



Framework of Municipal Solid Waste Incineration Plant Sustainable Operation

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Abstract: Sustainability of municipal solid waste incineration plant operation have not been well discussed since limited studies were conducted on Malaysian incineration plant. The significant reduction effect of incineration is obstinate to divert 40 percent of wastes from landfills as accorded in the 11th Malaysian waste plan. Since 1996, four incineration plants commenced operation in Langkawi, Pangkor, Tioman and Cameron Highland. Consequently, many issues emerged and were articulated by researchers merely as incineration issues, disregarding the success factors achieved by the plants. Research on operational success factors are important to enhance sustainability of Malaysian incineration plants. The objective of this study is to identify the operational success factors achieved by the incineration plants. This study also proposes a conceptual model to further understand the factors contributing to incineration plant operational sustainability in Malaysia and proposes an operational sustainability framework for incineration plants in Malaysia. The framework will enhance the sustainability of municipal solid waste incineration operation in Malaysia and broaden theories on operational sustainability epistemology.

Keywords: Solid waste management, Operation sustainability, Incineration operation framework

Paper type: Conceptual paper

1. Introduction

Waste disposal through incineration or thermal treatment is vital in reducing Malaysia's dependency on landfills (Rahman, 2013; Fazeli et. al. 2016). In contrast to landfills, size reduction incineration method is inevitably a technique employed globally (Commission, 2017). Advantage of incineration over landfilling is reducing the amount of waste by 90 per cent (Shamshiry et. al, 2015). Researchers were inclined towards systematic MSW incineration as the ultimate method accepted worldwide in reducing waste. (Fazeli et. al., 2016; EC Report, 2015) Incineration is conceivably the best alternative to the inflated landfills in resolving MSW as new and innovative incineration technology makes it possible to treat municipal and hazardous waste with minimal pollution while generating renewable energy at the same time (Rahman et. al., 2013). Lack of adequate incinerator facilities in Asian countries pose negative effects to the public and environment (Jaafar et. al., 2017; Agamuthu et. al, 2007). The use of sophisticated waste incineration plants is inevitable and other approaches should be considered as well, (Fazeli et. al., 2016). Consequently, it is essential to acquire a technology with the capability of incinerating high moisture level of wastes with low calorific value that operates at low cost as compared to the relatively cheap landfilling methods (Fazeli et. al., 2016).

Retrospectively, pilot incinerator plants were built since 1996 at Langkawi, Pangkor, Tioman and Labuan islands (Kadir et. al., 2013; Sharifah et. al., 2008; Fazeli et al., 2016) to examine the operational performance of established incineration technology on Malaysian municipal solid waste (MSW) condition. The pilot plants were discontinued due high moisture content of the waste, which contributed to high fuel costs and poor technical expertise in maintaining the incinerators (Kadir et. al., 2013; Sharifah et. a., 2008). In 2006, the three plants at Langkawi, Tioman, Pangkor islands were reconstructed and a new plant was constructed in Cameron Highlands (EPU, 2006; Zainu and Songip, 2017). However, not long after commencing operation in 2012, issues were also encountered by the plants resulting in discontinuation or closure. Incinerator plants in Malaysia were discontinued due to high operation costs in drying the moist waste (S. A. Kadir et. al., 2013; Tan S. T. et.al., 2104). Nevertheless, in 2018, only Tioman plant was functioning and maintained by an appointed contractor. New incinerator proposal will be studied further (The Star, July 3, 2018, Zuraida Kamaruddin, Minister of Housing and Local Authority). Despite two previous pilot initiatives, plant operational discontinuation indicates that MSW incineration operation in Malaysia was not well understood and articulated.

The Auditor-General report 2012 findings on major problems faced by the incinerators were insufficient expertise, failure to comply with the Environmental Impact Assessment criteria and incineration temperature lower than 850 Celsius degree. Some studies discovered technical defect in the air pollution control devices, safety, fuel consumption and improper incinerator design as the main incinerator problems (Shamshiry et. al., 2015). Studies conducted by Ali N.E et. al., 2016, revealed municipal solid waste incineration (MSWI) issues on the lack of efficient institutional framework and policies that contribute a factor towards the failure in promoting MSW incineration in Malaysia.

Investigating incinerator compliance to policies and regulations and the adverse impacts associated with the misuse of incinerator would enrich the literature and knowledge about solid waste treatment (Shamshiry, et. al., 2015). Studies on Malaysian incineration were conducted to identify issues faced by the pilot plants. On the other hand, it is believed that many issues were resolved by the plants during the course of operation. It is crucial to identify critical success factors for development of solid waste incinerators in Malaysia (Abdullah and Jalil, 2016). To remedy the gap, there is a need to conduct operational study, particularly on success factors of incineration plant operation in Malaysian. The objective of this study is to identify the operational success factors achieved by the incineration plants. This study further proposes a conceptual model and framework to further understand the factors contributing to operational sustainability of Malaysian incineration plants.

2. Literature Review

Issues relating to MSWI operational sustainability were articulated in various articles. Incineration or "thermal treatment" is a waste treatment disposal method involving burning waste materials at high temperatures into ashes, flue gas, and heat (World Bank, 1999; Jeremy et. al., 2013). Incineration plant refers to a facility or unit and equipment used in the thermal treatment, until the wastes are reduced to ashes (EU, FCC Group, 2017; Hickmann and Lanier, 2003). The main purpose of incineration plant is treating and reducing MSW volume (World Bank, 1999).

Incineration plant operation sustainability issues are issues that disrupt continuous plant operation due to unscheduled plant shutdown and downtime. According to Sjöblom (2013), sustainable incineration operation refers to the quality in the processes, amount of fuels utilized, quality of ashes and the associated process for efficient combustion and ash utilization. In the context of this research, incineration plant operational sustainability refers to the plant availability to continuously incinerate predetermined MSW volume and comply to environmental emission standards. Incineration operation plays a fundamental role in waste management where waste minimization is the foundation of sustainable waste management (Aja and Kayiem, 2014).

On the other hand, waste management concept is based on the principal of preventing waste from causing harm to human health, the environment with the ability to convert to resources (Pongracz et. al., 2002). Solid waste incineration and management are keys to sustainable environment and development (Aja et. al., 2014). MSW constitutes household and commercial waste that can be categorized into organic and inorganic, where organic waste comprises mostly of food and non-chemical substances. Inorganic waste are chemical-based materials and metals such as plastics, cans, household and office products, glass, ceramic, clothing and paper (Moh and Manaf, 2014; M. A. Kamaruddin et. al., 2016). Inorganic waste such as metals, plastics and paper can be sorted and separated at source or at the waste collection center for recycling or reuse.

A. *Malaysian pilot incineration plant initiatives*

Incineration pilot plants were introduced in 1996 at popular Malaysian tourist islands of Langkawi, Labuan, Pangkor, and Tioman (Fazeli et. al., 2016; S.A. Kadir, et. al., 2013) while the second initiative in 2008 at Langkawi, Pangkor, Tioman islands and Cameron Highland (Jereme et. al., 2015; PEMANDU, 2015; Ahamed et. al, 2016). The primary purpose of the incineration pilot plants was to evaluate the performance of Malaysian MSW with established incineration technology. However, not many studies conducted or published on the first initiative.

Many studies conducted has identified issues faced by Malaysian incinerators. Most of the articles indicate high operational costs in drying the moisture laden Malaysia MSW as the main cause of operational non-sustainability (Sharifah A.S.A.K. et. al., 2008; Moh and Manaf, 2017; PEMANDU, 2016; Aishah S. A. K. S. et. al., 2008; Hamid et. al., 2015). Other studies relate plant maintenance and inadequate volume of waste as the cause of operational non-sustainability. Malaysia could not maintain the smaller incinerators built in some of the Islands due to poor maintenance, high consumption of fuel and low volume of waste generated (Jereme et. al., 2013). Alternatively, inefficient institutional framework and policies was suggested as a contributing factor towards demoting waste minimization in Malaysia. MSWI lacks an efficient institutional framework and policies that contribute a factor towards the failure in promoting solid waste minimization in Malaysia (Ali et. al., 2016). The studies discovered that financial, waste condition, poor maintenance, and lack of institutional framework as the issues faced by the plants. More efforts should be emphasized towards contributions from a sustainable and ecological operation of MSW management in Malaysia (Tan et. al., 2014) and the performance of MSW incineration plants under Malaysian condition (Fazeli et. al., 2016).

Previous studies conducted on MSWI focused on issues rather than the success achieved by the plants. Malaysia could not maintain the smaller incinerators built in some of the Islands due to poor maintenance, high consumption of fuel and smaller quantities of waste generated (Jereme et. al., 2013). Alternatively, inefficient institutional framework and policies was suggested as a contributing factor towards demoting waste minimization in Malaysia. MSWI lacks an efficient institutional framework and policies that contribute a factor towards the failure in promoting solid waste minimization in Malaysia (Ali et. al., 2016). Studies revealed that financial, poor maintenance, waste volume and lack of institutional framework as the issues faced by the plants. More efforts should be emphasized towards contributions from a sustainable and ecological operation of MSW management in Malaysia (Tan et. al., 2014) and the performance of MSW incineration plants under Malaysian condition (Fazeli et. al., 2016). Studies should focus on the success of Malaysian incineration plants in sustaining operation. Thus, more studies must be conducted particularly on the operational sustainability of Malaysian incineration plants in order to identify and recommend resolution on the issues faced by the plants.

B. Factors relating to MSWI issues

High fuel cost in drying the moist Malaysian MSW, were mostly articulated as the main cause of incineration plant operational non-sustainability. The remaining four MSWI plants located at Pangkor, Tioman, Cameron Highlands and Semenyih has ceased operation due to high operational costs in drying the high waste moisture content (Sharifah et. al., 2008). Existing incinerators are ineffective and is inoperative due to financial constraints and the high moisture content in the waste is not suitable for the operation of incinerators (Moh and Manaf, 2017; PEMANDU, 2016). Usage of Incinerators were terminated due to high operation cost resulted from high waste moisture content (Aishah S. A. K. S. et. al., 2008). The high organic content in waste requires proper waste management system to treat the solid waste more efficiently (Hamid et. al., 2015). MSWI plant ceased operation due to high operational costs in drying the high waste moisture content (Sharifah et. al., 2008). Thus, high fuel costs in drying moisture laden MSW were considered as a financial factor that affected plant's operational sustainability.

Besides financial, studies also indicate that correct incinerator operational setting in waste processing, logistics, technologies and legislation can lead to achieving sustainable environment (Straka et. al., 2018). Other factors involved in waste management sustainability are environmental responsibility, social awareness, and economic profitability (Pitt et. al., 2009). Abdullah and Jalil (2016) identified five factors for success of MSW incinerators – the establishment of policies and legislation, responsible institutional structures, effective operations management, strong financial resources, awareness and active involvement of the public, good maintenance management and Strategic location. On the other hand, study conducted by PEMANDU in 2016 revealed issues relating to weak operational management of the MSWI plants. Other studies also relate plant maintenance and inadequate volume of waste as the cause of operational non-sustainability. There is a need to work towards a sustainable waste management system, which requires environmental, institutional, financial, economics, and social sustainability (Rathi et. al., 2006). Thus, to achieve sustainable incineration plant operation, the conceptual framework of this study shall be based on the articulated sustainability factors of plant management which includes financial, operations and maintenance, institution, environment, and technology.

• *Plant management factors*

Financial management, operations management and maintenance management suggested by Abdullah and Jalil, (2016) relates to the internal incinerator plant management.

- *Financial management*

Strong financial capability is fundamental among other factors to sustain incineration plant operation. Financial resources are the principal factor besides effective operations management and efficient maintenance management for sustainable incinerator operations (Abdullah and Jalil, 2016). Incineration plants should be appropriately managed by an effective organization with sufficient budget allocation (Kadir et. al., 2013). Waste disposal and diversion from open dumping to controlled operations can be achieved under stringent financial constraints (Wilson, 2017). The main costs of MSWI plant operation are labor, fuel, energy, repair and maintenance, emission monitoring and control, finance and reporting (ISWA, 2015).

To sustain incineration of MSW, governments must provide financial incentives and supports sorting at source by households (Towoloe et. al., 2016). The high moisture waste content will result in higher operational costs in incinerating the waste especially when fuel cost is escalating (Kathirvale et. al., 2004). Another issue that lead to poor MSWI financial position is due to bureaucracy. The Federal Government undertook MSWI initiative due to several factors including lack of human and financial resources (Zainu and Songip, 2017). Private participation in MSW management can improve service provisioning and management efficiency and relieved government's financial burden (Jereme et. al., 2015). Late concession payments by the authorities resulted in operational inefficiency of private operators (Moh and Manaf, 2017). On the other hand, other forms of financial support are essential to secure financial sustainability of the services under the local conditions of affordability and willingness to pay (Rodric and Wilson, 2017).

- *Operations management*

Effective operations management provides the foundation for sustainable incineration plant operation. Improper operations in waste sorting or disposal hinder ideal waste disposal, resulting in utilization factor constraints (Xin-gang, 2016). Incineration operation among others, must operate efficiently and effectively to achieve the ecological efficiency of minimizing dangerous Dioxin and Furan emission, protect refractory from damages, prevent ash residues and clinker formation, reduce fuel consumption and install additional equipment to control hazardous emission (Shamshiry et. al., 2015).

Malaysian incinerators had failed due to poor design, inefficient operation, poor maintenance and high diesel usage due to high MSW moisture content (Jereme et. al., 2014). The high moisture content in Malaysian MSW significantly affects incinerator operation since high moisture lowers the calorific value of the MSW (Tan et. al., 2015). MSWI operation would be interrupted if supply of MSW is inconsistent and inadequate. (Hinman and Kreps, 2016). In general, the ash characteristics depends on the MSW compositions, the operational conditions, the incinerator type and design of air pollution control system (Amat et. al., 2017). MSW incineration plants failure are usually caused by operation and maintenance failures (including lack of expertise) (World Bank, 1999). MSW incineration is expensive and require adequate operational maintenance by skilled staff, health concerns by the public and requires extended waste disposal contracts (Fatimah et. al., 2013).

- *Maintenance management*

Malaysia could not maintain the incinerators operation at the Islands due to poor maintenance, high fuel consumption and inadequate MSW quantity (Jereme et. al., 2013). When MSWI breaks down and maintenance is required, repairs can become very costly (Tan et. al., 2015). Adequate incinerator maintenance is important to mitigate the risk of harmful gas emissions (Batterman, 2004). Repeated scheduled maintenance must be performed to prevent combustion quality emission risks to the public (U.S. EPA, 1990). Incinerators usually require maintenance after operating for about three years (Shamshiry et. al., 2015). With high initial investments and long expected operational lifespan, cost factors adopt a

standard operation interval which relates to momentary plant closure for ordinary maintenance and eventually longer stops for upgrading (Massaruto, 2015).

MSWI plants can extant over thirty years with proper incineration maintenance assuming no additional land, unless plant expanded to process more MSW (Chaliki et. al., 2016). The Malaysian government prefers high MSWI maintenance costs for a cleaner environment (Ng WPQ et. al., 2014). Businesses incurs monthly or annually charges as MSWI operation and maintenance costs to gain an acceptable productivity level which include operator salaries, and maintenance of buildings and equipment (Soltani et. al., 2016). Ideally, incinerator maintenance must be performed by a trained and certified equipment designer and builder. Separating construction from downstream maintenance and operation responsibility between infrastructure developer and other maintenance operator has multiplied the problems (Hinman and Kreps, 2016). A Standard Operating Procedures (SOP) is developed to clearly define the roles of SWCorp and JPSPN in database development, management and maintenance (PEMANDU, 2015). The maintenance cost equates to less than one percent of the incinerator costs when computed using twenty years as the plant operational life (Panepinto and Zanetti, 2017). MSWI plants depended heavily on the costs in treating MSW due to the expensive equipment, operation and maintenance costs (Xin-gang et. al., 2016).

- *Institution factor*

Agency authority includes implementing strategies and enforcement of important laws through licensing or inspecting waste handling activities and controlling financial arrangements with users. The institution being the regulatory agency must possess adequate authority to perform its duties to enforce standards to all sectors. The accountability and transparency of the regulators are fundamental (ISWA, 2015). The success or failure of the MSWI privatization operations and their outcomes depends primarily on the institutional structures (Post et al., 2003, p. 850; Ahmed and Ali, 2004, p. 797; Cointreau-Levine and Coad, 2000, p. 5; WRI, 2003; p. 4). Environment standard policies cannot be implemented due to lack of competent staff, technical capabilities or monetary resources in the governing agency to implement and ensure compliance (ISWA, 2015). Two solid waste management agencies were established in Malaysia particularly by JPSPN which formulates plans for waste facilities, proposes policies, plans, and strategies, while SWCorp Malaysia implements the pro- posed policies, plans, and strategies (Moh and Manaf, 2017).

Without sound enforcement, operators avoid the implementation and maintenance of environmental compliance standards, disregarding the extent of environmental issues (Hinman and Kreps, 2016). Act 672 enacted on 1st September 2011 to standardize SMW and public cleansing services in Malaysia was devised to promote waste separation at source has failed due to poor enforcement (Moh and Manaf, 2017). Policy makers should resolve solid waste management facility issues and construct financially sustainable policies with affirmative environmental goals (Diaz et. al., 2007; UN Human Settlements Program (UN-Habitat), 2010). Different agency approach, government policy in the presence of various waste systems and management practices has resulted in redundant and inaccurate waste composition data (Kamaruddin et. al., 2016). Malaysian utility operators prefer build transfer (BT) method in development projects where the assets, remain the purview of the owner (Hinman and Kreps, 2016).

- *Environment factor*

Environmental standards are formulated to protect the environment from the negative effects through successful implementation by employing incineration technology to economically treat MSW according to regulations and the standards (Liu et. al., 2015). Existing environmental standards differ by countries, guided by their own set of principles (Streffer and Cansier, 2003). Country with higher environmental regulation and regime index is more concerned towards environmental quality. (Moosa, 2014). Regulations on MSW incineration bottom and fly ash treatment has been formulated to protect the environment (Ornebjerg et al., 2006). Waste management study by Moh and Manaf, 2017, indicate incineration method

involving waste to energy offers the highest environmental protection with the lowest carbon emission (0.195 Mt CO₂eq/y) compared to other waste management methods. Waste minimization method involving MSW reduction through incineration is most accepted method in reducing environmental impact in Malaysia (Ali and Siong, 2016). For an effective energy generation, the international Energy Agency (IEA) reported that a calorific value between 8 and 12 MJ/kg are produced by a ton of MSW (Melikoglu, 2013). The direct control or command and control approach in waste management, is necessary to protect public health and has staged an important role in providing effective environmental protection (ISWA, 2015).

The byproduct derived from incineration is hot combusted gas were composed primarily of nitrogen (N₂), CO₂, water (H₂O, flue gas), oxygen (O₂) and non-combustible residues (Tchnobanoglous et. al., 1993). MSW incineration releases flue gas, ash residues from combustion, and process wastewater. A Detailed Environmental Impact Assessment (DEIA) study was conducted during early project planning stage to study the environmental impact and establish certain design and operating criteria of the incinerator plant. DEIA operating criteria was obtained from the Department of Environment (DOE). Heat produced from MSW incineration displaces the consumption of fossil fuel if converted into electricity would decrease CO₂ emissions and is the best alternative for solid waste management in terms of economic and environmental impact on Green House Gas mitigation (Tan et. al, 2015). Incinerators in Malaysia expels exhaust/flue gas into the environment without any return on heat (Aja and Kayiem, 2014). The effectiveness of policies and regulations was drawn back due to the complexities of implementation that differed by location (Ma and Hipel, 2016). Defects in the air pollution control devices and inappropriate design are the mostly observed at the incinerators (Shamshiry et. al., 2015).

- *Technology factor*

The advantages of incinerator over landfills are the environmental benefits in lower carbon emission, minimize land contamination, inert form of emission without odor and minimum land utility (H. Rahman, 2013). Using advanced technological method in emission control as outlined by air pollution control regulation at the MSWI plant shall reduce the harmful gases from polluting the environment. Despite the issues, MSWI technology offers a promising outstanding financial performance and a significant reduction of GHG emissions (Inglezakis et. al., 2015). Effective solid waste management programs should be considered from the environmental, socio-cultural, policy, institutional and economic perspectives, and not only from the aspect of technology (Jaafar et. al., 2017).

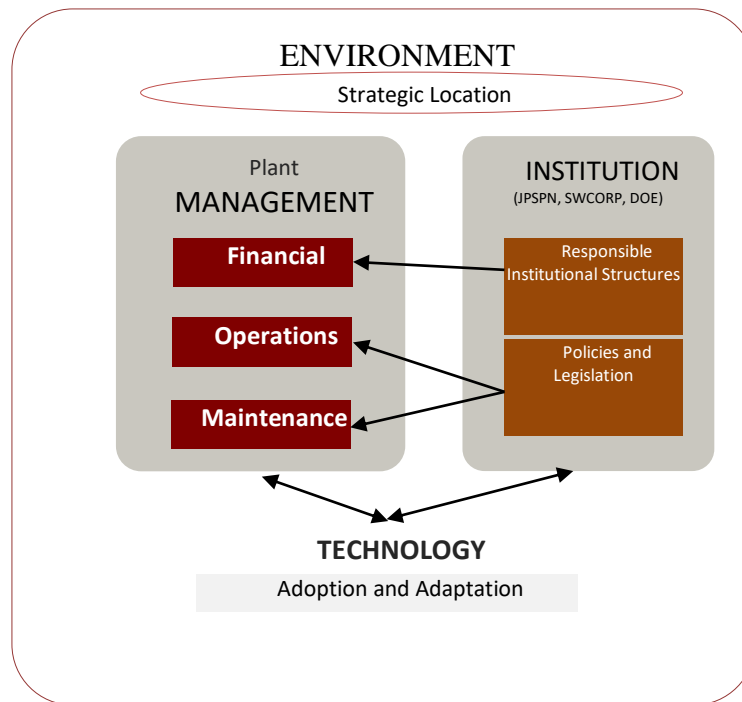
Sustainability of waste resource is important in MSWI technology operation of an incinerator where fluctuating waste resource would greatly reduce efficiency leading to technical and economic issues (Tan et.al., 2015). The study by Kathirvale et. al., (2004) found that incineration technology does not provides high returns on energy but is low in terms of environmental effect and the energy consumed to treat the MSW. Studies into solid waste management sustainability issues usually focus on the aspect of technology (Zurbrügg et. al., 2011). Local government occasionally analyzes various solid wastes issues exclusively from technology perspective (Guerrero et. al., 2013). Future technical advancements in incineration must consider the social, economic and environmental occurrence aspects in the technology adoption decision-making process.

3. Conceptual Framework

By combining the sustainability factors into functional categories, we can single out the operation factors that is critical to MSWI plant operation compared to other less significant factors. On the other hand, Abdullah and Jalil 2016, identified three additional success factors that leads the successful operation of incinerators which is effective operations management, strong financial resources, and good maintenance management. Economic factor which relates to global financial shall be represented by a single financial factor. Operations, financial and maintenance factors are considered as the plant management factor.

Social sustainability can be achieved through enforcement of policies and legislations by the agency or institution responsible structures. Thus, the amalgamation constitutes four functional categories that are associated to each other and can be consolidated into four main categories of management, institutional, technology and environment.

Figure 1. Proposed operational sustainability conceptual framework of Malaysian incineration plants



The proposed conceptual framework (Figure 1) for sustainable MSWI plant operation consists financial, operations and maintenance factors which were attributes of plant management as the core, bounded by institutional factors which were accountable towards the plant and the environment. The critical factor towards the plant's sustainability is plant management which is responsible towards the sustenance and survival of the incineration plant. The least contingent independent technology factor acts as moderating factors to all since newer technologies may improve the sustainability of MSWI plant operation. Institution played the role of governance in overseeing the plant's operation compliance to rules and regulation. In addition, adequate supply of waste is assumed sufficient in the context of Malaysian environment since incineration plant was designed and built to accommodate the volume of waste at the location. Sustainability of waste resource is very important in WTE technology operation of an incinerator where fluctuating waste resource would greatly reduce efficiency leading to technical and economic issues (S. Tan et. al., 2015). The framework deemed ideal, but all factors are detrimental towards operational sustainability of MSWI plant.

4. Research Design

A. *Research context*

Langkawi and Tioman plant shall be assessed based on the availability of resources and activities that occurs. Equipment and residual assessments will be performed at both plants. Observation on incineration operational conduct will be conducted at Tioman with some obstruction tests, carried out to examine the parametric values. Chemical tests will be conducted on the common residues. These are the remnants after combustion from the incinerator moving grate which are commonly known as bottom ash and fly ash from exhaust flue gases (Huang et al., 2006). These residues were quantitative analysis to determine the loss of ignition (LoI) and Ash leachability test (ALT). Some samples of bottom ash will be collected and sent to accredited chemical laboratory to determine the chemical contents. Incinerator residual analysis was used in analysing the principle function and performance of incineration plants.

Research shall employ qualitative case study approach in achieving the objective. Case study research emphasised four aspects towards design quality which are construct validity, internal validity, external validity and reliability. Qualitative research involves inductive reasoning while quantitative research is based on deductive reasoning (Cavana et. al., 2001; Yin, 1981). Case study research involves collection of data from multiple sources of evidence typically documents, archival records, interviews, direct observation, participative observation and physical artefacts as evidences (Yin, 2009: P98). Inductive research approach involves observation on a certain phenomenon and finally arrive at the conclusion. The inductive method relies on relentless comparison of data and theory. Among the six data sources, the most important case study information indicated by Yin (2009) were interviews. Unstructured interviews based will be employed in this research which focused on plant resources and Jabatan Pengurusan Sisa Pepejal Negara (JPSPN) official to gather the evidences. The approach adopted in this study shall determine the understanding of a phenomenon which conforms to the objective of this study and the underlying theories.

B. *Data collection*

This study shall gather both primary and secondary data. Primary data comprise the data collected by researchers based on the research problem while secondary data was data collected from other sources or by other researchers (Sekaran, 2003). Primary data will be collected from plant/equipment assessment, observation and interviews from Langkawi and Tioman plant. Secondary data shall be collected from documents, reports, journals and reputable magazines. Multiple data collection method involving plant assessment, observation, interviews and archival sources provides stronger substantiated construct in inductive research (Eisenhardt, 1989 P:538). The overall research activities shall comprise site visitations, assessment and description on the performance of the Tioman plant, site-monitoring and measurements and laboratory analyses of the collected samples. Technical and operational recommendation are required to improve the performance of the plants shall be identified and analyzed and recommended for implementation.

Interviews on higher level aspects of the MSWI plant governance will be conducted to JPSPN personnel and plant manager. This data collection activities conducted according to research plan and research schedule during plant visitation. Plant observation on operational conduct, equipment assessment and some tests were consolidated into a report titled “Langkawi and Tioman plant assessment and observation operational report”. All operational assessment and observation shall be based on plant’s Standard Operation Procedures (SOP) and equipment Operation and Maintenance (O and M) Manuals.

C. *Measures*

To determine validity and reliability of research results, investigations shall be conducted in triangulation manner. Investigation results will be verified based on specified analysis and assessment conducted on specific equipment and operation. Operational analysis and equipment assessment shall be conducted based

on indicated tests with expected results. Analysis and assessment forms shall be filled prior to conduct. The expected results are based on defined incineration standards and accepted practices which is the basis of validation. Outcome from analysis shall be validated with expected result. Similar analysis shall be done if there exist wide variance between outcome and expected result. Reliability of investigation result is determined through duplication method. In this manner, similar analysis conducted at the same plant would produce similar result. Thus, to indicate data reliability, analysis will be conducted twice and if results are inconsistent, another analysis shall be done to ascertain result.

D. Data analysis

This research will employ inductive research analysis using computer aided application to qualitatively analyze the abundant collected data. The data analysis process involves assessing data using analytical and logical analysis to examine relevancy of the data provided. The interviews which shall be transcribed into the system, requires data to be organized into specific perspectives defined earlier as management, institutional, technology and environment. The perspective of which resumes theoretical phenomenon of resource-based view (RBV), Agency Theory and Waste Management Theory defined earlier. Interview data shall be interpolated with the indicated phenomenon to justify findings. The vast data which is still in the raw stage must be coded consistently to avoid disorganization. Before findings can be interpreted, the underlying thoughts within the data "need careful teasing out" (Robson, 2002, p.387). The tools used for analysis and reporting should be determined in the early stages of the research process (Morgan and Krueger, 1997).

Data organization is expected to be laborious due to the enormous data in different forms. The system provides analysis result of in variety of formats for fine tuning and interpretation as research findings. Even though the data categorized and analyzed, it is still considered raw data until the final coding process. The computer aided system utilized in this research shall be used to organize the vast data that accumulated throughout the duration of research.

5. Results

Results shall be presented by case basis starting with the case selection, coding, emergent themes, development, case writing, within-case and cross-case. This is to reiterate that the purpose of this research is to explore MSWI plant operation in Malaysia where the findings would be technically inclined towards incineration technology and processes. The findings will be achieved through primary data collection and analysis of secondary documents from articles, documents at the plants, National Solid Waste Management Department (JPSPN) reports and web pages.

6. Conclusion

Past research indicated the need to investigate incineration plant performance under Malaysian condition to contribute towards sustainable and ecological operations (Fazeli, et. al., 2016; Tan et. al., 2014). This study builds upon the extant literature of plant incineration issues proposes a conceptual framework to identify the factors that contributes incineration plant operational sustainability in Malaysia. The proposed conceptual framework comprises the internal management factors of financial, operations and maintenance management in addition to the external agency, environment and technology factors.

The study further broadens the understanding of incineration plant operational sustainability and the success factors related to incineration plant operation sustainability in Malaysian. Future studies should consider to be conducted at Tioman plant in capturing the incineration operation success factors achieved by the plants and ultimately formulate a framework of sustainable incineration plant operation in Malaysia (Shamshiry et. al., 2015).

The suggested study should consider employing qualitative, case study approach through examining, observing and interviewing plant supervisors and managers. Case study design could increase

understanding of the success factors of Malaysian incineration plant operational sustainability. Semi-structured interviews is suggested during in-depth interviews with the plant operators to capture all information relating to their experience (Eisenhart, 1989; Yin, 1994).

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