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Investigation of Soil and Plant Nutrients in Residential Area in Parit Rasipan Drainage System

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Abstract. Nutrient pollution pertains to elevated nitrogen, phosphorous, and potassium concentrations within aquatic systems. Nutrient pollution is the process by which excessive nutrients, primarily Nitrogen, Phosphorus and Potassium (NPK), are supplied to bodies of water and can act as fertiliser, causing excessive algal growth. This phenomenon is also known as eutrophication. Excessive nutrient levels can cause more severe issues, such as low dissolved oxygen levels in the water. The main objective of this study has been to evaluate the soil and plant nutrient content in the residential area of the Parit Rasipan drainage system. NPK levels were determined by collecting soil and plant samples at four specified sampling points within the study area, both during wet and dry days, using the APHA 4500 NORG-B and US EPA 6010B (ICP OES) methods. In addition to that, the pH, Dissolved Oxygen (DO), and temperature were recorded in situ. Water samples were also collected and analysed for specific parameters, including Total Nitrogen (TN), Total Phosphorus (TP), and Potassium (K). The analysis used a HACH DR6000 Spectrophotometer and Atomic Absorption Spectroscopy (AAS). The study findings indicate that the soil concentrations of TN (1660–2250 mg/kg), TP (100–360 mg/kg), and K (1020–1692 mg/kg) fall within the range of low to very high classifications. In the meantime, it is noteworthy that the concentrations of TN (4780–7870 mg/kg), TP (821–1640 mg/kg), and K (702–9160 mg/kg) in plants have been categorised as ranging from moderate to very high. In the context of water quality monitoring, the collected data indicates that the pH levels range from 3.16 to 3.22, the dissolved oxygen levels range from 0.95 to 0.98 mg/L, and the temperature ranges from 29.30˚C to 26.34˚C, observed during both wet and dry weather conditions. In summary, based on the analysis of the findings, it can be determined that the Parit Rasipan drainage system demonstrates a significant concentration of NPK elements under both wet and dry weather conditions, primarily due to residential activities occurring within the area.

1. Introduction

Soil is crucial in supporting life on Earth because it functions as a water and nutrient reservoir, a waste filtering and degradation media, and an essential component in the global carbon and elemental cycles. It has evolved because of biological, climatic, geologic, and topographic influences on weathering processes. The classification of essential characteristics of management approaches and uses of land can be attributed to alterations in soil's physical, biological, and chemical attributes [1]. Acquiring enough information about the status of soil quality can facilitate a more expeditious comprehension of the detrimental processes affecting soils and enable the identification of areas of concern.

Human population growth is outpacing natural resource reserves, posing new challenges. Most solid waste in rural areas comprises domestic waste, which accounts for more than 90% of total waste [2]. The release of a large amount of greenhouse gases and a lousy odour contributes to air pollution caused by debris piled up and dumped anywhere [3].

This study aims to evaluate the levels of nitrogen, phosphorus, and potassium (NPK) in the soil and plants of the Parit Rasipan drainage system placed in a residential activity area. The primary objective of this study was to monitor and evaluate the water quality based on particular parameters at the Parit Rasipan drainage system. The parameters assessed in this study encompassed pH, dissolved oxygen (DO), temperature, total nitrogen (TN), total phosphorus (TP), and potassium (K).

2. Methodology of the study

2.1. Study area

A study on soil nutrients was carried out in Parit Rasipan, Batu Pahat, Johor. The drainage around the residential activity area was chosen as the source point. Figure 1 and Figure 2 represent the sample location from a satellite view (01° 51'04.2''N, 103° 05'49.9''E) and the current condition of the drainage system.

Figure 1. Sampling location from the satellite's view

Figure 2. Current condition of the drainage system

2.2. Soil and plant sampling

12 soil and plant samples were collected in wet and dry conditions. The area was divided into four grids, and three samples were collected in each grid. Composite soil sampling minimises soil variability impacts. This method combines subsamples into one composite sample, allowing for the averaging of soil properties over larger areas. 20–30 cm of soil was collected after removing debris.

Plant specimens were collected from the entire length of each plant along the grid line. Samples were bagged, labelled, and sent to the lab for analysis.

Figure 3. The sampling area is divided into four grids.

2.3. Soil and plant testing
TN concentration in soil and plant samples was determined using APHA 4500 NORG-B, while TP and K concentrations were determined using US EPA 6010B (ICP OES). Table 1 shows the soil nutrient content ranges classified by the Department of Agriculture Malaysia (DOA).

Table 1. Soil classification of nutrient content, N, P, K [4]

Nutrients	N(mg/kg)	P(mg/kg)	K (mg/kg)
Very high	>10000	>45	>546
High	6000-10000	25-45	312-546
Moderate	3000-6000	1-25	175.5-312
Low	1000-3000	3-10	54.6-175.5
Very low	<1000	<3	<54.6

2.4. *Water quality monitoring*
Twelve water samples were collected from the Parit Rasipan drainage system on dry and wet days for soil and plant sampling. The pH, DO, and water temperature were measured in situ using a Hanna Instrument HI98196 Multiparameter meter. TN and TP were analysed using a DR6000 Spectrophotometer using the Persulfate Digestion Method (Method 10072) and the Reactive High Range Phosphorus Molybdovanadate Method (Method 8114) HACH methods. K was analysed using Atomic Absorption Spectroscopy (AAS).

3. Result and discussion

3.1. Soil Nutrients

3.1.1. Total Nitrogen (TN)
During the dry day, TN concentrations at points 1, 2, 3 and 4 are 2010 mg/kg, 2090 mg/kg, 2250 mg/kg, and 2200 mg/kg, respectively. Meanwhile, on a wet day, the concentrations of TN at point 1 are 1660 mg/kg, point 2 are 1740 mg/kg, point 3 are 1820 mg/kg, and point 4 are 1810 mg/kg.

Figure 4 illustrates the variations in TN content in four-point soil samples, highlighting the disparity in soil TN concentration between wet and dry conditions at each location. The soil samples collected on dry days exhibit a greater concentration of TN in comparison to the soil samples collected on wet days. Besides, at points 3 and 4 in dry and wet day soil samples, the concentration of TN is higher at their locations, respectively, because it is closer to residential wastewater discharge. Consequently, the collected data has demonstrated a minor disparity in the concentration of TN between days characterised by wet and dry settings. Water evaporation from the soil's surface increases in dry conditions because of higher temperatures and lessened precipitation. This results in a higher concentration of nutrients in the remaining water [5].

Nitrogen is essential for plant growth. However, excessive nitrogen can cause soil acidification and reduce soil quality, negatively affecting crop productivity. The soil attributes strongly correlate with soil nutrient cycling and plants' absorption of nutrients. Plants can absorb soil-available nutrients, which helps improve soil fertility [6].

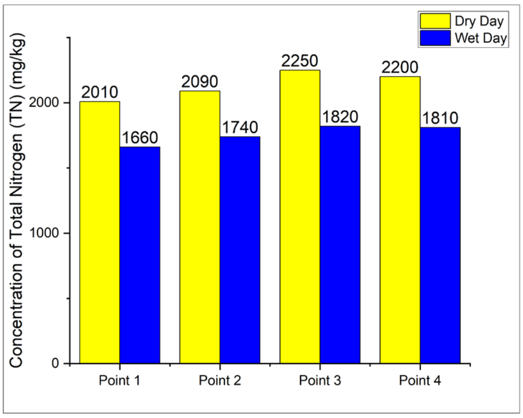

Figure 4. Total nitrogen (TN) concentration in soil on wet and dry days.

3.1.2. Total Phosphorus (TP)

During the dry day, TP concentrations at points 1, 2, 3 and 4 are 110 mg/kg, 200 mg/kg, 360 mg/kg, and 270 mg/kg, respectively. Meanwhile, on a wet day, the concentrations of TP at point 1 are 100 mg/kg, point 2 are 197 mg/kg, point 3 are 268 mg/kg, and point 4 are 260 mg/kg.

Figure 5 depicts the variation in TP concentration within soil samples collected at four distinct points. It is evident from the figure that the TP concentration in soil exhibits disparities between wet and dry settings throughout the different sampling points. The levels of TP show a greater concentration in soil samples collected on a dry day compared to those collected on a rainy day. The higher concentration of TP observed at sites 3 and 4 in both dry and wet soil samples can be attributed to their proximity to residential wastewater outflow. This study has demonstrated a minor disparity in the content of TP between days characterised by wet and dry conditions.

Minerals with a high phosphorus concentration can be found in soil. These minerals are divided into two categories, which are primary and secondary. Weathering is a geological phenomenon characterised by the gradual decomposition of minerals, resulting in the liberation of phosphorus into the soil solution and facilitating its uptake by plants. In contrast to secondary phosphorus minerals like calcium, iron, and aluminium phosphates, the phosphorus release rate is notably low. Conversely, the precipitation process is prolonged and entails a permanent conversion into metal phosphates. When these metal phosphates are dissolved in the soil solution, they can release phosphorus, although at a partially slow rate. The process of phosphate mineral dissolution, leading to the subsequent discharge of phosphate into the soil solution, might be considered a weathering phenomenon [7].

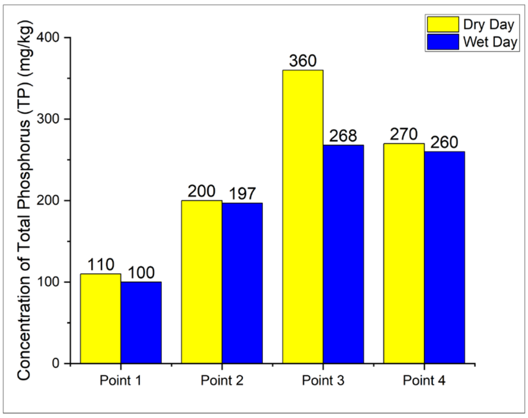

Figure 5. Total phosphorus (TP) level in soil on wet and dry days.

3.1.3. Potassium (K)

During the dry day, K concentrations at points 1, 2, 3 and 4 are 1030 mg/kg, 1120 mg/kg, 1692 mg/kg, and 1370 mg/kg, respectively. Meanwhile, on a wet day, the concentrations of TP at point 1 are 1020 mg/kg, point 2 are 1100 mg/kg, point 3 are 1690 mg/kg, and point 4 are 1350 mg/kg.

Figure 6 illustrates the potassium (K) concentration variation among four-point soil samples, highlighting the disparity in K level between wet and dry days at each location. Besides, at points 3 and 4 in dry and wet day samples, the concentration of K is higher than at points 1 and 2. As a result, there is a significant difference in K concentration between points 1 and 4, 2 and 3 on dry and wet days. The inorganic cation K is widely recognised as the most common, and plants need it to grow in the best way possible. K is responsible for protein synthesis, sugar transportation, nitrogen, carbon metabolism, and photosynthesis. It plays a substantial role in enhancing both yield as well as productivity. Moreover, the element K is critical in facilitating cell proliferation, a fundamental mechanism for plant functioning and advancement [8].

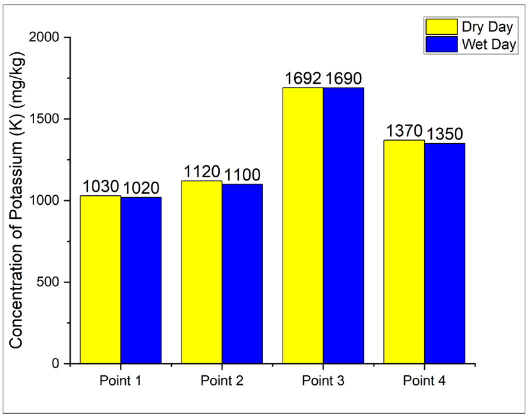

Figure 6. Potassium (K) concentration (mg/kg) in soil on wet and dry days.

3.2. Plant Nutrients

3.2.1. Total Nitrogen (TN)

During the dry day, TN concentrations at points 1, 2, 3 and 4 are 4860 mg/kg, 4780 mg/kg, 7870 mg/kg, and 7340 mg/kg, respectively. Meanwhile, on a wet day, the concentrations of TN at point 1 are 4780 mg/kg, point 2 are 6350 mg/kg, point 3 are 7750 mg/kg, and point 4 are 7320 mg/kg. Figure 7 illustrates the variation in TN content among four-point plant samples, highlighting the disparity in TN concentration between wet and dry days at every location. Besides, at points 3 and 4 in dry and wet day plant samples, the concentration of TN is higher because the residential wastewater discharge is closer to those points. Moreover, the concentration of TN in the plant samples does not exhibit a substantial disparity between wet and dry days.

One of the primary effects of nitrogen is an increase in chlorophyll production. This effect is accomplished through nitrogen's ability to produce larger leaf structures with more significant surface areas for pigment photosynthesis. However, excessive nitrogen makes the leaves proliferate, but it hurts the growth of other plants. The energy used to grow flowers is instead used to make more leaves, so plants may not even make the reproductive organs they need during the growing day. Thus, all the excess nitrogen in the soil cannot be absorbed by plants. These excess nitrogen levels slowly leak out of the soil through water runoff; the nitrogen is effectively in the form of nitrates when it leaches out of the soil due to microbial conversion. As a result, nitrate levels contaminate groundwater and drinking water [9].

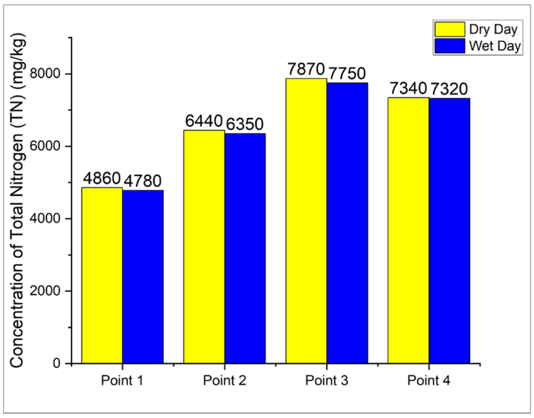

Figure 7. Total nitrogen (TN) concentration (mg/kg) in plant samples during wet and dry days.

3.2.2. Total Phosphorus (TP)

During the dry day, TP concentrations at points 1, 2, 3, and 4 are 840 mg/kg, 1160 mg/kg, 1640 mg/kg, and 1290 mg/kg, respectively. Meanwhile, on a wet day, the concentrations of TP at point 1 are 821 mg/kg, point 2 are 1150 mg/kg, point 3 are 1620 mg/kg, and point 4 are 1280 mg/kg. Figure 8 depicts the variation in TP concentration among plant samples collected at four distinct points. The data indicates the concentration of TP in plants exhibits variability between wet and dry days at each of the specified points. In points 3 and 4 in dry and wet day samples, the concentration of TP is higher than at points 1 and 2. Consequently, there exists a discernible disparity in the concentrations of TP between dry and wet days for points 1, 2, 3, and 4.

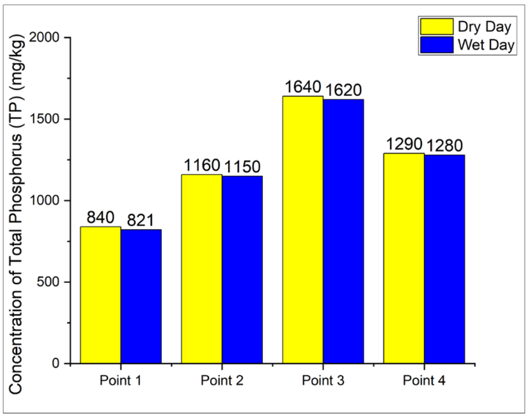

Figure 8. Total phosphorus (TP) concentration (mg/kg) in plant samples during wet and dry days.

3.2.3. Potassium (K)

During the dry day, K concentrations at points 1, 2, 3 and 4 are 710 mg/kg, 3100 mg/kg, 11500 mg/kg, and 9160 mg/kg, respectively. Meanwhile, on a wet day, the concentrations of K at point 1 are 702 mg/kg, point 2 are 3080 mg/kg, point 3 are 10100 mg/kg, and point 4 are 8650 mg/kg. Figure 9 illustrates the variation in K concentration among four-point plant samples, highlighting the variation in K concentration between wet and dry days at each specific point. The K concentration at points 3 and 4 in dry and wet day samples is higher than at points 1 and 2, respectively. As a result, points 1, 2, 3, and 4 have a considerable K concentration difference between dry and wet days.

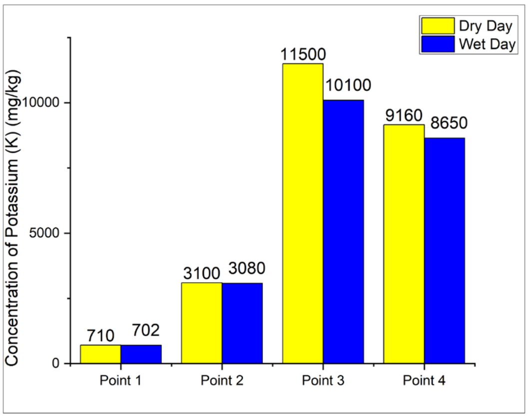

Figure 9. Potassium (K) concentration (mg/kg) in plant samples during wet and dry days.

3.3. Water quality monitoring

Monitoring water quality is of utmost significance in safeguarding the quality of water resources. This study involves the measurement of pH, dissolved oxygen (DO), and water temperature. Table 2 displays the water parameters determined for each sample obtained on dry and wet days. The average DO for samples collected during dry and wet days was 0.95 ± 0.04 and 0.98 ± 0.03 mg/L. DO is a significant measure in evaluating water quality due to its impact on the aquatic species inhabiting a specific water body. An excessively elevated or diminished DO level can have detrimental effects on aquatic organisms and compromise the overall quality of water.

Meanwhile, according to Table 2, the average pH for samples collected during dry and wet days was 3.16 ± 0.03 and 3.22 ± 0.03. The measurement of pH is a crucial factor in evaluating water quality, as it provides information regarding the level of acidity or alkalinity in the water sample. Water with a pH level lower than four is classified as highly acidic, which can negatively affect aquatic organisms and ecosystems [10]. Peat soil is recognised for its presence of ferric ions, which can contribute to water acidification through various mechanisms. A particular factor contributing to the increased acidity levels found in peat soils is the insufficient drainage conditions and the hydrolysis of organic acids [11]. The presence of organic acids in peat soil can result in the discharge of hydrogen ions, thereby leading to an elevation in soil acidity [12].

In addition, it is notable that the mean water temperature exhibited higher values for both wet and dry days, which is 29.30 ± 0.18˚C on the dry day and 26.34 ± 0.13˚C on the wet day. Water temperature significantly impacts the creatures inhabiting aquatic environments, as it plays a crucial role in modulating biological activity and chemical processes. As the temperature of water rises, there is a decrease in the water's ability to retain DO. Water with lower temperatures contains a higher DO concentration than water with higher temperatures.

Table 1. Water parameters for water samples

Day	Parameter		
	Dissolved oxygen, DO (mg/L)	pH	Temperature (˚C)
Dry	0.95 ± 0.04	3.16 ± 0.03	29.30 ± 0.18
Wet	0.98 ± 0.03	3.22 ± 0.03	26.34 ± 0.13

3.3.1. Total Nitrogen (TN), Total Phosphorus (TP) and Potassium (K)

Table 3 shows the level of nutrients (mg/L) in water samples. Total Nitrogen (TN) level during the dry day is 52 ± 3 mg/L, whereas during the wet day, they are 49 ± 2 mg/L. Excessive nitrogen can lead to excessive stimulation of aquatic vegetation and algae growth. The proliferation of these organisms can lead to the obstruction of water intakes, the depletion of DO during decomposition, and the reduction of light penetration in deeper waters [13]. Therefore, the phenomenon of wastewater eutrophication may manifest, resulting in the formation of aesthetically distasteful algal scum on the water's surface. Oxygen deficits transform nitrate into elemental nitrogen or nitrous oxide in surface water. When oxygen supplies reach zero, this so-called denitrification process releases oxygen reserves. Nitrate may be converted into ammonia by biological processes. Due to the oxidation of nitrite to nitrate by ammonium compounds, oxygen concentration in water is decreased [14].

Total Phosphorus (TP) concentrations during the dry day are 9.40 ± 0.27 mg/L, whereas during the wet day are 9.21 ± 0.13 mg/L. Eutrophication is caused when wastewater with a high concentration of P is discharged into an aquatic environment. However, P can be found in high concentrations in domestic wastewater, runoff from urban areas and lawns, leaking septic systems, and sewage treatment plant discharges. An overabundance of phosphorus can lead to the proliferation of algae and macrophytes in aquatic environments, reducing DO concentrations. Thus, algae blooms that produce algal toxins can also be caused by high P concentrations [15].

Potassium (K) concentrations during the dry day are 11.73 ± 0.16 mg/L, whereas during the wet day are 11.65 ± 0.09 mg/L. Potassium is common in wastewater. Thus, one of the risks to aquatic systems' water quality is households' emission of micropollutants. The wastewater comprises diverse inorganic and organic components, including toxic metals, dangerous chemicals, volatile compounds, and other components. These problematic chemicals can contaminate ecological resources and perturb their regular processes [16].

Table 2. The concentration of TN, TP, and K in water.

Day	Nutrient		
	Total Nitrogen (TN) (mg/L)	Total Phosphorus (TP) (mg/L)	Potassium (K) (mg/L)
Dry	52.00 ± 3	9.40 ± 0.27	11.73 ± 0.16
Wet	49.00 ± 2	9.21 ± 0.13	11.65 ± 0.09

4. Conclusion

According to the obtained results and subsequent analysis, it can be deduced that the study accomplished its stated objectives. The concentrations of total nitrogen (TN), total phosphorus (TP), and potassium (K) in water samples collected from the Parit Rasipan drainage system were successfully determined using various analytical techniques. These techniques included the HACH method, DR 6000 Spectrophotometer, Persulfate Digestion Method (Method 10072), Reactive High Range Phosphorus Molybdovanadate Method (Method 8114), and Atomic Absorption Spectroscopy (AAS). The findings indicate that residential activities significantly impact the degree of eutrophication observed in the Parit Rasipan drainage system. The entirety of the test locations exhibited pollution, as evidenced by the significant levels of TN, TP, and K. These findings suggest a significant degree of eutrophication throughout the Parit Rasipan drainage system.

Based on the findings of the soil study, it has been determined that the concentration of TN in the soil on a dry day is 2010 mg/kg, 2090 mg/kg, 2250 mg/kg, and 2200 mg/kg, whereas the amount during the wet day is 1660 mg/kg, 1740 mg/kg, 1820 mg/kg, and 1810 mg/kg. The data indicates that the level of TN is low., referring to the guidelines that the DOA states. Meanwhile, during the dry day, the concentrations of TP in soil are 110 mg/kg, 200 mg/kg, 360 mg/kg, and 270 mg/kg, and during the wet day, is 100 mg/kg, 197 mg/kg, 268 mg/kg, and 260 mg/kg. The data mentioned indicate a very high TP concentration in accordance with the standards provided by the DOA. However, the amount of K in the soil during the dry day is 1030 mg/kg, 1120 mg/kg, 1692 mg/kg, and 1370 mg/kg, whereas the amount during the wet day is 1020 mg/kg, 1100 mg/kg, 1690 mg/kg, and 1350 mg/kg. The results indicate a very high K level, as per the guidelines outlined by the DOA.

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