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Review Article

Risk of Respiratory Health Impairment among Susceptible Population Living near Petrochemical Industry- A Review Article

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Abstract

Background: Petrochemical industry emits air pollutants in abundance, which may harm human health, especially the population living near the industry. Children are reported to be the population group of main concern since this susceptible population spends the majority of their time outdoors and their active lifestyle can increase their breathing rate, which then leads to a greater inhalation dose of air pollutants and greater risk of health effects.

Method: The materials for this review were obtained from several on-line databases such as PubMed, Proquest, Scopus and Science Direct (year 1990-2015). In this review, we highlighted several relevant studies on respiratory health effects from petrochemical air pollutant exposure among children living in the neighborhood and highlighted the factors, which contributed to the severity of the health outcomes.

Results: Short term petrochemical air pollutant exposure increases respiratory symptom, reduces lung function and incidence of asthma especially for those who living within 5 km radius from the industry.

Conclusion: This review will provide a compilation of potential respiratory health outcomes that arises from the inhalation of petrochemical air pollutants among children.

Keywords: Petrochemical industry, Respiratory health effects, Children

Introduction

Industrialization signifies positive and vital economic growth in a country. Excessive growth of large-scale industries contributes to numerous environmental problems, especially the abundant release of air pollutant. The petrochemical industry is considered the dominant contributor of anthropogenic air pollution in a petroleum producing country. It can emit a wide range of point source pollutants such as volatile organic compounds, persistent organic pollutant and combustion end products that includes particulate matter (PM), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and volatile organic carbon (VOC) through the plant's operation (1-4). Apart from that, mobile air pollutants from the heavy traffic density around the petrochemical area may synergize pollutant concentration in the atmosphere. Exposure to mixtures of air pollutants may be significant to the residents living in the adjacent residential zones, especially in term of health effects (2, 5).

Based on literature reviews toddlers, young infants, people with respiratory diseases, elderly and children have been postulated as the higher risk group (6-8).

Air pollutants definitely have many health impacts on adults and children, but children are amongst the most susceptible group of the population.

The reason being, their physical and biological condition is still under development stage. Exposure to a highly polluted environment during their

childhood can alter the physiological development of the lungs (9, 10). In addition, they usually spend the majority of their time outdoors, especially at times when PM concentrations are higher than the usual. Their active lifestyle can increase their breathing rate, which leads to a greater inhalation dose of air pollutants and present a greater risk of contracting health effects (11). Furthermore, children are typically mouth-breathers, which cause air pollutants to be deposited deep in the respiratory tract, lungs and eventually the blood stream. In contrast, adults tend to breathe using their nose, which enables the reduction of some the pollutant concentration, especially larger particles (12). Poor health status among children will significantly affect their study performance, school attendance, productivity, and eventually trigger other illnesses (13). Thus, there is a need to understand the possible health outcomes from petrochemical air pollutant exposure among children.

In this review, we emphasize a summary of epidemiological studies conducted on various respiratory health outcomes among children who lived near the petrochemical industry.

Methods

The materials for this review was obtained from several on-line databases; PubMed, Proquest, Scopus and Science Direct. All the references used in this review were articles written in the English language with specific years of publication from the year 1990 to 2015. Besides that, the articles used in this study were full-published papers, including original scientific papers, reviews and letters, which emphasized on petrochemical air pollutants and the related public health effects. Occupational exposure was excluded from the search criteria. The keywords used were "petrochemical and acute health effect", "petrochemical industry and children", "petrochemical industry and respiratory health effects". Apart from that, a comprehensive search was conducted which mainly focused on articles related to association between petrochemical air pollutants and respiratory health outcomes among children only.

Results

Inhalation of petrochemical air pollutants such as PM, NO_2, and SO_2 can cause various acute health effects. Based on literature surveys, we found nine relevant studies on the association between petrochemical air pollutant exposure and acute respiratory health effects among children. The findings of those related studies are summarized in Table 1.

Asthma attack

Poor ambient air quality has been related to increased hospital admissions and emergency department visits due to asthma attacks. In a nested case control study (14) children aged less than 17 yr old who lived in close proximity to the petroleum refinery in Catano Municipality, Puerto Rico had a 44% risk of asthma attack with an odd ratio, OR of 1.44 (95% CI 1.33-1.56) as compared to the control population. The study was conducted based on 1,382 children cases who claimed insurance for physician diagnosed asthma attack during a period of 1997 to 2001, meanwhile the reference population were children free from asthma attacks on the day of observation and or had other respiratory problem excluding asthma apart from that, Smargiassi et al. (15) reported that high peak SO_2 emission from nearby oil refineries increased asthma attacks among children in Montreal, Canada with 263 case hospitalizations and 1,579 emergency visits for asthma during the year 1996 to 2004.

Self-reported asthma

Asthma prevalence is characterized by the frequency of previous and current wheezing episodes, frequent coughing without cold, influenza and having a lifetime history of asthma. There are several studies, highlighted the prevalence of doctor-diagnosed asthma among children who resided near industrial areas through questionnaires data. For instance, children aged 6 to 12 yr old, who were living close to six petrochemical plants in La Plata, Argentina had the highest prevalence of asthma, 24.8% and more asthma exacerbation, 6.7% (P<0.001) as compared to a population that lived in urban, semi-rural and residential area (16).

Table 1: Summary of scientific studies on petrochemical air pollutant exposure and acute health effect

Authors	Subject	Design	Tool	Outcome
Loyo-Berríos et al. (14)	Case: Claimed insurance for asthma attack Control a)Group 1: no asthma attack on the day of observation b)Group 2: no attack on the day of observation	Nested case-control 5 years follow up (Jan 1997- Dec 2001) Data was obtained from 2 health insurance companies in the Catano municipality of Puerto Rico.	Exposure assessment: Measuring distance from point source air pollution to the center of residency's census block	*1,382 asthma-related medical visits had been reported by 2 health insurance companies for a period of year 1997 to 2001 *OR adj for asthma attack per 1km decrease in the mean distance from a major source was 2.08 (95%CI 1.61-2.7) when be compared to group 1. *Children lived nearby to petroleum refinery had 44% risk of asthma attack with adjusted OR 1.44 (95% CI 1.33-1.56) in the comparison of control group1
Smargiassi et al. (15)	3470 children aged 2-4 years old Visit emergency department, (ED)	Time stratified case crossover, in Canada (1996-2004) *Assessment distance 0.5–7.5km *Conduct time stratified approach for case control days	Measure daily SO_2 at 2 fixed monitoring site SO_2 located close to the refineries and estimate from air dispersion modelling software, AERMOD	*Hospitalizations and emergency department, ED visits were more strongly related to peak SO_2 *The risks of ED visits and hospitalizations were more pronounced for same-day (lag 0) SO_2 peak levels
Wichmann et al. (16)	1212 children aged 6-12 years (voluntary) Argentina	*Cross sectional study *Area: 1)Polluted area: -Industrial(I) -urban(U) 2)Unpolluted area: -Semirural (S) -Residential (R)	* International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire *Air sampling *Lung function testing	*Children residing in the industrial area had significant greater prevalence of asthma, asthma exacerbations and more respiratory symptoms *Children exposed to higher levels of pollutants had lower lung function *Length of residence in the area was a significant risk factor
White et al. (17)	2361 children Age: 11-14 years (all children living in the respective study area)	Cross-sectional study in South Africa	*ISAAC written *Video questionnaire. *Meteorologically estimated exposure (MEE)	*Increased prevalence of asthma symptoms among children in the studied area *Self- reported asthma, exercise wheeze and hayfever showed no relationship with proximity to refinery and MEE *MEE was significantly associated with wheezing at rest, frequent wheezing at rest, recent sleep disturbance by wheezing, frequent sleep disturbance by cough.
Bhopal et al. (18)	1888 Children (less than 16 years) 6399 adult 16-79 years	*Time series case study *4 zone -Zone Teesside (ABC): close to petrochemical plant -Zone Sunderland (S): l25km from ABC	*Questionnaires *Air quality data obtained from local monitoring station	*Respiratory symptom higher among children with OR 2.01 (95% CI 0.90-4.50) *Self-reported illness among adult zone ABC is not significant (P>0.005) *Exposure to air pollutant not have clear effects on morbidity, possible exacerbation asthma or mortality.
de Moraes et al. (19)	209 children Age 0-14 years Brazil	Cross-sectional study in Brazil Sampling area: *5km from the industry Exposed group: *Live downwind Reference group:	*ISAAC questionnaires *air sampling (Real time air monitoring station)	*Exposed group had wheezing in the last 12 months 2 times as compare to reference group (OR_{adj} =2.01, 95% CI 1.01-4.01). *Male gender and children under 7 years old had greater risk of wheezing
		*Live upwind		*No association between crowding and wheezing

Table 2: Cond

Ayuni et al. (20)	120 children Age 10-12 years	*Cross sectional study in Malaysia *Studied group: 1km *Reference group: 10km from industry	*Questionnaire *Indoor air quality monitoring in classroom *Lung function test	*FEV_1/FVC% predicted was significantly different between studied and comparative group *Concentration PM_{10} and NO_2 have significant association with respiratory symptom and lung function *Proximity to industry, higher risk
Rusconi et al. (21)	Exposed group: 275 children Reference group:214 (Age:6-14 years)	Cross sectional study in Italy	*ISAAC questionnaire *Air sampling (3 weeks) *Lung function test *Malondialdehyde-deoxyguanosine (MDA-dG)	*Children in exposed area exhibited high risk wheezing symptom, decrement pulmonary function, enhance bronchial inflammation, and increase MDA-dG nasal mucosa *Air pollutant impair lung function and cause airway inflammation
Yang et al. (22)	470 children inexposed area 611 children in reference area	Cross-sectional study in Taiwan Exposed area, Linyuan Reference area: Taihsi, 130km from polluted area	*Adapted and modified questionnaire *Air quality data from local monitoring station	*High prevalence respiratory symptom among exposed children but insignificant except for asthma and upper respiratory symptoms *OR_{adj} asthma 2.76 (95% CI 1.19-6.39), OR_{adj} upper respiratory symptom 1.51 (95% CI 1.10-2.08)

Apart from that, the population also exhibited high risk of asthma (OR 2.76; 95% confidence interval; CI, 1.96-3.89) and asthma exacerbations (OR, 1.88; 95% CI, 1.25- 1.83) as compared to other areas after controlling for confounders such as age, sex, body mass index, proximity to busy roads and other non-petrochemical industries, length of breastfeeding, socioeconomic, and demographic characteristics of children or their families. White et al. (17) also highlighted the greater prevalence of asthma symptoms among children aged 11 to 14 yr, who was living nearby a petrochemical refinery in Cape Town, South Africa.

Another study in England (18) showed a contrast finding on the asthma risk among children below the age of 16 years. Children who resided in the Tessidie zone (close to petrochemical plant) have a low risk of asthma with an OR of 0.87 (95% CI 0.69-1.11) after controlling the confounders such as damp housing, overcrowding, parental smoking, family history of asthma, and gas appliances. Besides that, the author also clarified that exposure to air pollutants do not have clear effects on possible exacerbating asthma.

A recent study (3) also revealed similar prevalence of asthma in the exposed group and reference group. However, the adolescents aged 13-14 yr for both groups had greater prevalence of asthma 13.9% (95% CI 12.2-15.6) as compared to children aged 6 to 7 years with a total prevalence of 5.0% (95% CI 3.9-6.1).

Respiratory symptom

Respiratory symptoms among children are commonly assessed from questionnaires filled by their parent or legal guardians. In Brazil, 209 parents of children aged less than 14 yr old were requested to fill the questionnaire on respiratory symptoms, especially wheezing symptom. In this study, the difference in respiratory symptoms was being observed between two groups; exposed group were children who lived within the dispersion plume while the reference group lived upwind from the dispersion plume of the petrochemical complex. The statistical analysis showed a significant frequency of wheezing in the last 12 months as compared to the reference group (OR 1.81, 95% CI 0.94-3.50) and this is more obvious among boys (OR 2.5; 95% CI 1.21-5.18) after controlling the confounders such as age and community (19).

There was no significant difference in terms of prevalence of respiratory symptoms among children aged 6 to 7 years for both groups (3). Meanwhile, children aged 13 to 14 yr who lived 1 km from the petrochemical industry, had significantly increased prevalence of nocturnal dry cough as compared to the reference area (P<0.001).

A recent study (20) also showed greater prevalence of respiratory symptoms among primary

school children aged 10 to 12 yr who was living 1 km from the Kertih Petrochemical Industry, Malaysia as compared to the reference group; children who were living in 10km distance from the plant. The prevalence ratio cough, phlegm, chest tightness and wheezing were 5.09 (95% CI 2.23-11.65), 9.66 (95% CI 2.10-44.46), 9.08 (95% CI 1.09-75.0) and 9.07(95% CI 1.89-25.2) respectively. These indicate that proximity to the industrial zone, especially petrochemical plant play a significant role in worsening the respiratory health.

Lung function status

Spirometric test is frequently used to assess lung function status through a deep inhalation and expiration process via mouthpiece attached to a device namely spirometer. This measurement is reflecting a cumulative lung growth up to the age of children. In other word, children with highest lung function possess highest lung growth. In this review, several scientific studies have been identified demonstrating lung health condition among children living near the petrochemical industry. For instance, children who lived in the industrial area demonstrated significant decrease in forced expiratory volume in one second (FEV_1%) and the ratio of forced expiratory volume in one second over forced vital capacity (FEV_1/FVC%) as compared to the comparative group (P<0.001) (16). Statistical analysis also showed that the parameter of lung function test, FEV_1%, and FEV_1/FVC% had a significant negative association with PM_{10} concentration, (0.408 and -0.661), and $PM_{2.5}$ concentration in all sampling areas (0.414 and 0.672) respectively. In other words, high concentration particulate matter in ambient air of sampling area could impair lung function health. A cross sectional study (21) also demonstrated the same finding with the decrement of lung function among the exposed group with a prevalence rate for FEV1 -10.3% (90% CI -15.0-6.0%). Another study (20) also showed a significant decrease in FEV_1/ FVC% predicted between the exposed and comparative groups. However, FEV_1 and FVC demonstrated similar outcomes for both the respondent groups. Besides that, the authors also highlighted that the reduction of in FEV_1/ FVC% among the exposed group was influenced by high concentrations of indoor PM_{10} and NO_2, with an OR of 1.08 (95% CI 1.01-1.16) and 1.92 (95% CI 1.07-3.45).

Discussion

Factor affecting health outcome: Proximity

The majority of studies on petrochemical air pollutants exposure clearly characterized people who live within the specific radius (less than 5km from the industry) as the exposed group. Meanwhile the reference groups were residents living more than 10km and up to 130 km, and being characterized with low pollutant exposure (low traffic density). In contrast, a study (19) classified the exposed and control group based on wind exposure and respondent's location. The authors considered resident residing in location against the direction of wind as a community with less exposure to dispersion plume. However, in that study, the authors did not mention the interpretation of dispersion plume quantitatively, and this might bring up confusion in the understanding level of proximity of the source. Regarding the association between health effect and proximity to point source, several studies had concluded that exposure to petrochemical air pollutants bring significant respiratory health effects among children (16, 17, 19-21). In contrast, exposure to petrochemical air pollutants will not give significant health impact to the community living in close proximity to the petrochemical plant (3, 18, 22).

Behaviour emission air pollutant

Pulmonary health effects may vary between multiple studies, as the concentration and composition of air pollutants emitted from petrochemical plants are different. The emission of air pollutant relies highly on predominant wind direction, wind speed, relative humidity, sun radiation, precipitation and geographical factor. In addition, the industrial age, crude oil quality, production technology, pollution control technology, end product and by-product petrochemical productions are the vital variables in governing the composition of petrochemical air pollutants and adverse health

impacts. The existence of other industrial activities, construction activity and traffic pattern must be clearly characterized in describing the site of location that is to be studied because these elements can also impair the atmospheric quality (3).
Most of the studies related to petrochemical exposures are cross sectional studies, meaning that the investigation on health effects was conducted at a single point in time within one season only and therefore may create bias in reflecting real exposure. In other word, investigation during selective season may ignore the possibility of higher exposure of air pollutant during other seasons. The emission from the petrochemical plant from time to time may differ in terms of pollutant concentration as it strongly relies on seasonal variation, pollutant interaction and heterogeneity (23). The authors reported that air pollutant concentrations in different seasons might cause different health outcomes.
This evidence is supported by Cetin et al. (1) regarding high ambient VOC concentrations emitted from the petrochemical industry during summer season as compared to other seasons in Turkey. Meanwhile, nitrogen dioxide was recorded to be higher during the summer in comparative studies of microenvironment during winter and summer season (24). Hence, seasonal variability must be emphasized clearly in any comprehensive studies with an association with air pollutants and health outcomes.

Exposure assessment

Various tools are used in air quality studies in order to obtain quantitative data on petrochemical air pollutants, including fixed air quality monitoring station, ambient air sampler and individual air sampler. Based on petrochemical related literatures, four studies used ambient air sampler (15, 16, 20, 21), three studies used data obtained from local air quality monitoring station (18, 19, 22). Data obtained from local air quality monitoring stations constitute of a broader area. They can be used as a rough approximation or estimation of the actual exposure. However, the selection is representative of air quality monitoring stations, which plays a significant role in determining the accuracy of exposure.
The choice of representative background monitoring station for one sampling area must consider the distance between urban and peri-urban areas (25). For instance, if the study area was located within 2 km from the urban or peri-urban, the station will be selected as representative air quality station. However if the study area is located in a peri-urban area, but there were no station within the 5km radius, the researcher have the option to measure the respective air pollutant at all nearby stations.
There were no studies mentioning the distance of the representative station with study area except de Moraes et al. (19). The secondary data obtain from local air quality monitoring station may be imperfect due to gaps in monitoring network terms of the placement of the monitoring stations. Bhopal et al. (18) did mention the existing gap in air quality data from January 1992 until September 1994. Regarding personal air sampler, a single study used personal air samplers to measure indoor and outdoor air pollutants (15). It is important to note that a personal measurement does not provide a more valid data than a stationary measurement as it is often influenced by other sources than those on the focus of the point source emission. It thus may contribute to the additional confounding factor (26).
Apart from that, there is also air quality modelling approach, which had been used in elaborating exposure to petrochemical air pollutants. For instance, Smargiassi et al. (15) used dispersion modelling approach in assigning a comprehensive individual exposure by measuring daily SO_2 at two fixed monitoring sites where SO_2 located close to the refineries and estimate from AERMOD (American Meteorological Society/ Environmental Protection Agency Regulatory Model) atmospheric dispersion model. From this modelling, the authors are able to map the level of pollutant concentration and make a rigid conclusion on the association between SO_2 exposure from a petrochemical industry and admission to the emergency department due to asthma. This model is very useful and applicable in representing the point source

exposures in areas especially where there is no local monitor; or where monitors are not close enough to represent appropriately exposure to emission sources, more than 5 km radius. Other than that, air quality modelling approach in the form of a meteorological estimated exposure had been used in a study by White et al (17) as a cheapest tool to represent a linkage between exposure refinery air pollutants and respiratory symptoms.

Conclusion

The installation of petrochemical refinery and storage facilities emitted abundant of toxic air pollutants The emission might be controlled efficiently through the presence of effective pollution prevention technology, however the air pollutant able to escape accidently due to operational dysfunction or human error. Things become complicated if the petrochemical air pollutants failed to be controlled efficiently. Failure to do so will contribute negative impacts to the public health, especially to residence living close to the petrochemical area. Furthermore, children are frequently nominated as the susceptible population as they tend to inhale greater inhalation doses of air pollutants even though they have low lung capacity (7, 27).

Most of the epidemiological studies demonstrated that children living within the 5km radius from petrochemical industry have a greater risk of respiratory symptoms, poor lung function and asthma attacks. The poor respiratory health reported can reduce their performance in class; affect daily attendance and daily activities (13). Preventive measures must be taken in order to ensure children in the neighborhood can survive under low or minimal petrochemical air pollutants emission either in term of technology itself, stringent regulation or environmental barrier.

Ethical Consideration

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission) have been completely observed by the authors.

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