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A Study on Identification of Significant Environmental Aspects and Impacts of Piling and Foundation Works

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ABSTRACT The construction sector, which can contribute to a nation's economic growth is vital for the development of any nation. Improper management and poor control measures in this sector could lead to negative impacts to the environment such as air pollution, noise pollution, dust problem; solid and hazardous waste disposal and human health. Therefore this study was undertaken to identify significant environmental aspects and impacts of piling and foundation works, which is an early phase for any construction project. Identification of environmental aspects and impacts is very important in decision making to reduce the risk and possible impact at early stage of a construction process. Significant environmental aspects and impacts were identified using both qualitative and quantitative methods [1]. There were thirty one (31) environmental aspects from filing and foundation works identified. The most significant aspects were the activities from the drilling process, transportation, machinery activities and generator set (gen set) operation. Mitigations measures were identified which involved sediment control, equipment fuels and lubricants control and air pollution control. The mitigation measures are important to help the construction sector manage their activities in minimizing any potential impacts.

ABSTRAK Sektor pembinaan yang banyak menyumbang kepada pertumbuhan ekonomi adalah sangat penting bagi pembangunan sesebuah negara. Pengurusan yang tidak cekap dan langkah pengawalan yang lemah dalam sektor ini membawa kesan yang negatif kepada keadaan persekitaran seperti pencemaran udara, pencemaran bunyi, masalah debu dan habuk, pembuangan sisa pepejal dan sisa berbahaya serta masalah kesihatan manusia. Jesteru, kajian ini dijalankan bagi mengenalpasti aspek dan impak terhadap alam sekitar yang signifikan akibat daripada proses penanaman cerucuk dan kerja-kerja pembinaan asas tapak. Pengenalpastian aspek dan impak alam sekitar yang signifikan dijalankan dengan menggunakan kaedah kualitatif dan kuantitatif [1] di mana 31 aspek alam sekitar telah dikenalpasti daripada proses penanaman cerucuk dan kerja-kerja pembinaan asas tapak. Aktiviti yang dikenalpasti memberi kesan yang signifikan terhadap alam sekitar terdiri daripada proses pengorekan, pengangkutan, aktiviti daripada mesin-mesin yang terlibat dan juga operasi set generator (gen set). Langkah-langkah pengawalan bagi mengatasi masalah ini termasuklah pengawalan sedimen, pengawalan minyak dan pelincir peralatan serta pengawalan pencemaran udara. Langkah-langkah pengawalan ini adalah penting bagi meminimakan sebarang impak yang dijangka berpotensi memberi kesan terhadap alam sekitar akibat daripada aktiviti pembinaan.

(Environmental aspects and impacts, construction process, EMS)

INTRODUCTION

Malaysia's rapid economic growth and its aspiration to become a developed and industrialized nation has created a conducive environment for growth and simulated changes in development of the construction industry. The construction industry plays an important role in establishing the infrastructure required for socio-economic development and directly contributes

to economic growth. The Eighth Malaysian Plan (2001 - 2005) [2] recognized that the construction sector, which grew rapidly at 13.4 per cent per annum during the 1996 - 1997 periods, arose from active property market and accelerated development of infrastructure project. With continuous improvements in the Malaysian construction business environment, the market has attracted many new players. The Construction Industry Development Board (CIDB) recorded that registered contractors has risen from 5288 in 1996 to 62019 as at the end of December, registering 1172% growth [3]. According to Fadhlin [4], construction works undertaken for the public sector constituted more than 50 percent of total new construction works. Construction has consequential benefits for individuals by providing employment in building work or by stimulating business activities that provide wider employment opportunities [5]. The construction activities involve different parties at different stages. The development of a construction project from concept, feasibility study and preliminary design to completion of the project takes a long time and involves many phases and stages [4, 6]. It needs many people with different skills and various interests, a good materials procurement system and the use of equipment. All of these complex conditions have to be handled with good co-ordination to provide a smooth flow of activities. Although the construction sector plays an important role for development and economic growth, the adverse impact caused should not be avoided. Therefore, it is important to identify any activities at an early stage of the construction that could have significant aspects and impacts towards the environment.

Piling and foundation works is one of the construction activities in primary work packages. According to Peck *et al.* [7], foundation engineering is the art of selecting, designing and constructing the elements that transfer the weight of a structure to the underlying soil or rock. Heavy or large structures, such as tall buildings or massive complexes require foundations which can hold the load of thousands of tons, often in unstable or difficult conditions. As construction works lead to the source of significant negative impacts to the environment [8], it is important to incorporate environmental consideration in choosing the types of foundation and construction procedures. Piling and penetrative ground improvement methods are commonly used during the redevelopment to allow structures to be found. According to Kamon [9], ground improvement methods can be classified into five techniques, namely as displacement, dewatering, densification, solidification and reinforcement. However, environmental regulators are concerned that piling and penetrative ground improvement methods have the potential to create adverse environmental impacts, particularly on water, land, air and noise pollution.

Pile driving is an inherently noisy operation and severe environmental restriction should be enforced [10]. Related to noise pollution is the potentially more serious problem of ground vibrations and the consequent hazard posed to adjoining structures. In the case of bore piling, much of the noise emanates from the bore piling equipment engine and it is possible to reduce the steady noise level by improving the soundproofing quality of the engine enclosure [10]. In view of the Kuala Lumpur City Hall by-laws requirements on the control of noise pollution and vibration control, the trend is to build high rise structures on bored pile foundation [11].

The bored piling works, as required by the specific project element design, are necessary for the foundation support to the sub and superstructure of the specified project. The pile boring operations are performed using hydraulic, rotary drill rigs. The boreholes will be stabilized with drilling fluid such as bentonite and a temporary casing in the upper layer once the bore is progressed beyond the toe of the casing. After the pile location has been accurately set, excavation of the soil inside the casing is carried out. If extensive fluid loss occurs, drilling will be stopped immediately. The bore will be backfilled with the excavated material and re-drilling will then take place. When reaching the final depth, loose and remolded material and debris will be removed mechanically. Bentonite used for drilling fluid presents strong colloidal properties and it becomes gelatinous and viscous fluid [12]. This could cause environmental pollution. In line with the issues highlighted, this study was undertaken to investigate potential environmental aspects and impacts for foundation and piling works of a high-rise building construction project and to recommend mitigation measures that will able to assist other similar projects.

OBJECTIVES OF THE STUDY

This study is focused only on identification of environmental aspects and impacts for piling and foundation works. Environmental analysis was conducted on the whole piling and foundation process to identify potential environmental aspects of activities under the control or influence of the business in order to aim the objectives of this study which are as follows:

1. To identify potential environmental aspects and impacts for foundation and piling works of high-rise building construction.
2. To analyze the significant environmental aspects and impacts by using both qualitative and quantitative method.
3. To identify and compare the strengths and weaknesses of each method that had been used in the study.
4. To identify suitable measures that could be used to mitigate the significant impacts.
5. To recognize environmental impact towards surrounding environment; i.e. buildings and public.

With the objectives as listed, this study is essential in identifying environmental impacts from piling and foundation works during construction processes towards surrounding environment by identifying the aspect for their activities. The need to mitigate the environmental impact is the responsibility of all parties that are related to the construction industry. As it is an important industrial sector for all nations, construction industrial sector must ensure their activities are towards sustainable development.

MATERIALS AND METHODS

The study was conducted on piling and foundation work of a forty-four stories building. Site visits were conducted during the whole process of piling and foundation stage. Internal audit findings were also reviewed for comprehensive understanding and baseline information of the project with respect to the environment. All activity's input and output were identified and recorded. Two types of assessment, qualitative and quantitative adapted from Wang and Malaysia Standard (MS) ISO14004 [1, 13]] were used to identify the significance of aspects and impacts.

Method A (Qualitative)

Three aspects are concentrated in identifying significant impact by using Significance Matrix Assessment (SAM) which is identifying probability, identifying severity and identifying the level of control. Table 1 shows the Significance Assessment Matrix which has been used in Method A, whereas Table 2 shows probability criteria which has been considered in SAM. The column that is appropriate for the probability is selected and this will significantly associated with different severity criteria. Table 3 shows priority rating in SAM where there are four key criteria have been determined in order to assess the significance of priority. The response to these questions will define the individual level of significance for each significant criteria. Then, the significance ranking is inserted at the bottom of the column. The highest ranking in any column will define the maximum significance ranking for the impact under review. Table 4 shows the level of control which has been used in SAM where the level of probability is adjusted again according to the level of control to get the final judgment of the significance level. In this method, the probability of the impact is the driving force. The level of control is important to reduce or increase the probability or to remain the probability level. Method A categorizes the priority of significant impacts as 'Top', 'High', 'Medium' or 'Low'. Both of 'Top' and 'High' priority are considered as significant in this study.

Method B (Quantitative)

This is a quantitative method which involves a scoring scheme. It consists of five key criteria on environment and four key criteria on business. However this method places higher attention on the environment compared to business concerns, as can be seen through the scoring matrix. The order 1, 3, 5 and 7 is used as the score for each criterion to give significance score for each impact analyzed. All these criteria had been considered and scored by author's interpretation. To obtain the final score for each of the aspect, the score for each criterion is determined, and multiplied them all together. The significant impact is prioritized according to the scores, which total score for significant for this studies is identified as 1×10^5 to 1×10^6. Table 5 shows the calculations leading to significant results using method B.

Table 1. Method A – Significance Assessment Matrix (SAM)

ENVIRONMENTAL ASPECTS:		SEVERITY			ENVIRONMENTAL IMPACT : PROBABILITY			
Regulatory Compliance	**Corporate Standard**	**International Issues**	**Environment**	**Reputation**	**Very Unlikely**	**Unlikely**	**Likely/ Occasionally**	**Routine**
Not under regulatory control	No corporate standards exist	No international issues	No receptor	Would not be noticed	Low	Low	Low	Low
Release well below legal limit	Well below corporate standards	Subject to debate by NGOs / international concern	Minor impact on receptor / resource used	Community awareness (minor concern)	Low	Low	Medium	Medium
Release close to legal limits or where compliance status is not verified	Release close to corporate standards	Action being taken at government or industry level	Short term major (long term minor) impact on receptor / resource used	Likely to result in complaint from local community or staff member	Low	Medium	High	High
Release above legal limits	Release above corporate standard	Issue could prevent or limit access to overseas market	Long term major impact on receptor / resource used	Potential media coverage	Low	Medium	High	Top

Table 2. Probability criteria which had been considered in SAM

PROBABILITY CRITERIA:	
Very unlikely	Impact could arise under emergency conditions (e.g. : old machinery without services)
Unlikely	Impact could arise if control mechanism fail/no control measures
Likely/Occasional	Impact could arise after control measures during project duration
Routine	Impact arises during project construction

Table 3. Priority rating used in SAM

PRIORITY RATING	
Low	Not a priority for management
Medium	Manageable situations
High	Set specific targets & programs for improvement
Top	Immediate actions required

Table 4. The level of control used in SAM

LEVEL OF CONTROL		YES / NO
1	Very high level of physical & management control	If this is selected, reduce probability level by 1
2	Some physical & management control	If this is selected, probability level remains
3	Poor or no physical management control in place	If this is selected, increase probability level by 1

Table 5. Calculations leading to significant results (Example using Method B)

a.	**SCALE OF IMPACT**
Score	Description
1	On site only. Impacts do not extend beyond plant boundary
3	**Site vicinity, local community**
5	Regional (e.g. air basin, watershed area, etc)
7	Very large geographical region, hemisphere or global impact

b.	**SEVERITY OF IMPACT**
Score	Description
1	Not serious
3	**Minor damage or harm but clearly detectable impact e.g. within regulation limits**
5	Critical damage or harm / exceed standard or regulation limits
7	Very serious or catastrophic impact

c.	**PROBABILITY OF OCCURRENCE**
Score	Description
1	Very unlikely or rare occurrence
3	Unlikely occurrence, once per project duration
5	Probable. Likely more than once per project duration
7	**Frequent. Very likely to certain / routine**

d.	**DURATION OF IMPACT**
Score	Description
1	Less than one day during construction progress
3	Several days during construction progress
5	**During construction**

Table 5. The calculation to get the significant result (Example using Method B) (continued)

e.	**REGULATORY/LEGAL EXPOSURE CRITERIA**
Score	Description
1	No legal requirement / minor penalty for non compliance
3	**Significant legal or regulatory compliance requirements.**
5	**Major permit condition.**
	Major regulatory fines or penalties for violations or non-compliance.

f.	**TECHNICAL FEASIBILITY CRITERIA**
Score	Description
5	**Limited. Best available control technology or equivalent is already applied. Major technical challenges, disruptions or adverse impacts to product quality or productivity would occur. Alternatives are unproven for this application**
3	Reasonable. Alternative technologies exist. Implementation can occur with some limited impact to operations, productivity or product quality. Some technical barriers to overcome.
1	High. Proven alternative technologies exist. Implementation can occur with minimal technical barriers to overcome.

g.	**ECONOMIC FEASIBILITY CRITERIA**
Score	Description
5	**Very high cost. Return on investment criteria cannot be satisfied.**
3	Minimum return on investment criteria may be achieved / Investment would be considered significant.
1	Low cost. Return on investment criteria can be satisfied.

h.	**CUSTOMER BENEFITS CRITERIA**
Score	Description
5	**Marginal or negative. Application of available alternatives would have undesirable ramifications from the customer's perspective**
3	Acceptable. Application of available alternatives would be the customer
1	Preferred or desirable. Customer would prefer available alternatives

i.	**PUBLIC IMAGE / STAKEHOLDER CRITERIA**
Score	Description
5	Marginal or negative. Application of available alternatives would not have a positive impact on affected stakeholders or improve company's public image
3	**Acceptable. Application of available alternatives would have a slight positive impact on affected stakeholders or marginally improve the company's public damage**
1	Preferred or desirable. Application of the available alternatives would have a very positive impact on affected stakeholders and/ or clearly contribute to a positive public image

Total score = 3x3x7x5x3x5x5x5x3 = 3.5×10^5

Each method had been identified as having its own strengths and weaknesses. Method A could not identify the significance of each impact accordingly, within the same range. However, the level of control which has been looked in this method influence the aspect by reduces the probability. Control measurement influenced aspects by having low significant level. Even though Method B had identified available alternatives and identify scale of impact, it neglected the urgency of significant impact where the priority rating was not mentioned. Prior to the strengths and weaknesses of each method used, the combination of these two methods had been chosen to identify the significant environmental impact for piling and foundation works at site project.

RESULTS AND DISCUSSION

The site project is located within Kuala Lumpur, the city centre, between the busiest main roads, Jalan Tuanku Abdul Rahman and Jalan Raja Laut. The assessment of aspects and impacts has identified all those elements of piling and foundation works that interacts with the environment. Figure 1 shows the flowchart of overall construction process for Bore Pile and Secant Pile Wall which is the main activity during piling and foundation works at site project. Table 6 shows the activities identified for piling and foundation works, together with the aspects and impacts identified from the activities. As can be seen in Table 6, five major environmental impacts which are named as Human Health Impact (H), Land Pollution (L), Air Pollution (A), Water Pollution (W) and Non-Renewable Resource Depletion (R) that commonly take place in piling and foundation works during construction are considered in this study. There are 31 environmental aspects from piling and foundation works which had been identified from this study. They consist of thirteen (13) aspects for Human Health Impact (H1 to H13), six (6) aspects for Land Pollution (L1 to L6), four (4) aspects for Air Pollution (A1 to A4), two (2) aspects for Water Pollution (W1 to W2) and six (6) aspects for Non-Renewable Resource Depletion (R1 to R6).

Table 7 showed the result of significant impact by Method A and Method B. The result of significant environmental aspect and associated impacts result from Method A were 18 out of 31 aspects (85%) whereas associated impacts result from Method B were 13 out of 31 aspects (42%). Both qualitative and quantitative assessments had revealed that 11 out of 31 aspects (38%) identified as having significant environmental aspect and impact. From the result analysis, it shows that there are five activities that contribute to environmental impacts for depletion of nonrenewable resources; three activities contribute to air pollution, and one activity each contributes to environmental impact for land pollution, water pollution and human health impact. From this study, it was found that pollution prevention and mitigation measures during construction process are very important to control the environmental impact in the work area. The control measurement can be divided into three main groups which are sediment control, equipment fuels and lubricants control and air pollution control.

Control of sediment production and its introduction to the watercourse shall be prevented or minimized during all operations to complete the work. Sediment produced within the stream channel during construction should be retained in the work area and sediment retention should be accomplished by using a sediment trap or a barrier constructed of geotextile. During equipment operations, the contractor shall look for any leaks that may develop. In the event where any equipment develops a leak during the construction work, the contractor shall immediately remove the machine from the stream channel area and repair the leak. All excess fluids should be cleaned from the machine prior to its return to the work area. Any spillage of fluids during repairs shall be cleaned up, with contaminated soil removed from the project area and disposed of in an approved location for appropriate type of materials. All fuel stored on site must be in suitable container. Any fuel storage container used on sites which have greater capacity must be constructed of a double wall design, or must have a suitable containment structure as part of the tank. Contractor must service or repair equipment during construction where appropriate measures should be taken to prevent contamination of the soil and water during the service or repair operations. All waste fluids, filters, parts and other items related to machinery service and repair shall be removed from the work area and disposed in appropriate manner.

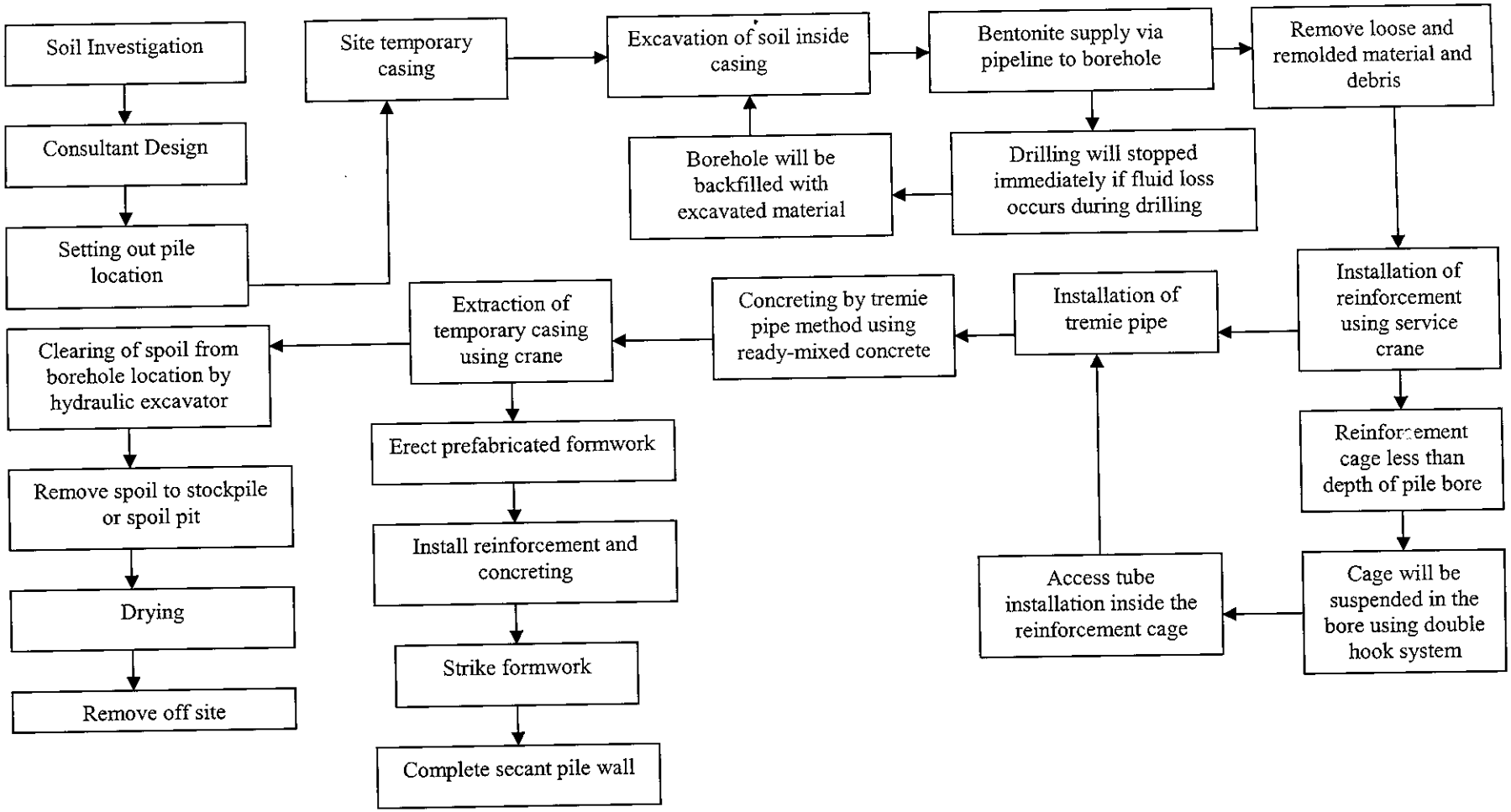

Figure 1. Construction process for bore pile and secant pile wall

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Table 6. Activities identification for piling and foundation works and their potential environmental aspects and impacts

ACTIVITY	SUB ACTIVITY	ASPECT	IMPACT
Making of Reinforcement Cage	Bar bending and welding	Steel bar usage	Depletion of Non-Renewable Resources (R1)
		UV arch flashes	Human Health Impact (H1)
		Steel bar waste generation	Land Pollution (L1)
Soil Investigation	Drilling	Noise	Human Health Impact (H2)
		Water discharge	Water Pollution (W1)
		Soil/earth removal	Land Pollution (L2)
		Consumption of fuel	Depletion of Non-Renewable Resources (R2)
Bored Piling	Drilling	Slippery site area	Human Health Impact (H3)
		Spillage of bentonite liquid (water discharge)	Water Pollution (W2)
		Soil/earth removal	Land Pollution (L3)
		Noise	Human Health Impact (H4)
		Falling object	Human Health Impact (H5)
	Machinery	Consumption of fuel	Depletion of Non-Renewable Resources (R3)
		smoke emission	Air Pollution (A1)
		Noise	Human Health Impact (H6)
Generator set operation	Supply electricity	Consumption of fuel	Depletion of Non-Renewable Resources (R4)
		Smoke emission	Air Pollution (A2)
		Noise	Human Health Impact (H7)
Concreting	Pouring the concrete to the hole	Concrete waste generation	Land Pollution (L4)
		Skin contact with wet concrete	Human Health Impact (H8)
Bentonite liquid making process	Mix bentonite powder with water into the mixer		Human Health Impact (H9)
		Skin contact with bentonite	
		Packaging waste generation	Land Pollution (L5)

Table 6. Activities identified for piling and foundation works and their potential environmental aspects and impacts (continued)

ACTIVITY	SUB ACTIVITY	ASPECT	IMPACT
On-site mobilization	Machine and vehicles usage	Struck by moving machine/ vehicles	Human Health Impact (H10)
		Noise	Human Health Impact (H11)
		Consumption of fuel	Depletion of Non-Renewable Resources (R5)
		Combustion emission	Air Pollution (A3)
Off-site transportation	Construction materials and waste transportation	Expose driver to road accident	Human Health Impact (H12)
		Consumption of fuel	Depletion of Non-Renewable Resources (R6)
		Combustion emission	Air Pollution (A4)
		Noise	Human Health Impact (H13)
General activity	Office and site activity	General waste generation	Land Pollution (L6)

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Table 7. Result for significant impact by Method A and Method B for piling and foundation activities

APS NO	ACTIVITY	SUB ACTIVITY	ASPECT	IMPACT	METHOD A	METHOD B
H 4	Bored Piling	Drilling	Noise	Human Health Impact	High	**3.5×10^5**
L3	Bored Piling	Drilling	Soil/earth removal	Land Pollution (landfill)	High	9.9×10^4
A 1	Bored Piling	Machinery	Smoke emission	Air Pollution	High	**1.3×10^5**
A 2	On-site Mobilization	Machine and vehicles usage	Combustion emission	Air Pollution	High	**3.8×10^5**
A 4	Gen set Operation	Supply electricity	Smoke emission	Air Pollution	High	**1.9×10^6**
W 2	Bored Piling	Drilling	Spillage of bentonite liquid (water discharge)	Water Pollution	High	**2.7×10^5**
R 2	Bored Piling	Drilling	Consumption of fuel	Depletion of Non-Renewable Resources	Top	**3.2×10^6**
R 3	Bored Piling	Machinery	Consumption of fuel	Depletion of Non-Renewable Resources	Top	**3.2×10^6**
R 4	On-site Mobilization	Machine and vehicles usage	Consumption of fuel	Depletion of Non-Renewable Resources	Top	**3.2×10^6**
R 5	Off-site Transportation	Construction materials and waste transportation	Consumption of fuel	Depletion of Non-Renewable Resources	Top	**1.2×10^6**
R 6	Generator set Operation	Supply electricity	Consumption of fuel	Depletion of Non-Renewable Resources	Top	**1.9×10^6**

Air pollution is generated from two major activities which are dust and emission from equipments and vehicles. Contractors should be prepared to suppress dust on both public roads and project access roads. The contractor also should be responsible to ensure that all equipment has proper and functioning emissions control systems. All equipment should have mufflers and are free of excessive smoke emissions. In the event of a contractor's equipment emitting excessive smoke, the equipment should be removed from the work area and repaired or replaced.

Other control measures that could be practiced in the construction industry especially in piling and foundation works is reducing the distance for off site transportation. By reducing the distance, the impact will be lower. Soil or removed earth mixed with bentonite in which this wastage can be used as byproduct as it presents strong colloidal properties and useful in reclamation process. The whole process of construction needs to be considered to ensure reduction in the waste generated, to prevent pollution and also to conserve natural resources. Environmental training and awareness among the employee, suppliers and sub-contractors is essential as awareness is the key point to ensure environmental awareness and its importance.

CONCLUSION

The study found that activities from drilling process, transportation, machinery activities and generator set operation have significant environmental impacts. The result of significant environmental aspect and associated impacts resulting from Method A were 18 out of 31 aspects (58%) whereas associated impacts result from Method B were 13 out of 31 aspects (42%) were identified in this study. Both qualitative and quantitative assessment revealed that 11 out of 31 aspects (36%) identified as having significant environmental aspect and impact. Drilling process leads to noise pollution which impacts human health, causes water pollution and pollutes land. Machinery activities during drilling also contribute to significant impact for depletion of non-renewable resources as machineries consumes fuel during its operations. Off site transportation and on site mobilization activities which transport the construction material also contribute to significant impact for depletion of non-renewable resources. Generator set which supplies electricity during construction work uses high rate of fuel consumption. This also resulted in significant impact for depletion of non-renewable resources. On site mobilization as well as generator set operation also resulted as significant impact for air pollution as both release smoke emission. Prior to the result analysis, depletion of non-renewable resources, air pollution, water pollution, land pollution and human health impact resulted as significant impacts from both methods for piling and foundation works. Identification of significant environmental impacts is essential for a company to design mitigation measures to control and reduce negative impacts according to their environmental policy and aspirations. This could be done by giving more attention to the aspects and activities that contributes to significant impact. Mitigation measures, compliance to regulations and guidelines are important to help the construction industrial sector control their activities that contribute to potential environmental impacts. From the study, it can be concluded that there is a need for legislature and guidelines to help the construction industrial sector control activities that contribute to significant environmental impacts and it can improve their environmental concerns.

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