Pasir Gudang incident were mainly generated from industrial activity. Most of the chemicals have a characteristic that can produce toxic gas in the air through reaction with other chemicals substances or rays. This causes the chemical potential to vaporize and produce fume or gaseous that may cause respiratory illness to the victims. The major symptoms from these chemicals may cause are related to inhalation exposure such as headache, nausea, vomiting, breathing difficulties, chest tightness and wheezing, dizziness, diplopia, and a productive cough etc. This is consistent with the fact that the main route of exposure for a chemical is from inhalation. There is no clear evidence to indicate that the victims in this incident are having a psychological manifestation since all chemicals involved are proven potential to cause the symptoms reported among victims. All post-emergency illnesses including mental and physical health need to be taken care of and diagnosed carefully before jumping into the conclusion that those illnesses are merely a manifestation of psychological panic or anxiety. Disseminating precise information about a hazardous occurrence to the public will help them to guide their judgment about the actual threats hence making any control and preventive actions taken by the authorities runs smoothly and efficiently. Follow-up health examination including mental health is reasonable to be implemented among victims in Pasir Gudang to ensure that they are free from any threats related to the occurrence. Biomarker testing should consider a specified period after exposure occurs. Due to the reactivity of some types of chemical and its short half-life, it is rendered limited for use as markers of exposure in the body. This maybe the cause of undetected chemicals in this incident. The involvement of political leadership and partnerships at all levels in mobilizing the industry sectors to bide with the law and regulations may reduce chemical pollution incidents in future. Strict action should be taken against industries that deliberately do not want to comply with existing laws and regulations related to chemicals discharge. Action on the worst pollutants and better enforcement of environmental laws with a heavier penalties or punishment may warn the industry of their commitment to protect the environment and the health of the public. Investment in cleaner production and consumption to counter pollution, alongside increased funding for pollution monitoring and infrastructure to control pollution also needed as way forward to support the industry.

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