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Identifying The Potential Sources of Chemical Elements in Drainage and Rivers Using Google Earth Imageries and Posteriori Knowledge

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Abstract: This study attempts to identify the potential sources of the chemical elements in the river and drainage water using in-situ water quality sampling and public domain satellite data. Monitoring the physico-chemical level of urban streams and rivers is important to secure sufficient water resources, an indicator to the ecological degradation in urban areas and an indicator of environmental pollution. Nonetheless, identifying the potential sources of chemical pollutants by field observation is constrained by hard labor activities, time, and cost. Having satellite imagery that provides land use activity information would be useful in determining the chemical sources. Therefore, the objective of this paper is to utilize the publicly accessible Google satellite images in identifying the potential sources of the chemical elements' presence in the water that is physically sampled and measured over the selected urban rivers and drainage of Johor Bahru. Three chemical elements were identified, ammonia (NH_3), nitrate (NO_3^-), and phosphate (PO_4^{3-}). The identification of the chemical sources is conducted based on the interpretation of the satellite-derived information together with the posteriori knowledge, experience, and inputs in an environmental chemistry perspective. The findings revealed that the proportion of land used did not always have a significant impact on the chemical content of the waterways. For ammonia, areas with significant hotspots (aquaculture, wet market) are more significant, although the size of the area is not dominant. The nitrate content, on the other hand, showed quite a distinct pattern linked to oil palm, intensive farming, and industrial or commercial areas. There was no distinct land use pattern associated with phosphate level. However, locations with high residential areas were likely to have high phosphate content in their respective waterways or drainage to the onsite investigations with minimal labor works, cost effective, and time efficient.

Keywords: Ammonia, nitrate, phosphorus, non-point source pollution, oil palm

1. Introduction

Urbanization has been associated with omnipresent effects on the water quality in the connecting drainage and rivers due to the presence of settlements, agro-activities, and impervious surfaces that lead to excessive amounts of water entering the channels [1]. For the following reasons, monitoring the physico-chemical level of urban streams and rivers is important. First, (1) is securing sufficient water resources. Certain locations of the direct water intake for the

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treatment plant were situated in urban rivers. Therefore, any significant pollution could threaten the quantity of water resources and cause a shortage in supply. Second, (2) to serve as an indicator of urban ecological degradation. For example, the presence of ammonia content beyond the average level that is commonly released by the innate processes could indicate disturbances to the ecosystem, whereas anthropogenic processes might occur. Thirdly (3), it can be used as an indicator for pollution due to unregulated agro-economic practices (i.e., excessive fertilization, animal manure), hazardous untreated waste from industrial, commercial, or housing, or any chemical related catastrophe, such as industrial boiler deficiencies that lead to significant ammonia released due to enormous cooling activities.

Johor Bahru, the second largest city in Malaysia with a 3.7 million populations [2] and still undergoing extensive urbanization and development, is exposed to environmental water quality degradation. Water supply is critical for urban rivers like Sungai Skudai and tributaries like Sungai Sayong and Sungai Semangar, which are surrounded by intensive farming and plantation. At present, Johor has among the largest oil palm plantation footprints in Malaysia, at about 658595 hectares [3], as well as oil palm mills which possibly emit chemical effluent. The total footprint for commercial agriculture (including oil palm) in Johor reached 894376 hectares [4]. These intensive farming and large-scale plantations had a great tendency to transport excessive chemicals, especially from the fertilizer and pesticide to the connecting stream prior to run-off. In addition, the unregulated waste from either industry, commercial or residential areas has already been a threat to deteriorating urban water quality, including excessive manure, improper water treatment [5], and hazardous chemical leaks such as ammonia [6].

Therefore, a consistent identification of the pollutant source is essential for preventive, mitigation, and assessment works. Nonetheless, the onsite physical investigation was constrained by several prominent factors including hard labor, time consumption and logistics. Not to mention that the drainage pattern in urbanized environments is very complex where artificial drainage that dominates were not following the natural topography and river geomorphology especially in terms of their tributaries, pattern, width and confluence [7]. An alternative support method in identifying the source of chemical pollutants is required to complement the stationary or non-stationary field measurement. Considering the logic of pollutants being merely transported from the nearby areas, utilizing drones or other modes of unmanned aircraft vehicles is only feasible for relatively small coverage (<0.5km) with low-rise features of buildings. The large and dense canopy of oil palm trees can sometimes affect the connectivity of drone signals. [8].

One alternative data support that potentially can be exploited in anticipating the preceding concern is to utilize the publicly accessed satellite imageries. Among the most sought-after sources, Google has been operationally shared such information through various platforms such as Open Street Maps, Google Hybrid, Google Earth and other websites which operate based on Google API like freemaptools.com. The quality of the data is decent with a fine spatial resolution (1-5m) and cloud cover free. In addition, it was also cost-effective as acquiring real satellite images is expensive not including incurring processing works. As a result, a direct retrieval of land use information is possible and can be done promptly. Considering that the user had posteriori details about the sites including scientific knowledge and experience in environmental chemistry, determination of the chemical pollutant's sources can be done with minimal field investigation. Nonetheless, a thorough study must be conducted to test this possibility.

Prior to the aforementioned situation, this study attempts to identify the potential sources of the chemical elements in the river and drainage water using public domain data. The objective of this paper is to utilize the Google Earth data to identify the potential sources of the chemical element's presence in the water over selected urban rivers and drainage of Johor Bahru. Three chemical elements were identified, ammonia (NH_3), nitrate (NO_3^-), and phosphate (PO_4^{3-}). The identification is conducted based on posteriori knowledge, experience, and inputs in the environmental chemistry perspective obtained from literature reviews, experts, and scientific reports. Land use, building information, and all the related information retrieved from Google Earth will be used as primary data in the identification process.

2. Materials and Method

There were four main phases in this study: (i) environmental water sampling, (ii) chemical laboratory tests, (iii) acquiring land use information from Google Earth images, and (iv) identifying the potential sources of major chemical elements using the derived land use information. Each phase will be explained in detail in the subsequent sub-chapters.

2.1 Environmental Water Sampling

Environmental water samples will be taken in selected rivers and drainage in the Johor Bahru areas. The sites were selected based on their respective dominant land use that might represent major pollutants or interesting chemical elements, including ammonia, nitrate, and phosphate. This might include large-scale farming and agriculture, industrial, residential, mining, and aquaculture. For every site, one liter of water samples was taken and stored in polyethylene terephthalate (PET) bottles for further chemical analysis in the laboratory. The coordinates for each station were recorded using the handheld Garmin GPSMAP 64st Worldwide Handheld GPS to identify its location in the corresponding satellite images.

1-2 samples were taken for dominant land use in Johor Bahru. The samples were taken to obtain the chemical elements in the water which attributed to the surrounding land use. The samples collected were depending on land use practices and accessibility of the locations. Many locations were difficult to access due to various environmental factors including private premises, thick bushes or secondary forests, and animal threats. The sampling process was held during 14-15 March 2020 over Senai, Skudai and Tiram areas of Johor Bahru.

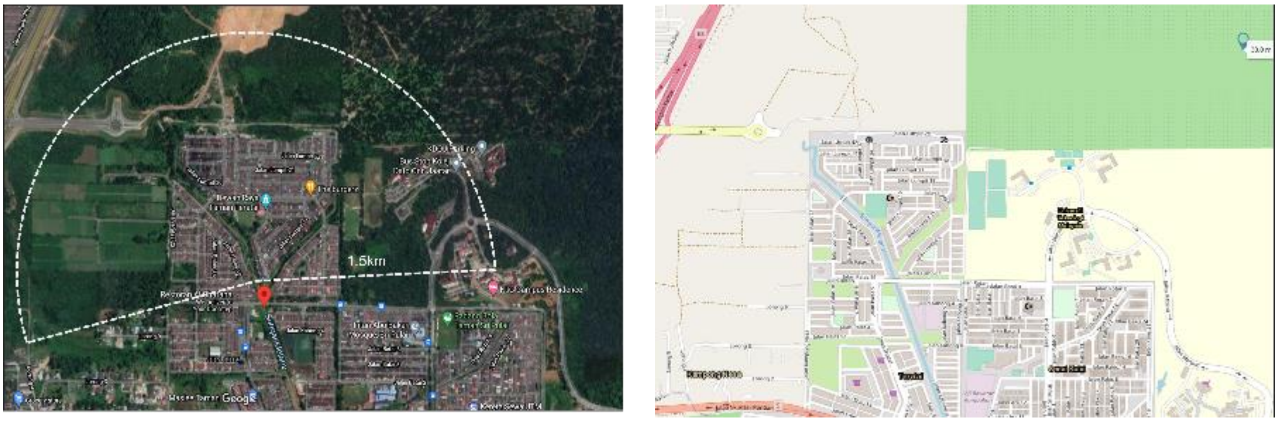
2.2 Chemical Elements Laboratory Test

All the water samples taken will undergo chemical tests in the laboratory to determine the corresponding common chemical elements present in urban waters and major pollutants resulting from natural or anthropogenic activities, which are ammonia, nitrate, and phosphate. The tests were conducted using the salicylate method for ammonia, the most common pollutant and hazardous chemical found in environmental waters if exceeding the permissible level.This method uses two reagents, sodium salicylate and sodium hydroxide, to encourage the formation of the blue color of indophenol. Sodium salicylate is used as a phenolic source and reacted with sodium hypochlorite in the presence of sodium nitroprusside as the catalyst. This method is used to quantify the amount of ammonium (TAN) in the water sample in accordance with its color intensity.

For nitrate, the test used involves the reaction of aromatic amines to prepare an intermediate diazonium salt, which can be used to produce an azo dye compound when reacting with nitrite. The detection limit ranges from 0-5 ppm and the color varies from pale blue to purple based on the nitrite concentration present in the water sample. The concentration should be below 0 ppm, and anything higher could pose a threat to aquatic life. The last chemical element, phosphate, can be detected in water samples using the standard method, 1995. The mixture of ammonium heptamolybdate, sulphuric acid, and tin chloride generates molybdenum blue. The color intensifies with the phosphorus concentration. The detection limit is from 0 to 10 ppm. The color will vary from yellow, green, and blue at a high phosphate level.

2.3 Extracting Land Use Information from Google Earth Imageries

To extract the information of the land use surrounding the sampling points, we utilized the public access satellite imageries and the corresponding land use from the worldwide web of https://www.freemaptools.com/elevation-finder.htm. This website provides up to date imageries from satellite and derived land use obtained from Google Earth API and Open Street Map respectively. The data was cloud free and possess very high spatial resolution (~1m). The still images of the Google Earth imageries will be downloaded together with their corresponding land use for all the sampling points. By identifying the coordinates, the land use proportion surrounding the sampling point about 2km is extracted and systematically tabulated. The extraction process was conducted based on the posteriori and knowledge from the subject matter experts of the researchers. Visualization of the spatial data was carried out using the QGIS 3.16.10 open-source software. Fig. 1 shows the samples of the data in QGIS system.



(a) (b)

Fig. 1 - Sample of the extracted data from Google platform, (a) satelliate imageries (API Google), and; (b) land cover information (Open Street Map)

2.4 Identifying The Potential Sources of Chemical Elements in Drainage and Rivers in Johor Bahru Using Google Earth Imageries and Posteriori Knowledge

With the land use information obtained from the publicly accessed Google Earth imagery surrounding the sampling points and chemical information acquired from the laboratory test, the source of the chemical elements was then determined. This is conducted by analyzing the proportion of the corresponding surrounding land use, assuming that those chemical elements were constituents of the respective land use. Specific posteriori knowledge and experience about urban environmental chemicals were adapted as shown in table 1. Posteriori knowledge and information refer to the specific past knowledge and experience held by the experts, which in this case, two environmental scientists familiar with the land use in Johor Bahru and its potential pollutants. In addition, the reference threshold for harmful chemicals in water was also incorporated.

Table 1. Chemical elements, posterior and expert's guidelines, and standard level for environmental safety

No.	Chemical elements	Posteriori and experts reference on the environmental water chemical sources	Harmful description	Sources
1	Ammonia	Ammonia and ammonium ions can be present in water through the decomposition of organic matter such as decayed plants and animals. The sources can be from natural ecosystems or anthropogenic. However, the amount of ammonia that was released into the water was relatively low for natural ecosystems compared to anthropogenic sources. Among the anthropogenic activities that may contribute to a large amount of ammonia in water are effluent discharge, fertilizer from agriculture, large-scale farming, and the excretion of animals. In the Johor Bahru area, large-scale farming, oil palm plantations, and poultry were common, dominating 85% of the green areas.	Class I, <0.1mg/l Class II, 0.1 - 0.3 mg/l Class III, 0.3 - 0.9 mg/l Class IV, 0.9 - 2.7mg/l Class V, > 2.7mg/l	Department of Environment, Malaysia [9].
			Trigger threshold, 0.021mg/l	Australian and New Zealand Guidelines for Fresh and Marine Water Quality [10].
			Rehabilitation standard, <0.4 mg/l	Ammonia in Surface Water — Rehabilitation Standard for the Ranger uranium mine. Australian Government, Dept. of Agriculture, Water & Environment [11].
			Odor effects, 1.5mg/l Taste effects, 35mg/l	National Headquarters and Laboratory [12].
			0.25 to 32.5 mg/l (ppm).	US Environmental Protection Agency [13].
2	Nitrate	Nitrate (NO_3^-) is a compound formed when nitrogen combines with oxygen. It can be found in most fertilizers, manure, and liquid waste discharged from various sources. Such common sources in the Malaysian environment include septic tanks, intensified farming, oil palm, unreticulated sewage disposal systems, industrial waste, and food processing waste. In Johor Bahru, all the sources are common. There are still a significant number of premises that do not have a proper treatment water system, especially residential and factories.	>11.3mg/l	Drinking Water Standards for New Zealand [14].
			>10mg/l	National Guidelines for Raw Drinking Water Quality [15].
			>10mg/l - harmful <3mg/l - safe	Minnesota Department of Health Environmental Health Division [16].
			>10mg/l - harmful <3mg/l – safe	Washington State Department of Health [17].
3	Phosphate	Phosphate in urban waters can come from multiple sources. It includes food processing industries, sewage treatment plants, leachate from garbage tips, and intensive livestock industries. Agricultural land use may transport phosphorus through run-off. Sources of phosphorus come from fertilizers or phosphorus-containing	>0.2 mg/l	National Water Quality Standards Malaysia [18].
			>100mg/l - over fertilization	National Health and Medical Research Council (NHMRC), Australian Drinking Water Guidelines [19].

pesticides. Most food products contain phosphorus in various organic and inorganic forms. Phosphorus may also come from household items and products such as detergents, flame-retardants, corrosion inhibitors, and plasticizers. In addition, lubricant emissions from the vehicle also contained phosphates, which can be transported to the drainage systems through rainwater. The Johor Bahru area consists of all the major phosphorus sources, especially agriculture, sewage treatment plants, and a high-density of road network.	0.01 - 0.03 mg/l - the level in uncontaminated lakes 0.025 - 0.1 mg/l - level at which plant growth is stimulated 0.1 mg/l - maximum acceptable to avoid accelerated eutrophication > 0.1 mg/l - accelerated growth and consequent problems	Water, Water Everywhere. HACH Company [20].
	Rivers and steams: 10-100 micrograms/l (0.01 to 0.1 mg/l) (as total phosphorus) Lakes and reservoirs: 5-50 micrograms /l (0.005 to 0.05 mg/l) (as total phosphorus) Estuaries and embayments: 5-15 micrograms /l (0.005 to 0.015 mg/l) (as phosphate-phosphorus) Coastal waters: 1-10 micrograms /l (0.001 to 0.01 mg/l) (as phosphate-phosphorus).	Australian Water Quality Guidelines for Fresh and Marine Waters [21].

3. Results and Discussion

3.1 Environmental Water Samples

Fig. 2 depicts the locations of the field water sample collection. There were 23 samples in total consisting rivers, drainage including waterways. 5 stations were taken in Sg. Johor, 6 samples were obtained in Sg. Tiram, 7 samples in Sg. Skudai area, and 5 samples in Sg. Pulai. Those selected areas were among the major rivers or drainage in Johor Bahru, for instance, Sg. Skudai was vital for supporting the freshwater supply, and Sg. Tiram catchment was heavily dominated by intensive farming and plantation, quarries, heavy industries, and even aquaculture. Those are the major contributors to chemical elements in environmental waters. For information, Sg. Tiram is one of the tributaries of Sg. Johor, one of the biggest and longest river in Johor. Sg. Pulai on the other hand, is the perfect representation of the urban areas with complex land use patterns, consisting residential, industries, oil palm, secondary forest and commercial areas. Therefore, all the samples taken are reliable to represent the dynamics and characteristics of selected urban rivers and drainage in Johor Bahru that contain chemical elements from surrounding land use.

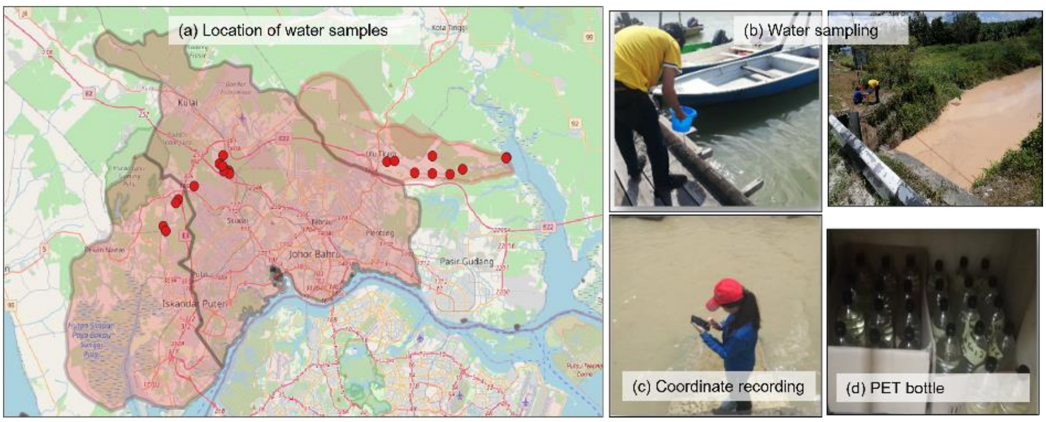


Fig. 2 - Collected water samples

3.2 Preliminary Results on Land Use and Chemical Constituents

The majority of the water samples (74%) had low ammonia levels (<0.2mg/l), where only six locations showed hazardous ammonia levels greater than 0.2mg/l. Three of the locations were located at Sg. Johor areas, Sg. Kong Kong, Sg. Redan and Kampung Salam Rakit. The highest concentrations of ammonia (>2mg/l) were found in Sg. Tiram. Almost half of the samples consist of nitrate content of more than 0.2mg/l (alert level). Areas in Sg. Tiram showed high levels of nitrate contents (~62mg/l). The range of nitrate contents for all locations was very high, which ranging from 5 to 120mg/l. In contrast to the ammonia level, the areas in Sg. Johor had low nitrate levels (<10mg/l). Almost all stations had phosphate levels higher than the standard, >0.2mg/l. The average level of phosphate is 1.7mg/l.

Seven major classes were identified includes oil palm, vegetable farming, residential, commercial & industry, bare soil, aquaculture and secondary forest. Oil palm, secondary forest, and residential areas were among the most dominating landscapes. The Sg. Pulai and Sg. Skudai areas had significant residential areas and oil palm. Sg. Tiram and Sg. Johor downstream were largely dominated by a large-scale oil palm, vegetable farming and secondary forest. In addition, there was a presence of heavy industries footprint in Sg. Tiram and Sg. Skudai areas (10-15%).

3.3 Identification of the Potential Sources of Chemical Elements Using Google Satellite Imageries

Fig. 3 showed the land use proportion for every sampling location and its corresponding ammonia value. The plausible sources for the high ammonia level in Sg. Tiram 10 and 12 is believed to be caused by the wet market, aquaculture, and intensive farming in the area respectively (Fig. 4(a) and (b)). The waste from the decayed meat, fish and plants from the wet market and aquaculture could be directly transferred to the river. Meanwhile, there are significant aquaculture activities in Sg. Kong Kong, Redan, and Kg. Salam rakit, which it is believed to be the primary contributor to the slight increase in ammonia levels. Feeds and fertilizer could be the main sources of the ammonia discharged into nearby water bodies (Fig. 6(c) and (d)). This finding also showed that the proportion of dominant land use has less implication towards the ammonia level except for aquaculture. Many locations dominated by oil palm and farming areas had low ammonia content in the respective streams.

Unlike ammonia, the nitrate contents showed quite a distinct pattern linking to the oil palm, intensive farming and industrial or commercial areas (Fig. 5). It was particularly apparent in the four locations, Taman Aman Senai, Sg. Tiram 12, 13, and 14 with nitrate levels greater than 80mg/l. The sampling points in Sg. Tiram were relatively close to each other, which could be attributed to the connecting effects of the water from Sg. Tiram 11 (120mg/l) being transported downstream. The findings in Taman Teratai and Taman Aman Senai suggested that intensive farming and specific heavy industries may have an impact on nitrate levels.

There is no distinct land use pattern correlated to phosphate level. It is noted that based on the land use proportion, locations with high residential areas tend to have high phosphate contents in their respective waterways or drainage systems (Fig. 6). It was further supported by the identification of five locations with low phosphate levels at non-residential areas. It is postulated that the main contributors to the high phosphate levels are unregulated waste from household products such as detergent, soaps, plasticizers, and garbage areas.

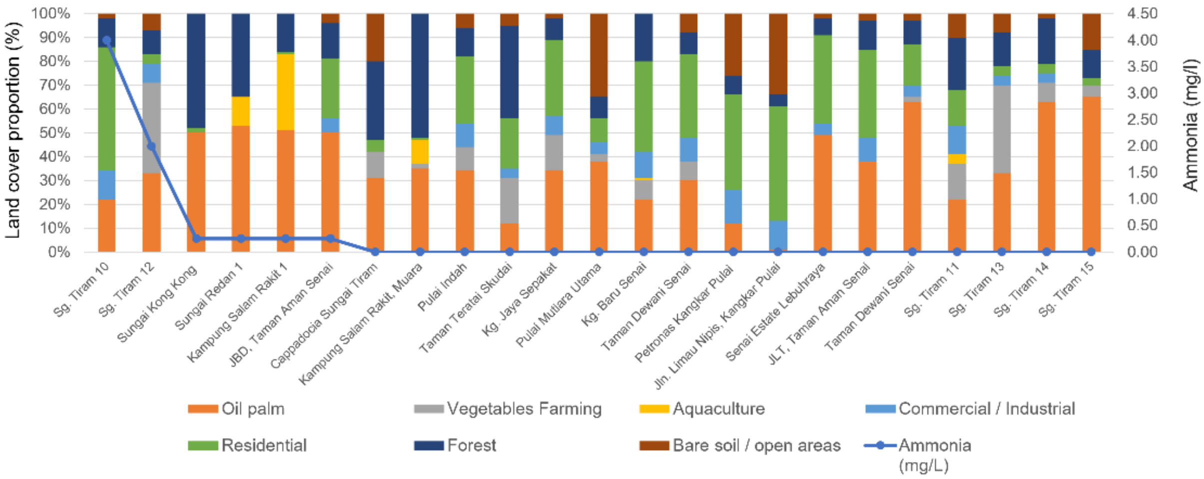


Fig. 3 - Ammonia content and the respective land use information

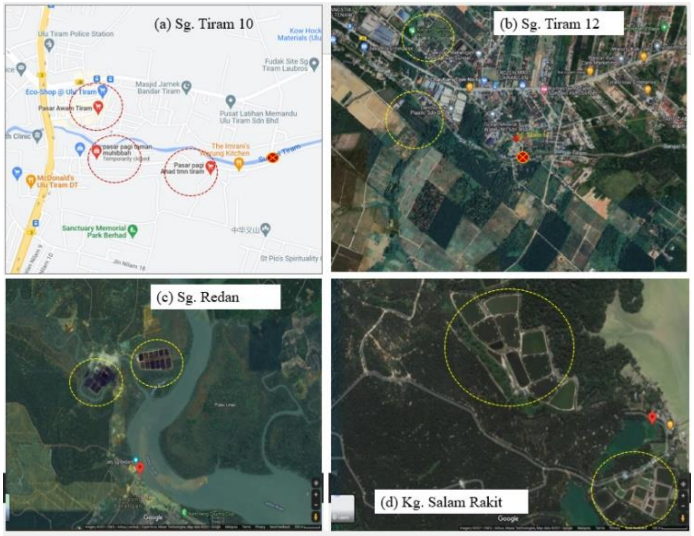


Fig. 4 - Specific areas that are plausibly the source of ammonia

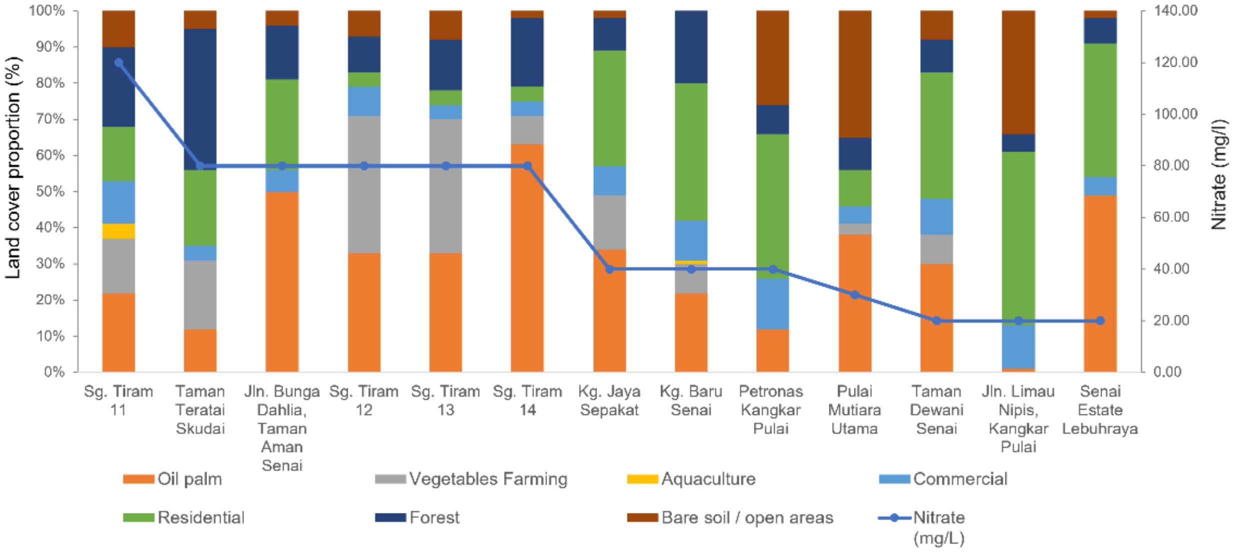


Fig. 5 - Ammonia content and the respective land use information

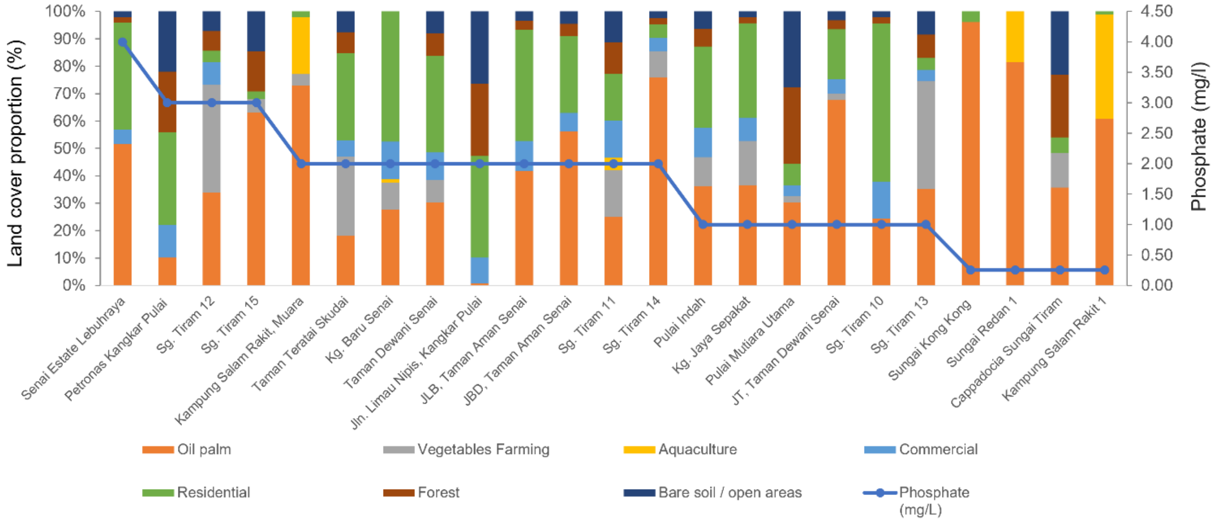


Fig. 6 - Phosphorus content and the respective land use information

4. Conclusion

Identification of the potential sources of chemical elements using the publicly accessed Google satellite imageries in Johor Bahru urban waters were presented in this study. The results showed that the size of the land use proportion did not always have a significant impact on chemical contents in the waterways. The areas with hotspots are more significant for ammonia, regardless of their size. The presence of the wet market and aquaculture area may contribute to the high ammonia contents in Sg. Tiram and Sg. Johor locations. The nitrate contents, on the other hand showed quite a distinct pattern linking to the oil palm, intensive farming and industrial or commercial areas. High nitrate levels in Senai and Skudai could be strongly associated with unregulated waste from the industrial areas and intensive vegetable farming respectively. No distinct land use pattern correlated to phosphate level. It is noted that based on the land use proportion, high residential areas tend to have high phosphate levels in their waterways or drainage. The findings of this study indicates that expert knowledge and posteriori can be used to properly interpret satellite imageries in order to identify the potential chemical element sources. The proposed approach should be sufficient in aiding the onsite investigations with minimal labor work, cost-effective, and time efficient.

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