

# Sustainable Development of Natural Spring Resources for Educational Landscapes: A Case Study of Politeknik Sultan Azlan Shah

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**Abstract:** *This study evaluates the hydrogeochemical integrity and technical viability of a perennial gravity-fed spring at Politeknik Sultan Azlan Shah (PSAS), Perak, as a primary water source for a sustainable Eco-Learning Park. Originating from the metasedimentary Kroh Formation, the discharge exhibits a distinct hydrogeochemical signature characterized by a high electrical conductivity (141  $\mu\text{S}/\text{cm}$ ) and an acidic field pH of 4.76. While trace element profiles largely align with national safety standards, the source is impaired by significant geogenic iron enrichment (17 mg/L)—exceeding regulatory limits by 56 times—and secondary microbiological contamination (Total Coliform: 5,000 MPN/100ml). This study argues that the spring's perennial nature provides a resilient, climate-adaptive resource for educational landscapes. However, it necessitates a multi-stage remediation strategy—specifically the Simple Groundwater Filtration System (SPATR)—to address site-specific geogenic and zoonotic risks.*

**Keywords:** Sustainable Water Management; Hydro geochemistry; Geogenic Iron Enrichment; Depression Spring; Kroh Formation; Eco-Learning Park

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## 1. Introduction

The integration of natural water systems into institutional landscapes offers a unique opportunity for sustainable development and environmental education. Natural springs, defined as points where groundwater emerges naturally at the earth's surface, are highly resilient resources that often maintain flow even during prolonged dry periods. For educational institutions such as Politeknik Sultan Azlan Shah (PSAS), the discovery of such a resource provides a platform for the development of an Eco-Learning Park, aimed at fostering students' understanding of environmental conservation and sustainable living.

However, the utilization of natural spring water for public landscapes necessitates a rigorous assessment of its hydrogeochemical and microbiological safety. In tropical regions like Behrang, Perak, groundwater quality is frequently influenced by geogenic processes such as the leaching of minerals from the underlying bedrock and environmental exposure to surface contaminants. Preliminary observations at PSAS indicated that the spring emerges from a valley. It sits on top of very old rock layers known as the Kroh Formation, which formed hundreds of millions of years ago.

These are known as depression springs because they form where the groundwater reaches the surface. However, because they are not protected, they often have high levels of iron and bacteria from forest animals. This paper presents a comprehensive case study on the assessment of this resource, focusing on its hydrogeochemical profile and the engineering strategies required to transform a raw environmental discharge into a safe, functional educational asset. By addressing these technical challenges, PSAS can demonstrate a model for the sustainable management of natural water resources within an academic framework.

## 2. Literature review

The emergence of natural springs is a hydrogeological phenomenon governed by the intersection of the local water table with surface topography. In metasedimentary terrains like the Kroh Formation, which comprises schist, phyllite, and limestone, groundwater storage and flow are dictated by secondary porosity and structural features such as faults and fractures. According to Winter et al. (1998), the interaction between surface water and groundwater must be viewed as a singular, integrated resource; meteoric water infiltrates permeable horizons to recharge the saturated zone, which eventually discharges in topographic lows such as valleys.

Recent studies by Zhang and Kumar (2024) highlight that geogenic iron (Fe) enrichment is a common characteristic of groundwater in such geological settings, occurring through the reductive dissolution of iron-bearing minerals like pyrite and mica during prolonged rock-water interaction. Furthermore, while these springs are naturally "fresh" in terms of salinity, their unprotected state in tropical rainforest environments makes them highly susceptible to zoonotic pathogens. Miller et al. (2025) observe that depression springs act as catchments for surface-borne contaminants during heavy precipitation, often leading to elevated concentrations of Total Coliform and *E. coli*.

Despite the perennial nature and significant potential of the spring at Politeknik Sultan Azlan Shah (PSAS) as a sustainable resource for the proposed Eco-Learning Park, a critical challenge persists. The water source exhibits extreme geogenic iron levels of 17 mg/L, which is more than 50 times the regulatory limit of 0.3 mg/L, alongside significant microbiological contamination. Consequently, the primary problem addressed by this study is the lack of a protective infrastructure and a robust remediation strategy to mitigate these geogenic and environmental risks, which currently render the raw spring water non-potable and unfit for safe public use within the institutional landscape.

## 3. Methodology

The research methodology was designed to evaluate the hydrogeological characteristics and chemical potability of the spring water at Politeknik Sultan Azlan Shah (PSAS) through integrated field and laboratory investigations.

### 3.1 Field Assessment and Sampling

- a) Site Investigation: A technical team conducted a field assessment on March 13, 2025, to perform visual observations and topographic mapping of the spring outlet located at coordinates 417286 N, 383688 E.
- b) Lithological Characterization: Surface observations were conducted along the access route to identify rock outcrops and structural features within the Kroh Formation.
- c) Sample Collection: Water samples, designated as PSAS1, were collected using standardized protocols for geochemical and bacteriological analysis.

### 3.2 In-Situ Physicochemical Analysis

- a) To minimize the impact of atmospheric oxidation on transient parameters, real-time measurements were performed at the point of discharge.
- b) Instrumentation: A YSI 556MPS Multi-Probe System was utilized to measure Temperature, pH, Electrical Conductivity, Total Dissolved Solids (TDS), Salinity, and Dissolved Oxygen.
- c) Chemical Screening: A Pocket Colorimeter was employed for the immediate detection of free chlorine (Cl) to differentiate between natural groundwater and potential municipal pipe leaks.

### 3.3 Laboratory Geochemical and Microbiological Assays

- a) Detailed analytical procedures were conducted at the Geochemical Laboratory Branch to quantify 41 separate elements.
- b) Metal and Mineral Analysis: Inductively Coupled Plasma (ICP) and Ion Chromatography (IC) techniques were used to detect cations and anions, including Iron (Fe), Manganese (Mn), and Sulphates.
- c) Microbiological Testing: The Most Probable Number (MPN) method was applied to quantify Total Coliform and E. coli concentrations.
- d) Quality Benchmarking: Analytical results were benchmarked against the National Standard for Drinking Water Quality (MOH) and the Groundwater Quality Standard (DOE).

## 4. Results and analysis

The assessment of the spring water at Politeknik Sultan Azlan Shah (PSAS) yielded critical data regarding its provenance, chemical composition, and biological safety. The findings are categorized into in-situ physical parameters and comprehensive laboratory geochemical/microbiological assays.

### 4.1 In-Situ Physical Parameters

Field measurements conducted at the discharge point provided immediate indicators of the water's hydrogeological origin. Temperature: The water temperature was recorded at 26.60 °C. Electrical Conductivity (EC): A high conductivity value of 141µS/cm was measured, serving as a primary indicator that the source is an origin from a groundwater aquifer. pH Level: The field pH was measured at 4.76, indicating an acidic and potentially corrosive nature. Salinity: The recorded salinity of 0.07 ppt confirms the source as fresh water. Chlorination Detection: In-situ testing using a pocket colorimeter showed no reaction, confirming the absence of chlorine and distinguishing the source from municipal water line leaks.

### 4.2 Laboratory Geochemical Analysis

Laboratory analysis of sample PSAS1 quantified the concentration of 41 elements to determine compliance with the National Standard for Drinking Water Quality (MOH) and the Groundwater Quality Standard (DOE).

### 4.3 Microbiological Profile

The microbiological assay revealed significant contamination, likely due to the unprotected nature of the spring head and exposure to zoonotic waste in the forested valley.

- a) Total Coliform: Recorded at 5,000 MPN/100ml, which fails the drinking water requirement of 0 MPN/100ml.
- b) Total E. Coli: Measured at 59.1 MPN/100ml, further confirming recent waste contamination.

#### 4.4 Geological Context of Findings

The geochemical anomalies, specifically the high iron concentration, are directly linked to the underlying geology.

- a) The site is underlain by the Kroh Formation (Ordovician-Silurian age), consisting of metasedimentary rocks such as schist, phyllite, and slate.
- b) The high iron (Fe) levels of 17 mg/L are a geogenic result of water interacting with minerals such as pyrite, mica, and magnetite found within this formation.

**Table 1: Result of Geochemical Analysis of Sample PSAS1**

Parameter	Unit	Analysed Value (PSAS1)	KKM/MOH Standard	DOE/JAS Standard
pH (Lab)	-	6.8	6.5 – 9.0	5.5 – 9.0
Turbidity	NTU	21.2	5	1000
Iron (Fe)	mg/L	17	0.3	1
Manganese (Mn)	mg/L	0.084	0.1	0.2
Total Dissolved Solids (TDS)	mg/L	61	1000	1500
Sulphate (SO <sub>4</sub> )	mg/L	28.31	250	250

Although the full list of 41 elements is not detailed in the summary table, standard geochemical suites typically include major ions (such as Calcium, Magnesium, Sodium, and Potassium) and trace metals (such as Arsenic, Lead, Zinc, and Copper) to ensure comprehensive safety benchmarking.

#### 5. Discussion

The discussion integrates empirical results with hydrogeological theory to evaluate the spring's potential as a long-term institutional asset.

##### 5.1 Hydrogeochemical Evolution and Aquifer Connectivity

The high electrical conductivity (EC) of 141  $\mu\text{S}/\text{cm}$  and the perennial nature of the spring provide robust evidence of its connection to a deep-seated saturated zone within the metasedimentary Kroh Formation. Unlike shallow surface runoff, which fluctuates with precipitation, the PSAS spring's consistent flow during drought indicates it is a depression spring where the water table permanently intersects the valley floor. The acidic field pH of 4.76 suggests that the groundwater is "aggressive," meaning it actively facilitates the chemical weathering of the host rock as it travels through subsurface fractures.

##### 5.2 Geogenic Iron Enrichment: The Reductive Dissolution Process

The most critical finding is the iron (Fe) concentration of 17 mg/L, which is approximately 56 times higher than the 0.3 mg/L KKM regulatory threshold. This extreme enrichment is interpreted as a geogenic process specific to the Kroh Formation's mineralogy, which includes pyrite, mica, and magnetite. As groundwater moves through these subsurface layers, the acidic conditions catalyze the reductive dissolution of iron, leading to high concentrations in the discharged water. This geochemical process explains the high turbidity (21.2 NTU) and the visible precipitation observed at the outlet upon exposure to atmospheric oxygen.

### **5.3 Microbiological Vulnerability and Zoonotic Influx**

The detection of Total Coliform (5,000 MPN/100ml) and *E. coli* (59.1 MPN/100ml) highlights the vulnerability of unprotected spring heads. The high bacterial load is attributed to the lack of physical barriers, allowing zoonotic pathogens from forest wildlife to infiltrate the source through surface runoff or direct contact. This confirms that while the water is chemically "fresh" regarding salinity (0.07 ppt), it remains biologically unsafe for direct human consumption without advanced sterilization.

### **5.4 Strategic Remediation for Institutional Sustainability**

To realize the goal of an Eco-Learning Park, a dual-layer remediation strategy is required:

- a) Infrastructure: Establishing a "No-Disturbance Zone" and a multi-tiered protection area to shield the intake from surface-borne pollutants.
- b) Filtration (SPATR): The system's aeration component is vital for oxidizing the 17 mg/L of ferrous iron into a filterable solid state.
- c) Sterilization: Integration of UV sterilizers is mandatory to eliminate the detected coliform counts, ensuring the water meets potability standards for public use.

## **6. Conclusion**

The investigation into the natural spring at Politeknik Sultan Azlan Shah (PSAS) confirms its viability as a perennial and resilient groundwater resource suitable for the development of an Eco-Learning Park. Assessment of Water Origin; Field observations and an in-situ electrical conductivity of 141  $\mu\text{S}/\text{cm}$  confirm the source is a depression spring originating from a saturated groundwater aquifer within the Kroh Formation. Determination of Mineral Content; Geochemical analysis successfully identified 41 elements, revealing that while most parameters meet national standards, there is a significant geogenic iron (Fe) concentration of 17 mg/L, which is approximately 56 times higher than the 0.3 mg/L regulatory limit. Evaluation of Safety and Potability; The study detected elevated levels of Total Coliform (5,000 MPN/100ml) and *E. coli* (59.1 MPN/100ml), indicating that the raw water is currently non-potable due to environmental exposure and lack of source protection. Technical Advisory and Remediation; The research successfully merited the proposal of a modular treatment strategy, specifically the SPATR (Simple Groundwater Filtration System), to mitigate iron and bacteriological risks.

### **Recommendation**

To ensure the sustainable and safe utilization of this resource, the study recommends the following:

- a) Source Protection: Establishing a multi-tiered protection zone and constructing a watertight catchment chamber to shield the intake from surface runoff.
- b) Advanced Water Treatment: Utilizing aeration for iron oxidation, followed by sand filtration and Ultraviolet (UV) sterilization to eliminate pathogens.
- c) Geophysical Characterization: Conducting a Geophysical Survey to further delineate the aquifer's subsurface profile and structural boundaries.

By implementing these technical and protective measures, PSAS can successfully leverage this natural spring to support its educational objectives while providing a safe, alternative water supply.

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## **Conflict of Interest Statement**

This study was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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