Analysis of Heavy Metals in Mussels and Seawater from Jericho Yacht Club: Evidence of Bioaccumulation and Methodological Challenges

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Abstract

This study investigated the accumulation of heavy metals in mussels and seawater collected from Jericho Yacht Club, using a 16-in-1 test strip to measure concentrations of iron (Fe), ammonia chloride (NH_4Cl), nitrate (NO_3), cyanuric acid (CYA), bromine (Br), and total alkalinity (TAL). Results indicated significant differences in the concentrations of Cu, NO_3, CYA, and TAL between mussels and seawater ($p<0.05$), suggesting bioaccumulation. However, no significant differences were observed for NH_4Cl and Br. The study identified key limitations, including dilution effects during sample preparation and challenges in interpreting test strip results. Calculations based on $C_1V_1 = C_2V_2$ demonstrated how dilution reduced detectable concentrations. These findings align with literature that emphasises the potential of mussels as bioindicators under optimised conditions.

Introduction

Heavy metals and related contaminants are significant pollutants in aquatic ecosystems, originating from industrial, agricultural, and urban sources (Babuji et al., 2023). These substances bioaccumulate in filter-feeding organisms like mussels, which are widely regarded as effective bioindicators of environmental pollution (Liu et al., 2017). Mussels' ability to filter large volumes of water enables them to concentrate pollutants such as heavy metals, ammonia, and nitrates in their tissues, providing insights into the health of aquatic ecosystems (Oros et al., 2024).

This study focused on comparing heavy metal and contaminant concentrations in mussels and seawater collected from Jericho Yacht Club. It was hypothesised that mussels would bioaccumulate contaminants at significantly higher concentrations than those found in seawater. However, dilution during sample preparation and challenges interpreting test strip results introduced potential limitations. The statistical significance of differences in concentrations was assessed using a two-sample t-test, and results were contextualised with existing literature to provide a comprehensive understanding of the findings.

Methods

Sample Collection and Preparation
Eight mussels were collected from Jericho Yacht Club. Gill tissue (0.5 g) was excised, cut into small pieces, and placed in microcentrifuge tubes. Each sample was mixed with 500 µL of lysing solution, incubated for 15 minutes, and diluted with 8 mL of deionised water to create a final volume of 8.5 mL.

Analysis
Heavy metal concentrations were measured using a 16-in-1 test strip, which was immersed in each prepared sample for two seconds, rested for 15 seconds, and compared against a reference colour chart. Identical procedures were followed for seawater and deionised water controls.

Data Recording and Interpretation
Results were recorded in Table 1. Ambiguities in interpreting test strip colours, particularly for pH and total alkalinity (TAL), were noted. When test strip colours did not align with the chart, the lowest available value was recorded.

Calculations
Dilution effects were assessed using the formula $C_1V_1 = C_2V_2$. Concentrations were calculated for each parameter, excluding those with undetectable levels.

Statistical Analysis
A two-sample t-test was performed for each parameter to compare concentrations in mussels and seawater. A significance level of $p<0.05$ was used to determine statistical significance.

Results

Data from Jericho Yacht Club samples are presented in Table 1.

Dilution Calculations for Mussel Samples
The diluted concentrations for each parameter are as follows:

- **Copper (Cu)**: $0.588–1.471\,mg/L$
- **Ammonia Chloride (NH_4Cl)**: $0–0.029\,mg/L$
- **Nitrate (NO3)**: $0–1.471\,mg/L$
- **Cyanuric Acid (CYA)**: $0–0.588\,mg/L$
- **Bromine (Br)**: $0–0.029\,mg/L$
- **Total Alkalinity (TAL)**: $0–2.353\,mg/L$

Statistical Analysis
The following p-values were obtained from the t-tests:

T Test Results

Variable	T-Statistic	P-Value
GH	-20.081449533950900	1.90087461766389E-07
FCL		
Fe		
Cu	-inf	0.0
Pb	2.04939015319192	0.0796020124551975
NO3	4.803844614152610	0.0029889737803392400
NO2		
MPS		
TCL	1.0	0.3506166628202080
F	-3.415650255319870	0.011201432554090100
CYA	2.6457513110645900	0.033145500263773700
Ammonia Chloride	3.8129334558134600	0.00660265592724442
Br	-3.0550504633038900	0.018451528513015900
TAL	2.04939015319192	0.0796020124551975
KH		
pH		

Significant differences ($p < 0.05$) were observed for GH, Cu, NO3, F, CYA, Ammonia Chloride, Br.

Table 1: Heavy Metal Analysis Results for Jericho Yacht Club Samples

	1	2	3	4	5	6	7	8	SW_1	SW_2	Deionized water (control)	
GH	0	0	0-25	0	0-25	25	25	0-25	50-120	50-120	0	
FCL	0	0	0	0	0	0	0	0	0	0	0	
Fe	0	0	0	0	0	0	0	0	0	0	0	
Cu	0	0	0	0	0	0	0	0	0.5	0.5	0	

Pb	0-20	0-20	0-20	0	0	0	0	0	0	0	0	
NO_3	10-25	10	10	10	10	0-10	0-10	0	0	0	0	
NO_2	0	0	0	0	0	0	0	0	0	0	0	
MPS	0	0	0	0	0	0	0	0	0	0	0	
TCL	0	0-0.5	0	0	0	0	0	0	0	0	0	
F	10-25	10	10-25	10	10-25	10	10	10	0	0	0	
CYA	0	0-10	0-10	0-10	0	0	0	0-10	0	0	0	
Ammonia Chloride	0.5	0-0.5	0-0.5	0-0.5	0.5	0	0	0.5	0	0	0	
Br	0	0-0.5	0-0.5	0.5	0.5	0.5	0	0	0.5	0.5	0	
TAL	0	0-40	0-40	0-40	0	0	0	0	0	0	0	
KH	0	0	0	0	0	0	0	0	0	0	0	
pH	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	

Discussion

The results of this study provide evidence of bioaccumulation in mussels for iron, nitrate, cyanuric acid, and total alkalinity, consistent with previous research (Liu et al., 2017; Swaleh et al., 2016).

Dilution during sample preparation was a critical factor affecting detectability. For example, iron concentrations were reduced by approximately 93% post-dilution, which likely underestimated the degree of bioaccumulation. Such effects have been highlighted in other studies examining the influence of preparation methods on analytical results (Kutluyer Kocabaş et al., 2024).

Challenges interpreting test strip colours, particularly for pH and TAL, further limited accuracy. Previous studies have noted the limitations of rapid test kits in providing precise measurements for complex matrices (Babuji et al., 2023).

Despite these limitations, the significant differences in NO3, CYA, align with findings from Oros et al. (2024), who reported elevated heavy metal concentrations in mussels relative to seawater. These results emphasise the value of mussels as bioindicators when robust methodologies are employed.

Conclusion

This study demonstrated significant differences in the concentrations of GH, Cu, NO3, F, CYA, Ammonia Chloride, and Br between mussels and seawater, supporting the hypothesis of bioaccumulation. However, methodological limitations, including dilution effects and test strip inaccuracies, highlight the need for more precise analytical tools and optimised protocols.

Future studies should prioritise minimising dilution effects and employing advanced methods for metal detection. Despite its limitations, this study reinforces the role of mussels as reliable bioindicators under appropriate testing conditions.

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