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INDUSTRIAL GROUNDWATER ABSTRACTION SUSTAINABILITY

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Abstract

The industries are Malaysian main groundwater users primarily for mineral water bottling and cooling applications. Industrial groundwater usages are charged once for well application drilling whilst the daily consumption usages are priced lower than piped water supply. Subsequently, its consumption increases yearly in addition with piped water supply being frequently disrupted. Thus this research aims to highlight the scenario with respect to daily operations of industries using groundwater. It is to identify factors that may influence any noncompliance or unsustainable abstractions of groundwater by the industries. In addition, this research evaluates related groundwater policies by the federal and states in Malaysia and discusses the probable effective groundwater governance in the country. A qualitative study was carried out involving analysis of documents and legislations, interviews involving industries, legislators and state water authorities, as well as site observations. This comparative triangulation analysis was used to find better results. Finally, findings showed the non-existence of groundwater policy in the country with insufficient and inefficiency of water management. Results also revealed the level of compliance among industries is moderate mainly due to limitations in monitoring and governance. Lack of specific legislation may perhaps be the main factors of non-performance. It proves that legal frameworks are crucial to secure the sustainability and maintain the quality of natural resources. Thus this paper puts forward an appropriate framework of governance and applications for industrial groundwater monitoring recommendations for any future research.

Keywords: Abstraction, groundwater usage, governance, industry

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1. Introduction

Worldwide water scarcity is a never ending situation contributed by surface water quality deterioration, higher demand by the population, industrial boom, and increased urban and economic development. Some countries especially developing countries were unwilling to invest in proper operational system resulting in unsafe and inadequate water supply as well as increased in labour and economy (Maliva & Missimer, 2012). Nevertheless, to some countries, groundwater is considered an alternative solution to support surface water demands and decrease malnourishment to the poor (Chaimanee, 2013). Nonetheless, the alternative resources tend to be unsafe in quality causing illness, disability and death.

Previously, it was estimated about 70 percent (%) of groundwater abstracted worldwide is used by agricultural activities while the balance is for drinking water (Smith et al., 2016). Pakistan is considered the highest country in groundwater usage and uses 94% of the resource for irrigation and followed by Saudi Arabia at 92% and Syria (90%). In terms of industrial groundwater usage Japan is the highest at 48% followed by Thailand and China both at 26% (Margat et al., 2013). Bangladesh was estimated using 9500,000 metre cubic (m^3) of groundwater by the industries in the year 2015 (Bhattacharjee et al., 2019). Locally in Malaysia, the resource is a reliable source during drought season in states Melaka, Sarawak and Selangor, and available in remote areas especially for the indigenous community. Even Langkawi and Pinang Island are wholly dependent on groundwater especially during peak holiday seasons (Azrina et al., 2012). All the same, Malaysian groundwater usage is still low with less than 2% used daily mostly in Kelantan for domestic water supply, while others for agriculture and production sector industry.

Statistically, groundwater usage increase by the agriculture sector and industry was three times higher than surface water irrigation (OECD, 2012). Even it is believed the industries are the culprits to the pollution menace and higher consumption of groundwater sources. Industries such as agro-processors; textiles and tanneries release toxic pollutants while extractive industries of gas mining or quarrying pose a great threat to the groundwater quality (UN, 2015). Even Indonesia and China industries had taken over agriculture which is worrying as it may lead to unsustainable usage of groundwater when industries continue to grow (OECD, 2012). Hence, this study focuses on analysing the groundwater usage by the industries in Malaysia to identify their usage as part of achieving resource sustainability planning in the country.

2. Problem Statement

The Malaysian local water stress is blamed on poor water management and unsustainable usage which is common in developing countries. The state of Selangor water demand is the highest among many states in Malaysia, generated from land development, socio-economic growth and energy generation. Selangor recorded the highest water supplied in 2020 with 4665 million litres per day (mld) but the situation was made worse with local water-stress situation and polluted water sources (MWA, 2020). This has brought attention to water stakeholders to list groundwater as a solution to meet the water demands in Selangor. Even the industries in Selangor mainly use groundwater as their water supply, for cooling or mineral water (Mridha et al., 2020; Saimy & Raji, 2015).

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However, groundwater is not widely used nor identified as a key environmental issue in Malaysia based upon low environment or human health cases reported (Saimy & Raji, 2015). The biggest groundwater users in the country are the industrial and agricultural sectors. Nevertheless, Malaysian groundwater data are hardly known, irregular, or understood and managed differently in each state. As stated by Gracia-de-Rentería et al. (2020), even empirical industrial groundwater usage globally is lacking. Plus, Malaysian awareness and socio-economic impacts on groundwater are low although some research exists on groundwater social aspects involving communities.

Nevertheless, increased groundwater usage is seen as a threat to bigger water problems in Malaysia. What the country experienced is a common issue in many developing countries whereby groundwater lacks attention, weak enforcement and legislation, as well as ineffective institutions (Bhattacharjee et al., 2019). The country also faces many challenges in regulating groundwater abstraction as the guidelines of each state are unstandardized (Saimy & Raji, 2015). Even document review on the Environmental Quality Act (EQA) 1974 citing only once on groundwater quality pollution control. It does pose a problem as industrial activities unavoidably affect the environment and create greater impacts with business expansion that requires more energy and resources. Industries are often willing to cut back on costs to maximise profit.

In 2020, water withdrawals by the Malaysian industry were projected to be 9756 mld but it went as high as 1.64 billion cubic meter (bcm) in 2017 which is about 29% freshwater withdrawals (KNOEMA, 2021; World Bank, 2021a). Thus it was proposed early recognition of risks of water resources which is vital to preserve the long-term viability to avoid further complications. Proper future development plan, studies and sustainability of groundwater as well as collaborations are needed (Ostrom, 2014). Population, economy and food security is at risk if water sustainability is not addressed (MWA, 2020). The quality and amount of groundwater throughout Malaysia should be monitored systematically for good distribution and reliability.

Therefore, this study is important as an evidence-based approach in planning towards governance and management of groundwater abstraction. It discusses issues related to industrial groundwater abstraction which would lead to bigger decisions on recommending a framework to be applied for the country and individual states in Malaysia. The recommendations are intended for the appropriate policy guidelines to be developed to achieve sustainable groundwater abstraction and effective governance in Malaysia. At the same time, the findings should be used to create and enhance groundwater awareness in industries, business stakeholders and the government. Subsequently, this would enable us to understand and deal effectively with groundwater abstraction sustainability.

3. Research Questions

This study would identify industries that are engaged with large amounts of groundwater abstraction to answer the following questions.

i. What are the current practices and compliance of Malaysian industry in using groundwater sustainably?
ii. Are the management implemented and available policies sufficient for sustainable groundwater abstraction by the industries?

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4. Purpose of the Study

This study explores the current local industrial practice on groundwater usage in Malaysia. It is also to determine the compliance standards of best management practices of groundwater in the country by the big users.

5. Research Methods

The case study approach of Malaysian industries was chosen to illustrate the current practices of groundwater by the industries for washing, mineral water and cooling (Figure 1). The case study is the key criterion in providing evidence of valuable insights and information. There were 34 stakeholders involved inclusive of the industries, as well as state and federal water managers which is suitable for a qualitative research to reach data saturation. Primary data involved interviews as well as site observations. State water stakeholders are from Selangor and Kedah state water authorities (SWAs) as only these two states in Malaysia are currently available with water enactments.

This descriptive study furthermore involved engagement and direct contact with industries in their natural settings within their respective factories to interpret the phenomenon, define feelings and attitudes in an approach (Sue & Ritter, 2012). Site observations were to verify the perspectives of a scenario. Upon locating and requests for an interview, many companies were taken out due to inactivity of wells, those industries that were not reachable and those refused to participate. The study did not apply cost-benefits analysis as it is a sensitive issue for any type of industry to disclose.

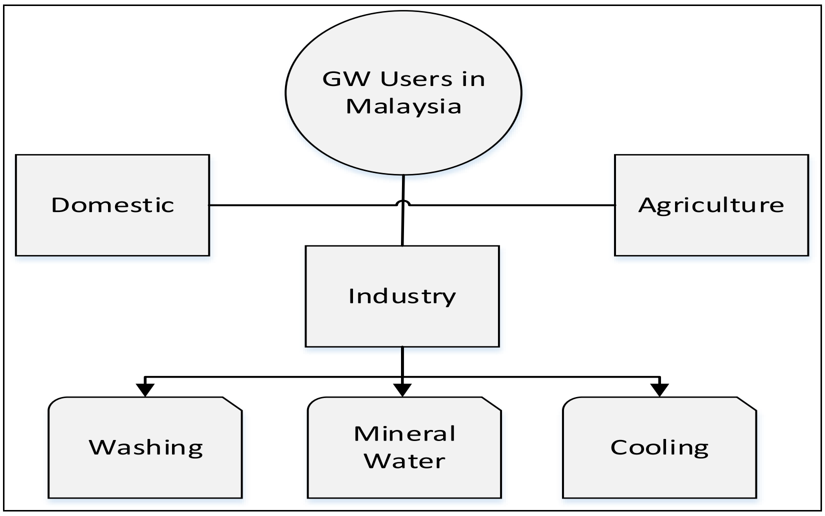

Figure 1. Major Malaysian industries using groundwater

Secondary data for the study were collected from existing documents, reports, newspaper articles, guidelines as well as international documents. International benchmarking and comparisons with other countries' and global organisations' such as the World Health Organisation (WHO), Food and Agriculture Organisation of the United Nations (FAO), World Bank and UN references were done to reflect on any weaknesses or strengths of local provision (Foster & Garduno, 2013).

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For triangulation purposes, the data composed from different subgroups were to ensure the study reflects real situations from different angles for reliability, clarity and validity (Harvard University, 2014). The comparisons were the main component in showing variations and ideas and notes for further actions. The subgroups comprised of (1) industrial water users; (2) legislators and policymakers; NGOs; and SWAs (3) documents analysis (Figure 2).

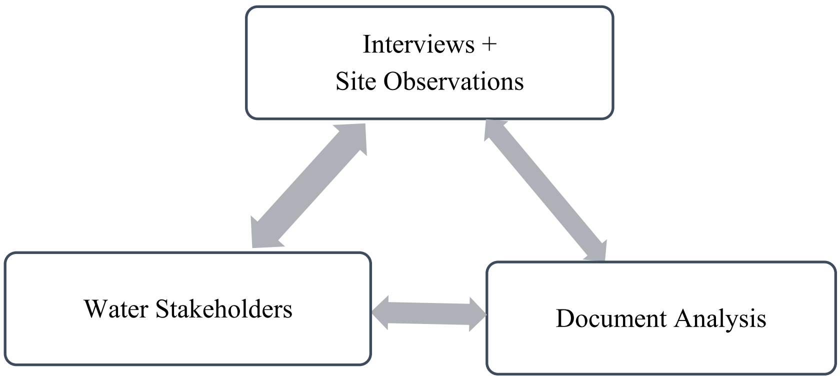

Figure 2. Triangulation for this study

6. Findings

Findings showed that overall; the industries in Johor were the highest groundwater user in the country followed by Selangor while the least industrial user is Perlis (MWA, 2020). The number of groundwater consumption in Malaysia started to increase from year 2004 and licenses for mineral water sourced from groundwater registration peaked in the year 2009 (MOH, 2013). The positive growth rates were parallel with the manufacturing sector registered in Malaysia in 2009 (BNM, 2011) together with a strong economic rebound of 4.1% between 2002 and 2008 (PwC, 2013).

The practice applied by the industries follows the available federal and state legislations and requirements consisting of licensing, well location and drilling, quality and limitation, in addition with economic drivers for the industries.

6.1. License and Permission

Under local practice, industrial groundwater well licences and permissions fall under respective SWAs. Kedah and Selangor, are each under state water enactments of Kedah Water Resources Enactment (Kedah, 2013) and Selangor Waters Management Authority (Selangor, 2012). States without water enactments were to refer to the state's Mineral Geosciences Department (MGD) under pursuance of the Geological Survey Act 1974. A license for a well with SWA requires license from state MGDs only if the amount exceeds 2500 litres per day (lpd). Mineral water licensing on the other hand is to be obtained and drilled by registered consultants under the state health departments (JKN). The cost for each license depends on the type and state jurisdiction.

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Selangor has 300 wells registered while Kedah with only 85 wells. From the total number of registered wells, only two factories in Selangor use groundwater for mineral water bottling and only one in Kedah. Findings showed many registered wells have been operating consistently for more than 15 years. In the United Kingdom (UK), 12 years is the maximum year a license is provided for each well subject to certain criteria. Continuation of licenses is subject to future planning documentations strategies. This study revealed that 14% of well operators have been operating since the early 1980s when during that time, there were no related guidelines available on data logging of aquifers and experts' opinions were not accounted for. Amendments should have been done for the operator to be bound by the recent legislations so that proper monitoring and control could be done. Even so, the ratio showed wells registered operating lower than the allocations given.

From this study, it was found many wells for agriculture and industries were unregistered; however, the numbers are confidential. These unregistered wells were mostly on private property thus difficult to monitor unless with a court's permission. In addition, the SWAs lack staff for detailed monitoring and enforcement. Overall, complaints received on the well operating licensing applications system were time consuming, confusing and cost a high amount of money. Notably some states have more water laws than others that involve multiple agencies, stages, and multitude of tests. Even sometimes they overlap each other on several occasions. There were cases where the wells were drilled and used prior to license application thus the pressure for the SWAs to approve only with a small amount of penalty. Therefore suggestions were brought up for the licenses to be combined and standardised and a need to impose a larger penalty both monetary and expulsion for the industries to be liable towards every action.

Any abandonment or unused wells are potential sources for groundwater contamination as it provides direct access from ground to groundwater. Kedah Water Resources Enactment 2008 states the license would be revoked if it is not used in two years. In Australia, a well is considered inactive if not used for more than three consecutive years (Skurray et al., 2013). However, Selangor does not state the number of years of inactivity that are considered inactive as it is regarded as unimportant by users. Although in accordance with the state water enactment; any well should give a notice of 14 days prior if operation is to cease.

6.2. Well Location Site and Operational Status

Well location and the securing land areas are very important for sustainable, good abstraction performance and quality of groundwater resources. Since land is a state matter according to the National Land Code (NLC) 1965, groundwater or any water resources are considered common-pool resources belonging to the state. An industry is to operate only on an industrial land title nevertheless conversion of land title can be applied by landowners to the related Land District Office (NLC 1965). Groundwater usage is addressed together with property rights and land use control as deemed by Foster and Garduno (2013). The source supplies, usages, services and control of pollution are respectively the State Water Board / SWAs agencies' management. In pursuance of the NLC 1965, State Authority may impose the development of the area or proportion of land. For the mineral water industry however, it has to be in accordance with MOH to oversee the developments and not intervene or affect groundwater quality.

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Only 9% of well operators own both the land and the industry itself. Other operators leased their land from owners with agreements. The same practice goes to Australia where the licensee needs to occupy the land needs a written approval, authorising the activities on the land (Skurray et al., 2013). A long period of land lease poses disadvantages of oblivious activities that may affect resource sustainability.

The guideline by the Department of Environment (DOE) established the Guidelines for Sitting and Zoning of Industry and Residential Areas in 2012 but many were unaware of its existence and wells and industrial plants were built without referring or abiding to it. The Guideline had set 100m of primary zoning with only several acceptable amenities or types of agricultural trees allowed (DOE, 2012). This study found that the industries were 17% surrounded by rubber trees and 50% with palm oil trees.

Any development within 150m of the sensitive area would cause a shift in land-use patterns that modify the pressure. Land developments or land use of 1km radius surrounding the point source need to be controlled (MOH, 2013). Almost all of the manufacturing plants are located in the outskirts of town. Analysis from the interviews showed 50% of the operators were located 101-200m away from any other development, while 24% of the manufacturing plants were located less than 100m away. Only 33% of the plants' operations were located more than 300m away from other developments surrounded by natural forests. This indicated the primary buffer zones of the factories are not in accordance with the DOE or MOH (2009). That is why it is proposed land use and property rights should be dealt with to maintain natural resources (Foster & Garduno, 2013; Skurray et al., 2013).

Even each well point to the processing factory itself is deemed a factor in groundwater quality (MOH, 2013). Nevertheless there is no specification or exact distance recommended between the well's point source and the factory. The point source–factory distance requirement is to determine the appropriate type of activities within the distance to maintain the water quality. The distance should suit the pump pressure used. In addition, the operators need to identify the steps taken to prevent water from contamination during the water transfer before processing (MOH, 2009).

The recharge zones are natural ways for precipitation or infiltration in maintaining the sustainability of the resource (Pandey, 2012). However, neither the SWAs nor the federal government considers natural recharge criterion in their acts or guidelines. Findings from the interviews noted that there were no requirements on recharge and were confirmed by all operators.

Unbalanced recharge and discharge would lead to cases like the Langat River Basin that experienced land subsidence 1km away from the extraction point (Ismail, 2010). An industry had also experienced repetitive groundwater deficits although its location is approximately 2 kilometres (km) away from a natural lake. Henceforth recharge is an important element to be inserted in groundwater regulations. A sinkhole was also reported near to an industrial well location and findings determined that the well was drilled in limestone bedrock that is porous in characteristics. 83% of the well locations were chosen by consultants or experts. The consultants should be aware of the long-term risk involved. There were even several groundwater elevations in Kuala Lumpur that managed to cause contamination to the Klang River and weakened nearby buildings structures. With the availability of state water enactment such as in Selangor, the SWA bears the responsibility to manage groundwater water table in preventing depletion, land subsidence or other adverse effects but it is not with states without water enactments

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6.3. Well Drilling and Depths, Groundwater Allocation and Quality

Abstraction affects the sustainability of groundwater. To ensure the act of abstraction would not bring any impact, well drilling, number of wells, allocation and safe yield and safety equipment need to be determined.

The Well Drilling Guideline by MGD recommended drilling to be carried out only by registered drillers and findings showed almost all operators hire consultants from the MGD or private drillers. Only 6% of the wells were dug by the operators themselves but were done in the 1990s. This was proven from site observations where the wells were using an old method of pumps.

However, stakeholders' responses from the interviews confirmed that the selection of suitable well location and drilling activities were complicated. The Guidelines for Groundwater Drilling, Abstractions and Monitoring in 2009 by MGD was set up to guide drillers but not made compulsory. Nevertheless, there are several stakeholders from the government department that do not know of the existence of specific guidelines indicating weakness in information segregation amongst staff.

Majority of the operators (83.33%) have wells more than 100m deep while others were less than 100m deep (16.67%). This aligns with the research from Nasiman et al. (2011) that the optimum depth of well and discharge rate are between 100m to 150m depth. Shallow wells are prone to pollution as stated by the Dept. of Environment and Conservation, Canada (2013). In Canada, only wells that meet the certain criteria of well depth with quality were allowed to abstract. This is not the case in Malaysia.

Groundwater levels indicate water scarcity (Cooley et al., 2014). Groundwater impacts are usually delayed, diffused but chronic. Some areas recharges slower naturally than other places putting at risk of water table decline and depletion. It is a common practice where prevention, mitigation or monitoring actions are taken only after accidents happen, which is too late and expensive.

Pumping test has to be done periodically to make sure the allocated amount given is consistent with the water table. Testing is done by the operators themselves or by the state MGD and the reports sent to respective SWAs. The permissible amount allocated differs monthly depending on the weather and location equitable for social and sustainable environmental practice (Lubis et al., 2013; Skurray et al., 2013). Allocation differs between domestic and industrial usage with higher volume to the industries; and lower than 2500lpd for domestic uses. There were certain cases where the limits were breached but were not reported.

In addition, following the Mineral Geoscience Department (MGD), it is necessary for equipment to be installed for well water quality monitoring, abstraction amount and groundwater level. Findings showed 50% of the well was not equipped with any monitoring devices as there are no requirements from any water enactments or guidelines. Selangor Waters Enactment Authority 1999 however requires every licensed well to be attached with a water level measurement tool with sand filters to avoid meter malfunction. Nevertheless, only 33% of the operators signified installation of water level measurement while others consider it as unimportant. Likewise, 3% of the respondents installed cameras for well monitoring on their own initiative for any possibilities. Nevertheless, each licensed production well for mineral water under Food Regulation 360A is required to have a well layout plan for securing well point source monitoring.

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The water table has to be measured before any sampling to provide information on temporal trends of groundwater (including flow direction and rates) (Ismail, 2010). Analysis of data shows that many operators have their water levels monitored themselves or SWAs. The operators have to monitor the water level themselves and reports sent to the SWAs or MGD (states without water authorities). MOH is only concerned in mineral water quality monitoring.

Water quality monitoring is compulsory for water abstraction on a periodic basis (Ismail, 2010). The Environmental Quality Act (EQA) 1974 is consulted in pollution control of groundwater. Scheduled daily monitoring is necessary and frequently if any pollution is present until the water quality has improved. Groundwater for the mineral water industry needs to be protected against pathogenic microorganisms by selecting only one type of water treatment (MOH, 1985). There were several cases whereby mineral water was found contaminated with algae presumably affected by high temperatures. The occurrence showed that there exists a lapse in water quality monitoring that needs to be addressed.

Countries like Australia, Spain and Jordan ensured their sampling was done only by consultants or water authorities. Sampling done by operators would create cheating opportunities. Findings showed the groundwater abstraction qualities by the industries are caused by three categories; anthropogenic; natural and; unknown (Table 1).

Table 1. Groundwater Quality Pollution Factors

Factors	Detail	%
Natural Causes	Weather, Infiltration/ Precipitation	18
Anthropogenic	Unregulated Development and Activities	29
Unknown	-	6

29% of anthropogenic factors may directly or indirectly impact the environment and groundwater. Industries using groundwater for cooling systems have the tendency to produce high temperatures of wastewater. Not all industries have sedimentation tanks for the water to cool off before discharged into the drain. To make matters difficult, MOH does not have the authority to demand a stop or prevent misdemeanours if related to the mineral water industry. This is where SWAs should exist to control and monitor the developments for future usage.

Groundwater is related to geology, climate and land use thus any physical changes to the surrounding area would probably cause groundwater quality changes and aquifers stress (California Water Board, 2015; Jha, 2013). Parameters of natural cause such as the Total dissolved solids (TDS) may probably be caused by the salinity of total mineralisation. There are reports of high turbidity during the dry season and increase in microbial contamination level and waterborne outbreaks during the rainy season. The chemical constituents of groundwater however used to understand groundwater processes. Furthermore, land structure of the industrial premises with different types of formations would affect the precipitation process, recharge and residence time.

6.4. Economic Driver

The demand and consumption factors in the country are useful to prevent over abstraction and control of usage by the industries. It is important to understand the user profiles as part of the required

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approaches to improve governance as suggested by Foster and Garduno (2013). But many of the negative economic impacts were usually neglected (Jha, 2013). The economic driver for an industry is to increase productivity and profitability that have led to more pressure on groundwater resources and caused detrimental impacts to humans and the environment.

The number of groundwater abstraction licenses applied by industries to Selangor SWAs and compared with the Industrial Production Index (IPI) showed relation with the number of production output (Saimy & Raji, 2015). However, judging by the positive economic profitability of using groundwater, the socio-economic condition will prompt higher and intensive groundwater exploitation. Groundwater abstracted in the country in 2019 was 92m^3 (DOSM, 2020) and increased to 94 m^3 in 2020 (World Bank, 2021b) which is the second freshwater source for water distribution in the country.

Another economical factor is the fee charged for groundwater abstraction. States with water enactments would profit by the groundwater charges. The groundwater fee is cheaper compared to the tariffs from piped water supply. This is supported by Gracia-de-Rentería et al. (2020) that mentioned the industries behaviour of using groundwater is factored by the cost of piped water supply that showed the economic yield of groundwater is thrice of surface water. The two SWAs in Selangor and Kedah indeed charge for groundwater abstraction amount, while Sabah since 2015 and Melaka since 2012. However, there is a provision in LSANK whereby certain users may be exempted from paying the water charges. The statement should however be clearer and detailed or deleted as it may cause discrimination.

States without water enactments would be making a loss of revenue even though the operators are making profit from free water sources. The state water departments without water acts do not have any jurisdiction to force the operators to pay for an abstraction license nor the amount of abstraction. The amount collected may not be many, but could be used for future upgrades and maintenance and boost the state's economy. Nevertheless, low prices of groundwater may induce inefficient water usage and discourage water-saving attitudes and technologies (Maliva & Missimer, 2012). It may also deter operational and development of financial resources. The price charged should be the market valuation of the groundwater economy in the state.

There are business owners who tried to minimise their operational cost by having another factory at the same location. The action would be economical but the concern of the additional factory may (i) contaminate groundwater source and; (ii) the activities within the buffer zones may loosen the earth structure. Sadly, the existing HACCP principle under MOH focuses only on quality control of food processes whereas it should cover the contamination factor within the area too.

The analysis throughout the whole study managed to obtain the strengths and constraints of groundwater abstraction by the industry in the country. Findings overall showed advantages of having state water enactments and the abstractions were more controlled. There should be other future research on groundwater issues in other countries to understand the approach and actions taken.

7. Conclusion

In conclusion from the study, the following themes were derived from Malaysian industrial groundwater practise and governance. The themes are presented in a framework below (Figure 3) to show

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the essentials in a sustainable groundwater management by the Malaysian industry that includes abstraction, plant size, resource sustainability and monitoring.

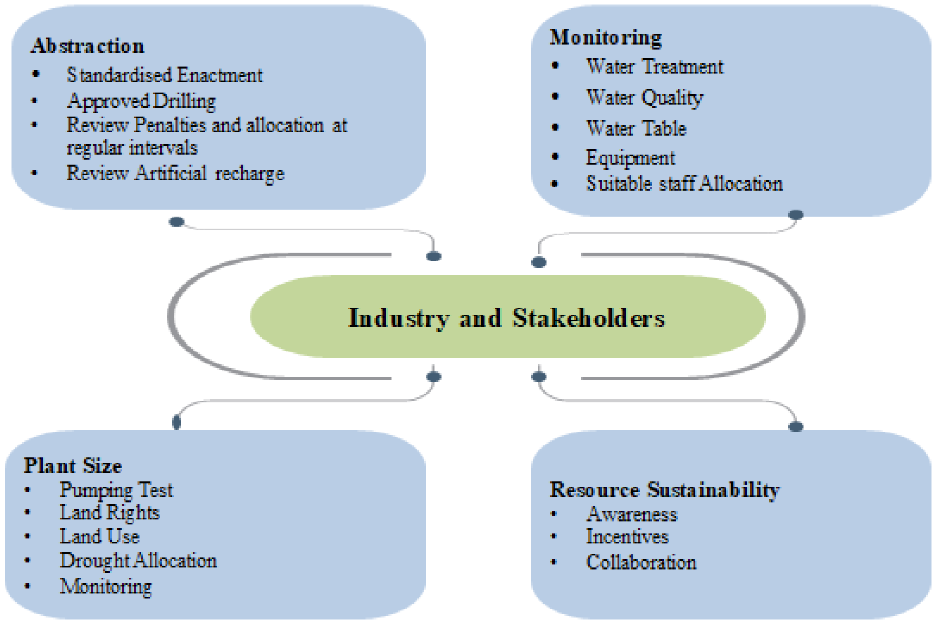

Figure 3. Proposed Industrial Abstraction Framework

Water is a source of conflict to land owners, users, governance and others that may mismanage the natural groundwater. Therefore, to avoid such conflicts, the land rights, land use category, licensing and optimum plant size should be determined to ensure minimal problems. It should be under the operators' liability to ensure their land sitting and activities are legitimate according to the rules.

Groundwater quality, treatment, storage and locations should be one of the top priority concerns. Regular inspections of equipment maintenance are recommended to ensure the standards of procedures (SOPs) are followed. Monitoring should be done by the authorities itself, not by the operators to reduce foul play. The appropriate and standardised water pricing, licensing fee, penalties, and other details were suggested to secure the resource and its sustainability from different sectors and users by using different options, technologies and approaches. The governance needs to act immediately to secure the water demands and supplies.

The major challenges faced in groundwater management in Malaysia are the lack of national groundwater policy for reference and standardise groundwater guidelines for the whole country. Even if such a policy exists, there need to be more law-abiding and avid implementation supervision with the power to enforce. Malaysia needs to improve on water governance generally and be prepared for higher usage of groundwater. Good governance of natural resources is achievable when there are initiatives and commitment. There should be encouraged for further studies in groundwater with the government department on thorough groundwater availability details in Malaysia.

Industries having a role in achieving SDGs must urgently use water efficiently and responsibility. Companies share the responsibility of resource sustainability with the government, suppliers, and

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customers and are integrated in the companies' core business models. Industries should seek to understand the transformations required to achieve sustainability in all aspects of their productions especially in natural resource usage. The groundwater resource conservation promotion must be encouraged by efficient usage and appropriate facilities provided.

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