

GROUNDWATER QUALITY ASSESSMENT IN SMALL ISLAND AQUIFER, MABUL ISLAND, SABAH

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Abstract

Mabul Island depend mostly on groundwater as a major source of water supply for domestic and tourism industry purposes. There was no inflow from river and the highest level was 4.2 meter above mean sea level. Rainwater is the only source of recharging the groundwater to sustain the quality. Over-abstraction of fresh groundwater lens leads to saltwater intrusion and deterioration of its quality. This study aimed to assess and understand the groundwater characteristics in the fragile aquifer of the island. In order to assess this issues, a groundwater sampling was collected 4 times between March 2018 to October 2019 from 15 dug wells scatter in the island. The geochemistry concentration of chloride and electrical conductivity usually used to determine saltwater intrusion. This study focuses on the assessment of freshwater lens mixing and salinization. The mixing fresh groundwater lens situated from 2.5 to 2.9meter depth below ground level (bgl) which quality defer from 1,218 to 23,170 μS . Depth below than 4 meter from ground level is considered as seawater. Most of the groundwater pumping wells came from the tourism industry and were not used for a drinking purposes. Most of the groundwater was identified as saline water and only a part of the island shows slightly saline water based on the ionic strength and chloride concentration. Based on the analysis of groundwater lens quality and density dependent flow model indicate that the island's coastal aquifer has been encroached by seawater. Extensive research is currently being carried out worldwide in order to understand the mechanisms of SI and develop strategies to control the process. For example, costly technological solutions, such as desalination, barriers or injection wells have been implemented to deal with the reduction in freshwater availability. Consideration for this technologies factor affecting saltwater and freshwater interface.

Keywords: Saltwater intrusion, Groundwater Lens, Geochemistry, Chloride, Ionic Strength

Introduction

The development of groundwater resources in oceanic islands and mainland coastal areas are a delicate issue and careful management is required if water quality degradation due to the encroachment of sea water is to be avoided. In many cases, difficulties arise when aquifers are pumped beyond their natural recharge rate and sea water is drawn into the system. Problems can also occur when excessive pumping at individual wells lowers the potentiometric surface on a localized scale and causes

upconing of the natural interface between fresh water and saline water. Coastal and island aquifers are also sensitive to sea level changes such as postulated rises due to global warming. The associated volumetric expansion of sea water and melting of snow caps would increase the extent of sea water intrusion and reduce the availability of fresh groundwater resources. Saltwater intrusion is a major concern commonly found in coastal aquifers around the world. Saltwater intrusion is the induced flow of

seawater into freshwater aquifers primarily caused by groundwater development near the coast (Falkland, 1993). Where groundwater is being pumped from aquifers that are in hydraulic connection with the sea, induced gradients may cause the migration of salt water from the sea toward a well, making the freshwater well unusable. Because fresh water is less dense than salt water it floats on top. The boundary between saltwater and freshwater is not distinct; the zone of dispersion, transition zone, or saltwater interface is brackish with saltwater and freshwater mixing.

Under normal conditions fresh water flows from inland aquifers and recharge areas to coastal discharge areas to the sea. In general, groundwater flows from areas with higher groundwater levels (hydraulic head) to areas with lower groundwater levels. This natural movement of fresh water towards the sea prevents salt water from entering freshwater coastal aquifers (Barlow, 2003). Groundwater pumping/development can decrease the amount of fresh water flowing towards the coastal discharge areas, allowing salt water to be drawn into the fresh water zones of coastal aquifers. Therefore, the amount of fresh water

stored in the aquifers is decreased (Barlow, 2003).

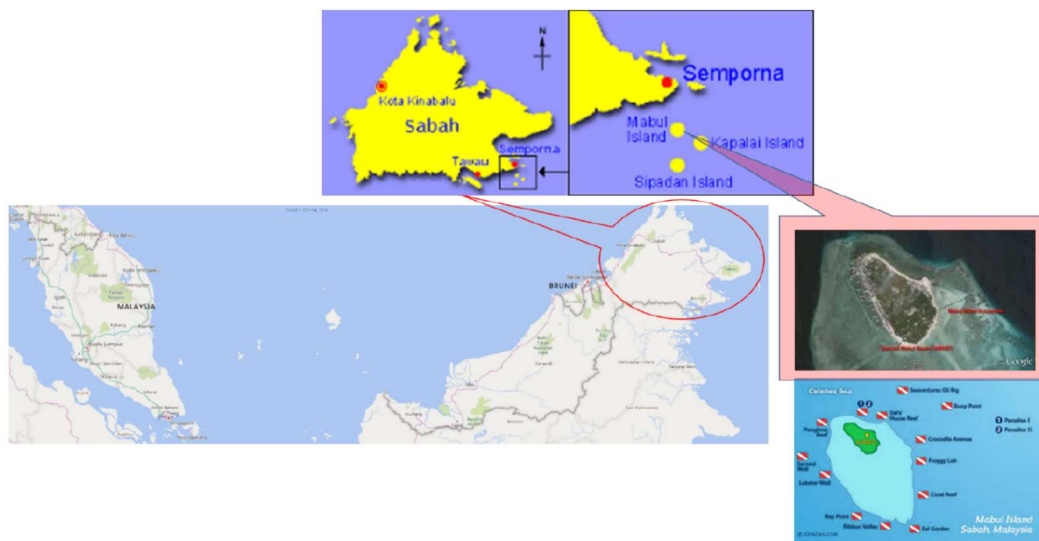
This unfavourable situation caused a great concern to peoples living island. This is because of seawater intrude toward inland will lead to saltwater intrusion into coastal aquifer that contaminate the freshwater supply (Priyanka & Mahesha, 2015). Contamination of 2 – 3% of saltwater into coastal aquifer will increase the waters salinity and resulting in water quality degradation (Abd-Elhamid & Javadi, 2011). The problem also experienced by villagers living in the area of this study. Most of the residents used groundwater withdrawn from the dug wells. Mabul Island depends entirely on groundwater and rainwater resources for basic uses such as for watering crops and washing clothes. In some parts of the island, the current rate of groundwater extraction is depleting the resource faster than it is being recharged (Idris, et. al., 2014). In conjunction to this problem, a study is carried out to confirm the major sources of groundwater quality pollutants based on sampling wells that located scattered in the island to assess the concentration of saltwater intrusion into the wells.

Material and Methods

Mabul Island, Sabah is approximately about 0.4 km² in area and is classified as a small island. Indeed, approximately 90% of the area is covered by coastal sediment sand and developed for tourism activities. Samplings were carried out at 15 private wells, scattered in the island (March 2018, October 2018, March 2019 and October 2019). Samplings were conducted by performing in situ measurements of selected water quality parameters such as electrical conductivity (EC), total dissolve solid (TDS), salinity, pH and turbidity. The villages involved for which geochemistry data were samples included Kg. Mabul, Kg. Rama-Rama and Kg. Tengah. The locations of sampling point are shown in Figure 1.

Groundwater were sample using polyethylene bottles based on the methods described in APHA (2005). In-situ analyses were conducted in the field using multiparameter sonde YSI 6600 for the Electrical Conductivity (EC), pH, dissolved oxygen (DO), redox potential and temperature. Major cations (Ca²⁺, Na⁺, Mg²⁺ and K⁺) were determined using inductively coupled plasma mass spectrometry (ICP-MS) model Nexion 300X, made by PerkinElmer from United State of America (USA) according to the Environmental Protection Agency (EPA). Major anions and all analyses were performed in the water quality laboratory and follow the procedures referred to APPA (2005).

a)



b)



Figure 1. a) Study area and b) public wells sampling location

Results and Discussion

Major anions and cations, pH, conductivity, total dissolved solids, as well as the temperature and colour were assessed on all samples collected. The results show that: pH range is 6.71 - 9.94, conductivity between 510 -15,650 $\mu\text{S}/\text{cm}$ (25 °C), TDS range 360 - 11,141 mg/L and chloride concentration ranges from 2000 - 10889 mg/L. More than 86% of samples, Cl^- concentration exceeded the WHO (1984) value for standard drinking water (250 mg/L) and in 66% of samples, Cl^- concentration exceeded the WHO (1984) highest admissible concentration (600 mg/L). This high Cl^- concentration is

due to mixing with seawater. Minimum and maximum of water quality parameter results are summarised in Table 1.

All geological environments may contain naturally occurring saline water resulting from geochemical processes within each geological setting. Naturally, highly saline waters typically have Cl^- as the dominant anion and Na^+ as the dominant cation.

Sodium and Chloride concentration in 15 dug well shows that well W7, W8 W12 and W13

has the lowest values (Figure 2). The is because the wells are located at the center of the island and villagers use buckets to draw water from these well and not a centrifugal pump

Table 1. Summary of water quality parameter (min-max) of groundwater.

	W1		W2		W3		W4		W5		W6		W7		W8		W9		W10		W11		W12		W13		W14		W15	
Parameter	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
pH	7.4	8.1	7.3	7.6	7.1	7.3	7.2	7.5	7.1	7.8	7.1	7.4	7.4	7.4	7.3	7.6	7.1	7.3	7.2	7.5	7.5	7.7	7.1	7.4	7.1	7.4	7.3	7.5	7.0	7.3
Alkalinity	183.0	318.3	186.0	259.0	235.0	458.6	230.0	314.0	162.0	256.0	254.8	299.0	228.8	297.0	171.2	395.0	142.3	319.0	244.2	278.0	211.0	247.0	154.8	371.0	192.3	290.0	291.3	341.0	269.2	373.0
Conductivity	2908.0	9995.0	2695.0	15746.0	6565.0	12915.0	4520.0	23481.0	5377.0	11310.0	4314.0	6703.0	1609.0	11506.0	1218.0	2809.0	3429.0	3811.0	2193.0	2688.0	1994.0	5737.0	1302.0	5766.0	1755.0	4157.0	8448.0	18070.0	12480.0	24732.0
Calcium	86.8	204.0	88.9	260.0	210.5	317.6	178.1	234.0	129.0	283.0	187.0	267.7	115.0	252.0	102.2	141.0	192.0	276.9	148.0	174.8	114.1	152.0	129.5	207.0	154.0	193.3	192.7	287.7	305.3	371.4
Magnesium	81.0	259.0	100.6	374.0	115.0	565.2	84.0	249.8	120.0	456.3	79.0	200.8	35.9	316.0	22.8	63.0	56.0	119.1	40.0	71.2	86.0	191.5	28.5	96.0	43.7	90.0	321.0	722.5	454.7	1710.3
Sodium	661.0	2484.0	813.4	3777.0	1051.0	5293.7	775.0	2221.5	1258.0	4010.2	684.0	1798.4	254.4	2989.0	140.7	560.0	533.0	1058.3	324.0	535.8	728.0	1619.4	196.5	962.0	329.9	922.0	2995.0	6246.2	4040.4	15960.2
Potassium	27.0	80.0	27.6	128.0	49.0	128.8	39.0	77.0	48.0	113.1	36.0	61.0	12.7	95.0	8.1	24.0	38.0	53.5	30.0	59.6	27.0	49.7	11.9	39.0	20.9	35.0	90.0	184.0	105.9	289.8
Chloride	837.4	4976.0	820.6	9332.0	2070.0	5649.0	1360.0	3237.0	1937.1	6200.0	1154.9	3910.0	433.1	5518.0	240.0	845.0	771.3	3860.0	402.6	775.0	1278.6	2435.0	224.0	1419.0	361.5	1474.0	2854.0	9120.0	5480.0	10889.0
Fluoride	0.2	0.4	0.3	0.5	0.0	0.5	0.3	0.4	0.1	0.5	0.3	0.3	0.0	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.2	0.3	0.3	0.4	0.1	0.1	0.0	0.1	0.0	0.3
Nitrate	9.4	22.5	43.0	94.0	121.1	299.0	190.4	218.0	85.0	139.8	134.0	160.5	1.2	75.8	19.0	106.0	303.0	574.0	153.0	270.9	7.7	20.0	70.7	192.0	115.0	25.7	19.4	33.5	0.2	3.0
Sulfate	71.0	528.0	143.6	667.0	318.0	750.0	194.0	417.0	277.0	602.0	217.7	370.0	77.5	605.0	53.4	134.0	194.0	221.0	133.0	176.0	141.0	296.0	53.5	251.0	67.7	207.0	412.8	1160.0	523.0	1333.0
Iron	0.1	0.5	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.1	0.3	0.0	0.3	0.0	0.3	0.1	1.9
Manganese	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zinc	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1

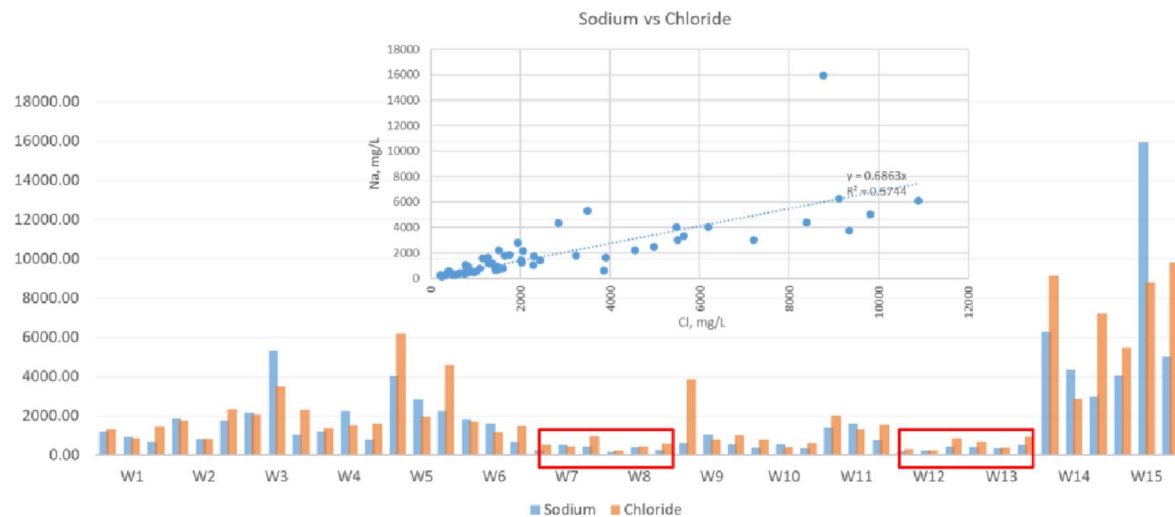


Figure 2. Sodium and chloride concentration from 15 dug wells

Classification of hydrochemical facies for groundwater according to Piper diagram is shown in Figure 3. Although various hydrochemical facies were observed, NaCl type is dominant. Large proportions of the groundwater show NaCl type, which generally

indicates a strong seawater influence (Pulido-Leboeuf, 2004) or upconing of saltwater, while CaCl water type is indicating salinization and cation exchange reaction (Walraevens & Van Camp, 2005).

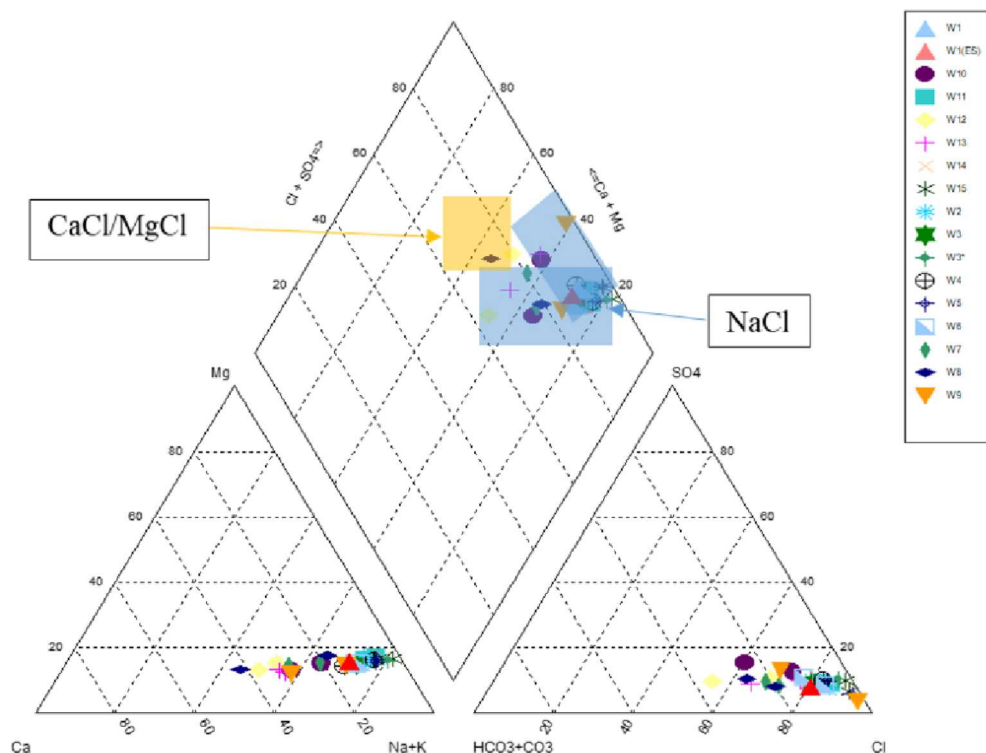


Figure 3. Water types in Mabul Island according to piper diagram were CaCl/MgCl and NaCl. (after Nawal, et. al., 2011)

Figure 4 shows the composition of salt ions vs selected wells (W1, W8 and W15). These well which has low to high concentration of Chloride. The salt component of W8 which has more Calcium (19%) and less Chloride (38%)

than W1 (Ca²⁺ - 6%; Cl⁻ - 43%) and W15 (Ca²⁺ - 3%; Cl⁻ - 50%). The composition component of salt ions can describe the salinity of each well in the island.

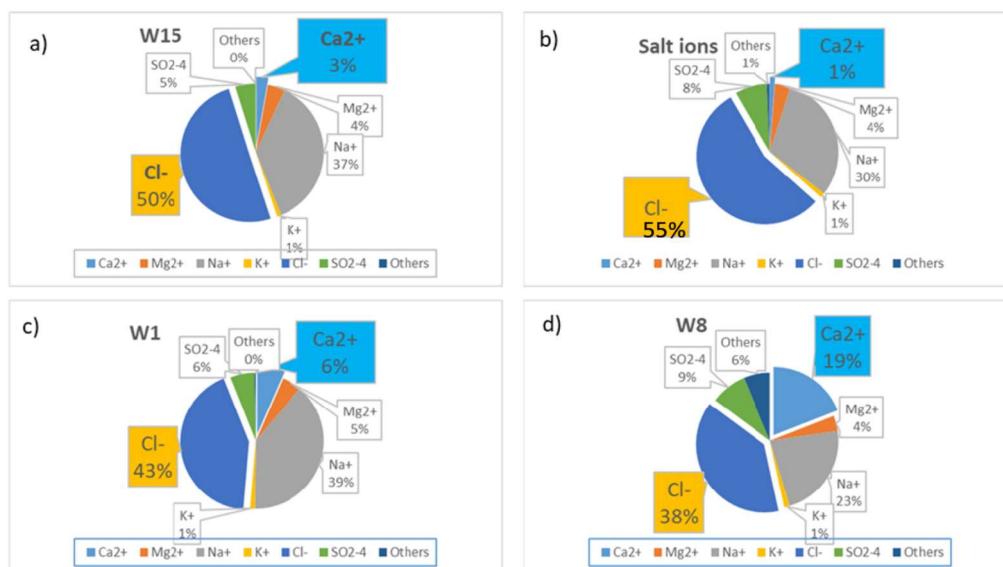


Figure 4. Diagram showing concentrations of various salt ions in the contamination of groundwater from seawater. The composition of the total salt component in a) W15, b) Seawater, c) W1 and d) W8

The impact of ongoing salinization found during pre-monsoon can be evaluated by the ionic strength variation in the groundwater. Figure 5 shows the water type classification based on ionic strength and Cl concentrations.

The Cl was chosen because it is the most abundant ion in seawater. The scheme of ionic strength plotted against Cl on log-log scales produce of five major classes; fresh, slightly fresh, moderate, slightly saline and saline.

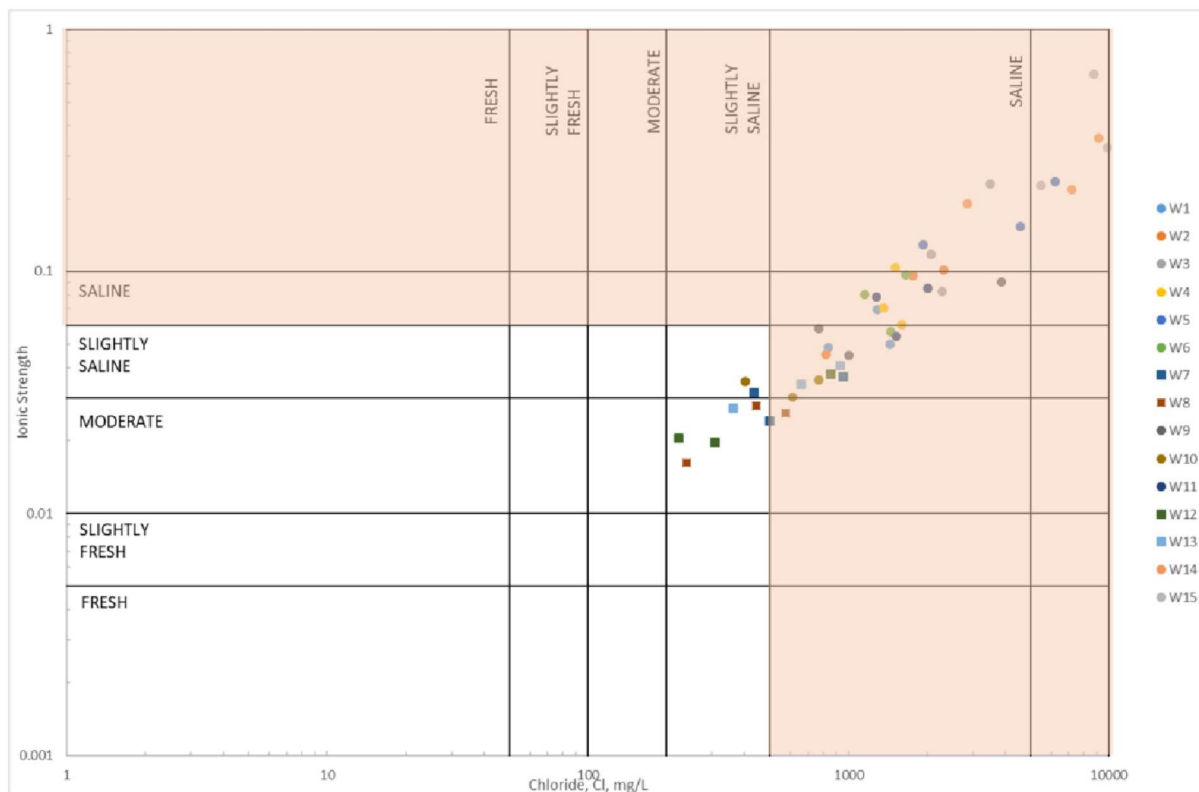


Figure 5. Assessment scheme for seawater intrusion based on ionic strength (I) against Cl concentration (after Mohd Isa & Aris, 2015)

Conclusion

Most of the wells are contaminated by saltwater. This may due to the excessive pumping activity from the resorts and the villagers. Chloride and sodium and EC have high value and were found to be exceeded the Malaysian and WHO drinking water standard. The values of water quality parameters such as pH and turbidity from all samples collected from public wells of the villages were found to be within the recommended limits of WHO. The

concentrations of 7 heavy metals (Cu, Zn, Mg, Fe, Cd, Pb and As) were also measured and found to be well below the standard maximum concentrations. However, it is also important to investigate other potential water contaminations such as microbial and radiological materials for a longer period of time, including human body fluids, in order to assess the overall water quality of Mabul Island.

Acknowledgement

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ARSENIC REMOVAL BY ACTIVATED CARBON FROM DURIAN HUSK

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Abstract

The preparation of activated carbon from durian husk, variety D175 which also known as Udang Merah by chemical activation technique using zinc chloride (10%) as activating agent and its ability to remove arsenic in aqueous solutions were reported in this study. The proximate analysis of durian husk and the characterization of activated carbon using FTIR, SEM and SEM-EDX were evaluated. The influence of various factor such as weight of absorbent, arsenic concentration, contact time and pH were studied. Result from the study suggest that activated carbon prepared from durian husk, D175 has potential to be a promising precursor for the production of activated carbon with the excellent adsorption capacity to remove arsenic in aqueous solution.

Keywords: Durian Husk; activated carbon; arsenic; adsorption; kinetics

Introduction

Heavy metals pollution has become one of the most serious problem nowadays. The removal of heavy metals from the environment is of special concern due to their persistence – high solubility in aquatic environment, can be absorb by living organism. If the metals are ingested beyond permitted concentration, they can cause serious health disorder (reduced growth & development, cancer, organ damage, nervous system damage, death) (Ali et al., 2019; Zayat et al., 2006).

Contamination Sources – discharges by industries such as agrochemicals, petrochemicals and fertilizers and leaching of metals ion from the soil into lake and rivers by acid rain. Arsenic toxicities – skin manifestation, visceral cancers, vascular disease. Maximum Concentration Limit – 0.050 mg/L, Environmental Quality Act 1974, DOE – Standard A (0.05 mg/L) & Standard B (0.10 mg/L) (DOE, 1974), Environmental Protection Agency (EPA) – 0.01 mg/L (<https://www.epa.gov/dwreginfo/drinking-water-arsenic-rule-history>).

Basically, adsorption involves mass transfer

process, which a substance is transferred from liquid phase to solid surface, and then bounded by physical and/or chemical interaction (Asadullah et al., 2014; Babel and Kurniawan, 2003). The fundamental concept in adsorption science also involves the explanation via adsorption isotherm fitting. A variety of equilibrium isotherm models have been formulated in terms of three fundamental approaches i.e. kinetic consideration, thermodynamics and potential theory (Foo and Hameed, 2010).

Generally, activated carbon (AC) is known as a versatile adsorbent. Its absorptive properties are due to their high surface area, microporous in structure and has a high degree of surface reactivity. In addition, different functional groups are present on AC surface with well-developed internal microporous structure and hydrophobic internal surface (Ansari, 2009; Ioannidou and Zabaniotou, 2007). Few researchers have reported the production of activated carbon from durian biomass (Mohktar et al., 2013; Foo and Hameed, 2012; Chandra et al., 2007). In the present work, a by-product from agricultural industry, namely durian husk was