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INDOOR ENVIRONMENT SUSTAINABILITY OF RESIDENTIAL-INDUSTRIAL HOUSING IN MALAYSIA

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ABSTRACT: The importance of sustainable development has been internationally recognised and the principles have been widely used as an impetus for promoting housing sustainability. In the situation of mixed-use urban development in close proximity to heavy industrial areas in Malaysia, rising incomes are developing hand in hand with higher expectations for better and more sustainable housing designs. Negative environmental impacts due current deficiency in Malaysia's approach to the implementation of sustainable development principles can be seen in this case study of the Pasir Gudang Industrial Area in Malaysia. This study aimed to highlight the level of residents' satisfaction with living near the industrial area, and to relate their awareness of the relevance of sustainable principles with indoor environmental conditions, which found that the residents' has limited understanding of the environmental problems in their indoor living conditions and in their neighbourhoods. This study has suggested that proactive and integrated involvement by housing authorities from all levels of government in Malaysia should be encouraged in order to rationalise the approaches to develop better planning solutions for such mixed-used urban developments. This initiative should then encourage housing vendors to provide innovative 'smart' technological changes to their projects and so, to achieve a new direction in sustainable housing development.

Key words: *Housing, Indoor Air Quality; Mixed-use Urban Development; Residential-industrial Neighbourhood; Sustainibility.*

1.0 Introduction

Malaysia's rapid economic and industrial growth is characterised as a mixed-use urban areas development that incorporate residential industrial areas. These residential areas support the industry by providing them manpower. This type of mixed-use urban development helps to promote the aims of Agenda 21 for Sustainable Construction in Developing Countries which recommend the development of the economic system (duPlessis, 2002). It involves rapid transformation of urban built environment (Alias Z.,

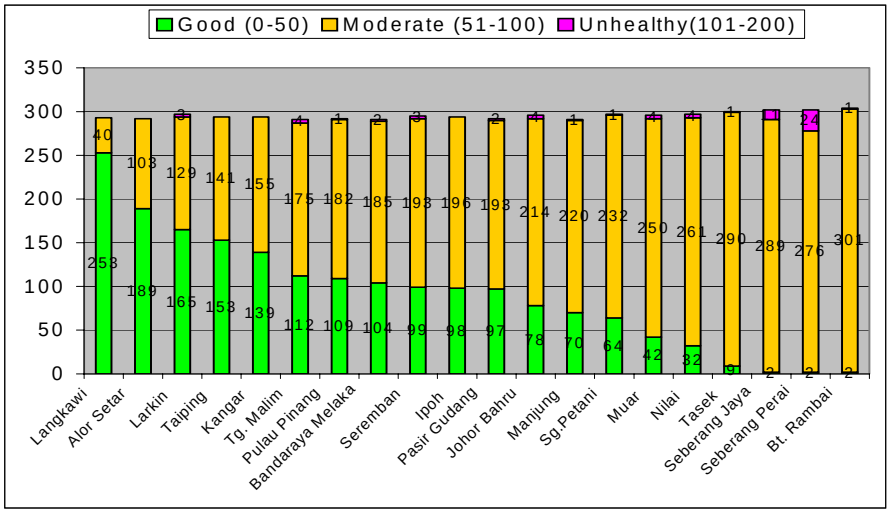
1992). There will be very much environmental deterioration in the third world due to industrialisation, depletion of traditional sources of energy and raw materials, constant population growth, pollution of natural resources, the destruction for economic ends of various animals and plants species, water, air and noise pollution, and the negative inherent consequences of industrial pollutants (B. Hamm & Muttagi P.K., 2001).

In Malaysia, centres that experience prolific growth in population and housing well above the national average are the Klang Valley (encompassing Kuala Lumpur and its conurbation), Georgetown-Butterworth (including the fringes), Johor Bahru Pasir Gudang Industrial Zone, and a few industrial zones on the west coast, east coast, and in Sabah and Sarawak (STRATEGIES, 1998). These major growth centres are expected to evolve into principal localities for economic opportunities, jobs and innovations, due to rapid industrialization and urbanisation. It is predicted that these rapid growth centres will attract increasingly more people and, therefore, will generate greater demand for housing and other social services like modern communications, and for the provision of infrastructure.

Rapid economic development associated with urbanisation and industrialisation produces both positive and negative impacts on housing development. The lack of usable arable land for urban development further results in some housing estates being nestled within industrial establishments. According to the United Nation Economic and Social Commission for Asia and the Pacific (UNESCAP, 2003), it is common for the residents within industrial establishments to face the worse indoor quality problems. Carbon dioxide, carbon monoxide, radon gas, formaldehyde off-gassing, and combustion products, are some of the gases commonly found inside the homes of these areas.

STRATEGIES (1998) also reported that during the early stages of industrialisation in Malaysia, environmental problems stemmed predominantly from the relative lack of planning development, and from inadequate infrastructure. Rapid economic development through urbanisation, industrialisation, and from other land-use activities, later gave rise to water, air, and land pollution, and these factors persist today as serious environmental problems. Air pollution is approaching critical levels in a number of urban areas of Malaysia such as Kuala Lumpur, Petaling Jaya, Johor Bahru, and Prai. The problem is expected to grow both in complexity and extent in the face of expanding manufacturing activities, and will be exacerbated by an increased reliance on individually-driven vehicles for mobility.

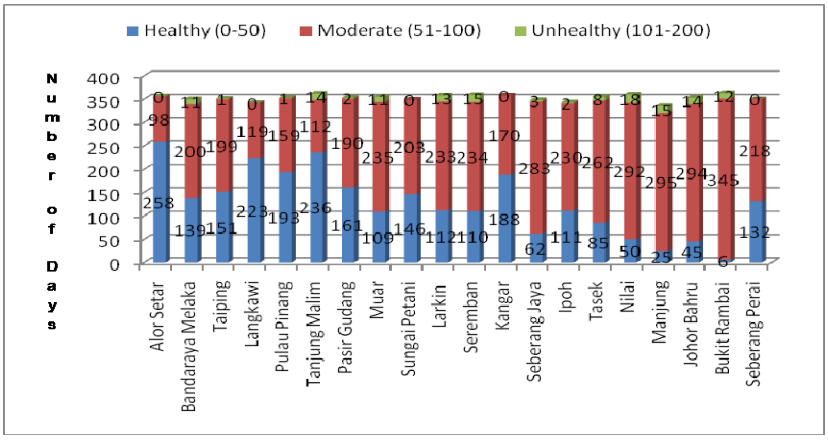
The following Figure 1& 2 presents the annual west coast peninsular Malaysia air quality report for the year 2002 and 2006 as supporting evidence. By taking Pasir Gudang Industrial Area (PGIA) as the example, this figure illustrates that in the year 2002, PGIA experienced 97 good days, 193 moderate days, and 2 days of unhealthy outdoor air quality conditions (DOE, 2003).



Source: Malaysian Environmental Quality Report 2002

Figure 1: Air quality of west coast peninsular Malaysia, 2002 (DOE, 2003)

The occurrence of 193 moderate days within (51-100µg/m^3) which were recorded for Pasir Gudang in outdoor air quality of for the year 2002, indicates that unhealthy indoor air quality occurs here at level that exceed the Malaysian Indoor Air Quality (MIAQ) Code of Practice recommended level 50µg/m^3. These conditions remain after years in which the air quality of west coast peninsular Malaysia for 2006 reported slightly similar pattern as shown by Figure 2 below.



Source: Malaysian Environmental Quality Report 2006

Figure 2: Air quality of west coast peninsular Malaysia, 2006 (DOE, 2007)

The recorded of 190 moderate days within along with 2 unhealthy days were recorded for Pasir Gudang in outdoor air quality of for the year 2006. This is again indicates that unhealthy indoor air quality occurs here at level exceeded the MIAQ recommended healthy level. While the proportions show that this area enjoys moderate conditions of air quality, the results from on-site measurement of this study at the selected houses in Pasir Gudang provide evidence that the indoor air quality problems and contaminants are drawn from outside.

Useful Indoor Air Quality (IAQ) guidelines have been produced by the World Health Organisation's (WHO) (World Health Organization Regional Office for Europe, 2000). Table 1 below describes the long-terms goals of indoor air quality parameters.

Table 1: Word Health Organizations long-term goals of IAQ (World Health Organization Regional Office for Europe, 2000)

Parameter	**Averaging time**	**Limit for acceptable indoor air Quality**
Gaseous pollutants		
Carbon monoxide	8 hours 1 hour	9 ppm 35 ppm
Nitrogen dioxide	1 hour not to be exceeded more than once a month	0.1 – 0.17 ppm
Ozone	8 hours 1 hour	6 pphm 3 pphm
Particulate pollutants		
Smoke	Annual mean	$40\mu g/m^3$ (90% of observation below this limit)

In Malaysia, the Department of Safety and Health of the Ministry of Human Resources has, however, recently produced an IAQ Code of Practice. This was launched in July 2005 (DOSH, 2005). This code of practice will apply to all non-industrial places of work in industries listed under Schedule 1 of the Occupational Safety and Health Act 1994 (Act 514). A list of indoor contaminants and the maximum allowable limits are shown in the following Table 2. Although this code of practice is not meant for residential premises, it can be used as a guide for setting the limits of concentration that are allowable in an indoor environment.

Table 2: List of contaminants and the maximum limits (DOSH, 2005)

Indoor Air Contaminant	**Eight-hour time weighted average airborne concentration**	
	ppm	**mg/m^3**
Carbon dioxide	C1000	
Carbon monoxide	10	
Formaldehyde	0.1	
Respirable particulates		0.5
Total volatile organic compound	3	

Where:

- *C is the ceiling limit*
- *mg/m^3 is milligrams per cubic meter of air at 25^{o}C and one atmosphere pressure*
- *ppm is parts of vapour or gas per million parts of contaminated air by volume*

Malaysia has, however, experiencing high chances of negative environmental impacts due to its efforts to boost the rapid industrialisation of its economy. Many aspects of the residential environment and living conditions of houses located near industrial areas potentially affected. The deficiency in the nation's approach towards implementing sustainable development in this type of mixed-use urban development is evidenced in the case of Pasir Gudang Industrial Area.

This study, therefore, aimed to highlight the level of residents' satisfaction with living near the industrial area. The objectives of the study are to relate their awareness of the relevance of sustainable principles with indoor environmental conditions, in which on-site indoor air quality measurement are also conducted to determine the response from the residents. Results from this study appeared in that the residents' has limited understanding of the environmental problems in their indoor living conditions and in their neighbourhoods.

2.0 Methodology

The Pasir Gudang Industrial Area (PGIA) in Johor State, Malaysia, was chosen as the case study area for this research. It was originally a rubber and oil palm plantation estate, and has now a total development area of 13,132 hectares. PGIA consists of Pasir Gudang Port, heavy industries (steel, oil and gas production), medium industries (electrical appliances, food processing etc), light industries (components), residential areas, and other amenities. The entire area has approximately 13,000 houses and units. It was built according to a housing scheme, and was developed by building companies. This area is experiencing a rapid growth in residential numbers, and at the same time, it is increasingly exposed to industrial pollution. There is an urgency to respond to issues

such as need for appropriate housing design, a need to improve the quality of the resident's indoor environments, and the need to identify any remedial measures that could be put in place to mediate these concerns.

This research employed a randomly administered questionnaires survey and an on-site measurement methodology for gathering air quality data. The questionnaire survey sought information about the house occupant's satisfaction with the house design and layout, and with their perceived indoor environments. The questionnaire explored their levels of satisfaction about natural indoor lighting, inside air movement, dust/soot intrusion, indoor temperatures, and the occurrence of damage to their housing materials. The house occupants were also asked about the frequency of their health symptoms, and about their awareness of the principles of sustainable development. 205 responses were received in total from an overall number of 300 distributed questionnaires. This number represented a response rate of 68.3%. The random distribution of questionnaires to participant respondents resulted in the inclusion of 11 suburbs in the data collection process. These suburbs were considered to be located within reasonable distances of Pasir Gudang Industrial Area. Taman Air Biru, Taman Bukit Dahlia, Taman. Mawar, and Tg. Puteri Resort, are all located within the 1km zone around the industrial area. Taman Cendana, Taman Pasir Putih, and Taman Scientech, are situated in the 2km zone, and Taman Nusa Damai, Taman Cahaya Masai, Taman Kota Masai and Kg. Kopok Baru fall, within the 3km zone.

In order to verify the house occupant's about their indoor environments, both outdoor and indoor air quality data measurement were carried out in Pasir Gudang in year 2005. These measurements were conducted using a MiniVol Portable Air Sampler (Airmetrics, 2001) and DirectSense IAQ Pocket PC (Graywolf, 2003). Three houses were selected for measurement. These houses were chosen according to two criteria: the distance from the industrial area; and the type of house. Suspended particulate and gas contaminant measurement were made in two double-storey detached houses at a distance of 1 and 3km from the main industrial area. A third measurement was made in a single-storey detached house at a distance of 2km from the industrial area. Similarity of house type to the ones for measurement at 1 and 3km was provided by the fact that this latter house had a mezzanine floor. An on-site measurement also has been conducted in year 2008 to identify the recent outdoor and indoor air quality. A house has been selected for this returned visit.

3.0 Results And Discussion

The questionnaires survey identified three major aspects affecting Pasir Gudang residential indoor environment quality. These are: the house design and layout; the indoor environmental conditions; and the respondent's lack of awareness of sustainable development principles which may have resulted in not all of the associating the current state of their health to their reported environmental conditions.

Variables affecting house design and layout were ranked by order of importance. Although more than half of the respondents (55%) had been satisfied with house design and layout with only13.2% being dissatisfied, room size (32.2%) was most favoured by respondents as the most important source of dissatisfaction. This was followed by ventilation (29.3%), orientation/layout (28.7%) while building materials (25.8%) was a slightly less cause for concern.

Over two thirds of respondents (66.9%) claimed the occurrence of pollution from dust and soot in their houses. Most respondents viewed pollution from industrial emissions and transportation (63.4% and 50.8%) as being the first and second sources for this respectively. Nearly half (48.8%) of the respondents were unhappy with the poor natural air circulation in their house, and poor ventilation (40.9%) was scored as the most important cause of this. More than one third (36.1%) agreed that they had poor natural lighting, and insufficient openings or the size of doors and windows was considered to be the primary cause. Only 30% of respondents were concerned by the high humidity, but humidity from outdoors was marginally considered to be the main cause (27.3%). High numbers (over 50%) noted corrosion and discolouration effects on their building materials and furniture. UV light penetration was considered to be the most likely cause since 81.5% of respondents lived on intermediate lots with no side windows. Discolouration effects were also not evenly distributed across the study area. The highest proportion of reports was by respondents living closest to the main industrial area (59.1% of those in the first kilometre around the industrial area by comparison to 36.6% and 40.8% further away). Poor quality of building materials was also, thus, rejected as a possible cause. This indicated that the most likely occurrence of damage to building materials came from acid rain which resulted from industrial area emissions.

Result from on-site measurement conducted in three occasions support the effect of corrosion and discolouration. Table 3.0 below illustrates the results of the first round of air quality measurement in January 2005. A second round of on-site measurement was conducted in December 2005 in order to confirm accuracy of the earlier data which portrays by Table 4.0. The measured indoors suspended particulates reading ranged $125\mu g/m^3$ – $291.5\mu g/m^3$. The third round on-site measurement conducted in Mac 2008 displays by Table 5.0. The indoor on-site measurement captured a suspended particulates at $120\mu g/m^3$ along with $180\mu g/m^3$ at outdoor. These measurements are above allowable level of $40\mu g/m^3$ – $50\mu g/m^3$ as proposed by WHO (WHO,1998) and Malaysian Indoor Air Quality (MIAQ) Code of Practice (DOSH, 2005).

Table 3: Results of indoor and outdoor suspended particulates and carbon monoxide (8 hours measurement) in Pasir Gudang – January 2005

Location	**House Type**	**Date of sampling**	**Suspended Particulates (PM10) µg/m^3**		**Carbon Monoxides (CO) ppm**	**Temp. (^{o}C)**
			Outdoor	**Indoor**	**Indoor**	**Indoor**
Taman Air Biru	Double-storey detached terrace	22/1/05	250	250	3.3 – 5.2	31.2-32
Taman Pasir Putih	Single-storied detached terrace	23/1/05	229.2	166.7	3.8 – 4.1	33.6 - 34
Taman Nusa Damai	Double-storey detached terrace	24/1/05	208.3	164.6	3.4 -4.3	30.6-31

Table 4: Results of indoor suspended particulates and carbon monoxide (8 hours measurement) on two occasions in Pasir Gudang – December 2005

Location	**House Type**	**Date of sampling**	**Suspended Particulates (PM10) µg/m^3**		**Carbon Monoxides (CO) ppm**	**Temp. (^{o}C)**
			Outdoor	**Indoor**	**Indoor**	**Indoor**
Taman Air Biru	Double-storey detached terrace	21/12/05	125	125	1.6 – 3.1	30.7 - 31
		27/12/05	125	125	1.8 – 2.4	29.6 - 31.9
Taman Pasir Putih	Single-storied detached terrace	22/12/05	186.5	125	1.9 – 2.7	29.6 - 30.4
		28/12/05	291.5	230	1.3 – 1.8	29.3 – 30.1
Taman Nusa Damai	Double-storey detached terrace	23/12/05	202.4	166.7	0.9 – 2.9	28.2 - 29
		29/12/05	290.7	250.0	0.7 – 2.9	29 – 31.3

Table 5: Results of indoor suspended particulates and carbon monoxide (8 hours measurement) on two occasions in Pasir Gudang – February & March 2008

Location	**House Type**	**Date of sampling**	**Suspended Particulates (PM10) µg/m^3**		**Carbon Monoxides (CO) ppm**	
			Outdoor	**Indoor**	**Outdoor**	**Indoor**
Taman Air Biru	Flats/units	22/03/08	170	-	2.0 – 3.8	
		23//03/ 08	213	-	2.4 – 4.2	
Taman Scientex	Double-storey detached terrace	09/02/08	181	120	2.2 – 3.0	0.9-2.0
		22/03/08	155	-	2.0 – 2.8	

This actual air quality data, therefore, serious health and environmental significance for the residents of Pasir Gudang who have to deal with the issues of indoor comfort, dust/soot intrusion, material damages, and health complaints in this kind of residential-industrial neighbourhood on an everyday basis. Just under a third of respondents (30.7%) felt that they were living in unhealthy conditions, although higher numbers (36.9%) agreed that they had frequent health problems. This suggested that some may not have recognised that the environment in which they lived was the most probable source of their frequent health problems.

A high number of respondents admitted that they were not aware of the concept of sustainable development. This lack of awareness of these principles (67.3% of respondents) appears to have major factor in limiting the responding residents' understanding of the environmental problems that are occurring in their indoors areas and neighbourhoods. This high score provides strong evidence that Malaysia need more initiatives to promote the ideas and awareness of sustainability among house occupants.

The results of the questionnaires surveys and on-site measurements of air quality in Pasir Gudang Industrial Area during 2005 and 2008 indicated that this residential-industrial indoor housing environment suffered contamination from outdoor sources. This condition is unsustainable? This introduces doubt about the implementation of current development policies and practices including the use of zoning, the environmental management system, and also the adequacy of the present system of integration of responsibility amongst stakeholders. There is, also, now only limited pressure on the legislators at federal, state and local levels, on housing designers and developers, to improve the quality of the housing product. All levels of government in

Malaysia, and all stakeholders, whether they are public or private decisions-makers, must integrate and rationalize their approaches in order to produce better sustainable planning solutions for residents of mixed use urban developments.

4.0 Study Recommendation

Incorporation of sustainable development principles for communities is the new approach needed for modifying human behaviour in order to ensure that we can sustain the living environment, and the economy and society. There is no doubt that current conditions which include such as factors as low incomes and knowledge levels makes for the slow community acceptance of sustainable initiatives. A greater knowledge and awareness of these are crucial aspects need to be considered when promoting housing development sustainability.

In order to promote housing development sustainability, the relevant authorities, which include the Ministry of Housing, and the local authorities and housing stakeholders, should provide sufficient initiatives to encourage more integration on effort in applying sustainability concepts. The Ministry of Housing and local authority have to facilitate the efficient processing of housing development application without compromising any opportunity for the application of unsustainable development practices. The local authorities also need to play their role in enforcing the application of and compliance with sustainable guidelines. These bodies can also influence the development of better sustainable guidelines for housing by contributing their own particular knowledge of local conditions to the planning processes. A better planning process can be achieved by integrating this responsibility with that of other agencies such as Department of Environment (DOE) and Department of Safety and Health (DOSH). DOE and DOSH should be able to make specific and informed recommendations for better indoor/outdoor air quality in all residential-industrial areas of Malaysia by insisting on stricter environmental controls on the industries in these areas. Developers could also be to promote sustainable concepts to encourage market-demand initiatives which would be likely to make the communities accepting the sustainable house.

In pursuit positive objective, the local authorities would be capable of utilising their administrative power to ensure compliance to the guidelines or related criteria for any development in their region. Local authority must include more sustainable development principles in their planning must make more intensive efforts to ensure the local communities gained healthier living standards in the Master Planned Communities (MPC). These MPCs should aim to provide an ecologically sustainable basis for future mixed-use developments. Respect for biodiversity will be substantially integrated into the physical and material aspects of any development proposed under a MPC. The MPC's should, themselves, facilitate the development of an awareness of sustainable housing development issues for all participants. MPC's work by demonstrating sustainable principles and help communities to determine core development elements. These include: the need for environmental protection; the provision of housing of

economic development and of transportation services. They also provide an understanding base for developers or builders to use, and from which to provide innovative solutions which an then applied to issues of sustainability or environmental sensitivity. It would be expected that improved house designs would then translate to improved indoor environment.

Future MPC's provide more guidance in regards to orientation, space layout, and the indoor environment quality for homes. All developers and builders could improve their housing development strategies with respect to sustainability by focusing more on the importance of building for indoor health and comfort than merely on cost. This approach should also motivate them to improve the physical conditions of their houses by providing good designs that are responsive to both climate and other environment conditions, while at the same time, taking responsibility for the maintenance of biodiversity and natural systems. MPC's should also encourage all housing developers to broaden up their viewpoints, and this, in turn, should result in a wide variety of building styles, house floor plans, lot sizes, landscaping styles, and of course, pricing options, which should then be more widely available throughout the Malaysian community. This initiative might then encourage housing vendors to provide innovative 'smart' technological changes to their projects and so, might achieve a new direction in sustainable housing development.

5.0 Conclusion

The above discussion explains the consequences for residential indoor environmental quality of not incorporating the principles of sustainable development in housing developments in residential-industrial neighbourhoods in Malaysia. It has been recognised that Malaysia needs an expanded integration within all sectors of the housing industry in order to promote these principles. In the provided example of the Pasir Gudang Industrial Area, little progress can be made without first improving the level of public awareness and consent. A high level of public awareness of sustainable development principles can give an impetus to an expanded public participation in development applications, and can encourage more public comment on such matters. This should ensure a bright future and more general public acceptance of the sustainability agenda itself, and for the proposed Master Planned Communities which are to be implemented for better sustainable living.

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