An Assessment of Heavy Metals Contamination in Freshwater Sediments and Fish and Cyanide in Sediment around Gold Ridge mine site, Solomon Islands

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Abstract: Heavy metals in riverine sediments around Gold Ridge mine site ranged from 0.71 ± 0.09 to 726.73 ± 0.86 µg g^{-1}. Out of all the metals that were investigated in the area, only arsenic metal claimed the highest concentrations for all sites within the area with values exceeding those of the WHO and EPA guidelines. The moderate type of contamination was shown for cyanide in sediments with values of 0 to 4.41 ± 0.35 µg g^{-1} which exceeded the WHO limit of 1µg g^{-1}. The values of metals recorded for the two selected fish species Gobiidae, *Belobranchus belobranchus* and *Rhyacichthys aspro* ranged from under 0 to 2.59 ± 0.38 µg g⁻1. The use of these fish species as bio-indicators of heavy metal contamination in rivers around gold ridge proved them suitable to use as bio-indicators for future studies in the area. The sequential extraction of heavy metal in sediments indicated that most metals were present in the non-resistance fraction, a fraction that was readily available to move in the environment. Comparing the present study to the baseline study in the same area, indicated a simple % ration of, Cu (17%), Pb (78%), and Cr (54%), Cd (no data) and as (55%) were noted for all metals in the sediments. The present study confirms a significant increase of metals over years in rivers around the Gold Ridge mine site. The highest levels of metals and cyanide in riverine sediment around gold ridge mine site, compared to other Pacific studies, are attributed to the discharge of wastewater from the tailing dam in the area.

Keywords: Pollution, heavy metals, cyanide, sediments, sequential extraction, Gold Ridge mine

Author Biography:

The presenter for this PIURN conference presentation is Mr. Timothy Aihunu, an Assistant Lecturer in Chemistry at the School of Science and Technology, Solomon Islands National University (SINU). He holds a Bachelor of Education degree in Chemistry and Education from the University of the South Pacific (USP). Since joining SINU, Mr. Aihunu has contributed to teaching undergraduate chemistry courses and supporting student research in environmental science, particularly in the area of environmental pollution and sustainability.

The main author of the study, Dr. Dickson Michael Boboria, a Senior Lecturer in Chemistry at SINU with extensive expertise in Analytical Chemistry. He holds a PhD in Analytical Chemistry, a Master of Science and a Bachelor of Science degree. Dr. Boboria has led several environmental monitoring and assessment projects in the Solomon Islands, with a strong research focus on chemical pollutants in aquatic ecosystems and their implications for public and ecological health.

Together, Mr. Aihunu and Dr. Boboria will present findings from their recent study titled *"An Assessment of Heavy Metals Contamination in Freshwater Sediments and Fish and Cyanide in Sediment Around Gold Ridge Mine Site, Solomon Islands."* This research evaluates the levels of selected toxic elements and cyanide in river sediments and aquatic organisms near the Gold Ridge mining site. The study provides important scientific data to inform environmental policy, risk assessments and the sustainable management of freshwater resources in the region.

1. INTRODUCTION

Mining activities, particularly gold mining, can cause long-term contamination of freshwater environments with toxic and persistent pollutants such as heavy metals and cyanide. Cyanide, commonly used in gold extraction, and heavy metals can accumulate in sediments, which act as reservoirs for these pollutants, eventually affecting aquatic life and human health through bioaccumulation in edible fish.

The Gold Ridge mine, an open-pit gold mine in Guadalcanal, Solomon Islands, has experienced significant environmental challenges, including heavy metal and cyanide pollution in surrounding rivers. Past operations led to contamination of river sediments, and incidents such as the 2014 flash flood and uncontrolled dam discharge in 2016 further elevated risks for downstream communities that rely on the rivers for water and food. Previous studies focused on total heavy metal levels in sediments, especially arsenic, but did not assess metal bioavailability or contamination in aquatic organisms. This study aims to fill that gap by investigating the current levels of heavy metals and cyanide in sediments and in two commonly consumed fish species, *Belobranchus belobranchus* and *Rhyacichthys aspro*, to assess potential ecological and human health risks.

Using sediment quality guidelines (SQGs) and pollution indices like the Enrichment Factor (EF) and Geo-accumulation Index (Igeo), the study also includes sequential extraction analysis to determine the mobility and environmental risk of these metals. With the mine reopening in 2022, updated risk assessments are crucial for ensuring the safety and well- being of the local population.

2. MATERIALS AND METHODS

2.1 Study Area and Sampling Sites

Sampling was conducted in the upper catchment of the Metapona River, including Tinahula and Savohio Rivers. Seventeen sites were sampled for sediments (including controls), and fish samples were collected at four locations where two target species were present. A total of 21 stations were sampled

2.2 Sediment Sampling and Digestion for Metal Analysis

Triplicate sediment samples were collected, preserved at –20°C, oven- dried, homogenized, sieved, and digested using nitric acid and hydrogen peroxide. Samples were analyzed by Atomic Absorption Spectroscopy (AAS) with appropriate quality checks and certified reference materials.

2.3 Sediment Sampling for Cyanide Analysis

Cyanide was analyzed in the same sediment samples collected for heavy metals. Samples were stored at ≤6°C and extracted with NaOH before analysis using titration methods. Complex and free cyanide forms were distinguished through a distillation process involving chlorinated and unchlorinated samples.

2.4 Total Cyanide and Reflux Distillation

The USEPA Method 9010 was used to determine total cyanide via reflux distillation and titration. This process distinguished between chlorinated and unchlorinated forms and eliminated interferences using specific reagents. Accuracy was validated using recovery tests and reproducibility studies, yielding 98–99% recovery.

2.4 Fish Sampling and Digestion for Metal Analysis

Forty fish samples were collected from four river sites. Muscle tissues were dissected, oven-dried, digested with nitric acid and hydrogen peroxide, filtered and analyzed for metal content using AAS.

2.5 Quality Control

Certified reference materials were used for sediments, fish tissues, and cyanide samples. Blanks and triplicates ensured accuracy. Detection limits and coefficients of variation were reported.

2.6 Sequential Extraction

To assess metal bioavailability, the BCR sequential extraction method was applied. Metals were separated into four fractions (bioavailable, reducible, oxidizable and residual) and analyzed by AAS.

3. RESULTS AND DISCUSSION

3.1 Total metal contamination

Table 1: Mean contents (µg g^{-1}) of heavy metals in (±) standard deviation and pH for the riverine sediments at 16 sites around the Gold Ridge mine.

Sites	Cu	Pb	Cr	Cd	As	pH
Tinahula Bridge S1	103.37 ± 1.60	142.44 ± 0.620	59.71 ± 1.31	1.77 ± 0.260	512.03 ± 0.490	7.63
Tinahula Bridge S2	71.07 ± 1.35	166.72 ± 2.14	59.72 ± 1.31	2.19 ± 0.070	726.73 ± 0.860	9.12
Tinahula Bridge S3	113.01 ± 1.36	183.79 ± 1.24	81.06 ± 2.91	2.45 ± 0.030	655.88 ± 0.590	8.91
Tinahula Bridge S4	55.94 ± 0.620	16.17 ± 0.390	36.02 ± 0.410	1.15 ± 0.090	619.14 ± 2.95	7.82
Tinahula mid-stream	44.05 ± 0.630	15.49 ± 1.73	28.86 ± 0.310	1.22 ± 0.250	344.22 ± 0.430	7.92
Mean	59.980	53.850	33.270	1.20	223.690	
% recovery	96	93	90	93	97	
LOD	0.42	0.62	0.36	0.22	0.33	
CV	2.1	0.8	1.2	0.5	1.5	

The total metal contamination analysis revealed that heavy metal concentrations in river sediments were highest near the Gold Ridge mining area and decreased downstream. The upper stream sites near the Tinahula Bridge (S1–S3), close to the tailing dam discharge point, were the most contaminated. Mean concentrations across all sites were: Copper (Cu): 39.53–103.37 µg/g, Lead (Pb): 12.10–183.79 µg/g, Chromium (Cr): 18.53–81.06 µg/g, Cadmium (Cd): 0.71–2.45 µg/g and Arsenic (As): 42.11–726.73 µg/g. The contamination pattern followed the order: As > Pb > Cu > Cr > Cd, with arsenic being the most dominant and widespread metal. High arsenic levels were attributed to weathering and mineral formation at the site, as well as interactions with aluminum (Al) and iron (Fe) hydroxides under alkaline conditions (pH ~8), which enhance as retention in sediments.

Sites near the discharge point had higher pH and Al levels (7000–13000 mg/kg), promoting arsenic precipitation and sorption. The data also showed a notable increase in metal concentrations compared to a previous study (Albert et al., 2016), with percentage increases for Cu (17%), Pb (78%), Cr (54%), and as (55%). Cadmium was not assessed in the earlier study. These increases are linked to ongoing effluent discharges from the abandoned tailing dam during heavy rains and flooding, resulting in metal accumulation in sediments. Downstream and marine sites exhibited lower as levels, likely due to dilution and sediment partitioning. Comparison with similar mining-impacted sites in the Pacific further emphasized the significant contamination at the Gold Ridge site.

3.2 Sequential extraction of heavy metals in sediments from freshwater areas

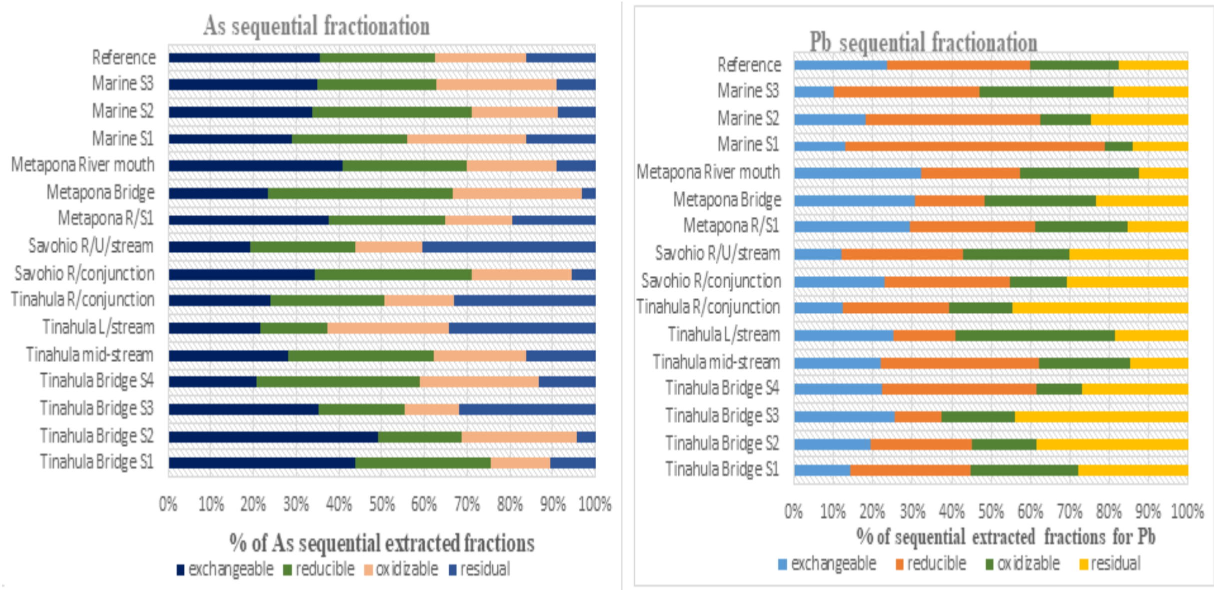

Figure 1: showing the Sequential extraction for As, Pb, Cu, Cr, and Cd in freshwater sediments around the Gold Ridge mine.

The analysis of total heavy metals in river sediments near the Gold Ridge mine revealed elevated concentrations of metals, particularly in areas close to the mining discharge points. The upstream sites near the Tinahula Bridge (S1–S3) were identified as the most contaminated, largely due to their proximity to the tailings dam where mining wastewater is released.

Metal concentrations and patterns ranged as follows, Copper (Cu): 39.53–103.37 µg/g, Lead (Pb): 12.10–183.79 µg/g, Chromium (Cr): 18.53–81.06 µg/g, Cadmium (Cd): 0.71–2.45 µg/g and Arsenic (As): 42.11–726.73 µg/g**.** The order of metal abundance was as > Pb > Cu > Cr > Cd, with arsenic (As) being the most dominant contaminant. The elevated metal levels, especially near Tinahula Bridge, confirm direct influence from *mining discharges***,** tailings dam overflow and hydrological factors like flooding and sediment transport**.** Arsenic levels were notably high due to secondary mineral formation and weathering**, i**nteraction with high aluminum (Al) content**,** enhancing as adsorption and alkaline pH (~8) at discharge sites promoting arsenic precipitation and reducing leaching.

The spatial distribution of Arsenic levels decreased downstream (Savohio River confluence to Metapona River and marine sites) due to dilution from river confluence and attenuation through sediment partitioning. A temporal comparison to Albert et al. (2016), metal concentrations significantly increased as Pb (78%)**,** Cr (54%)**,** As (55%)**,** Cu (17%)**,** while Cd was not analyzed in the earlier study. The increase reflects ongoing pollution from the abandoned tailings dam, particularly during heavy rainfall and flooding**.** A comparison was also done with other Pacific mining-impacted sites, affirming that heavy metal contamination at Gold Ridge is substantial and persistent, posing continued environmental risks.

3.3 Cyanide in sediments

Table 2: Mean levels (µg g^{-1}) of cyanide in (±) standard deviation for the Gold Ridge River sediments obtained for all sites in this study.

Stations	**Total cyanide**	**Free cyanide**	**Amended cyanide**	**pH**
Tinahula Bridge S1	2.06 ± 0.18	0.74 ± 0.02	1.32	9.71

Tinahula Bridge S2	3.33 ± 0.31	1.16 ± 0.03	2.17	9.83
Tinahula Bridge S3	4.41 ± 0.35	2.18 ± 0.06	2.24	10.23
Tinahula Bridge S4	0.94 ± 0.05	0.31 ± 0.03	0.63	7.92
Tinahula mid-stream	0.85 ± 0.15	0.31 ± 0.02	0.54	7.53
Tinahula L/ stream	0.78 ± 0.01	0.59 ± 0.02	0.19	6.52
Metapona Bridge	0.49 ± 0.09	0.36 ± 0.02	0.14	6.52
Reference site	0	0	0	7.31
Mean	0.940	0.403	0.535	
EPA	0.1	___________	________	Department of Environment and Conservation, 2010
Proposed levels in Great Lakes sediment	0.25	___________	___________	Ogoyi et al., 2011
Background levels	1	__________	__________	Albert et al, 2016

The study assessed total, free, and bound cyanide levels in riverine sediments near the Gold Ridge mine. Cyanide concentrations ranged from 0 to 4.41 µg/g for total, 0 to 2.18 µg/g for free, and 0 to 2.24 µg/g for bound cyanide. Most sites showed cyanide levels below 1 mg/kg, except for Tinahula Bridge sites (S1–S3), where levels exceeded 1 mg/kg due to direct discharge from the mine's tailing dam.

Higher cyanide concentrations at these sites were linked to high pH values (above 9), which enhance cyanide stability. The poor structural integrity of the tailing dam and environmental conditions (e.g., rain and flooding) contributed to cyanide seepage into sediments.

Downstream from these discharge points, cyanide levels dropped below 1 mg/kg due to natural degradation processes (oxidation, photodecomposition), lower pH (6–7), and possible dilution or transport by floodwaters. At the marine site (Marine S3), cyanide was undetectable, suggesting complete degradation or no contamination from the tailings.

CONCLUSION

The study concludes that open-pit mining at Gold Ridge poses a significant risk of environmental contamination. Elevated levels of heavy metals (especially arsenic) and cyanide were detected in river sediments, exceeding 2011 baseline levels. While contamination is moderate compared to some neighboring countries, it remains a concern due to the mobility of metals found in non-resistant forms, making them prone to environmental movement during disturbances.

Contaminant concentrations were highest near the mine and decreased downstream, influenced by flooding and water dynamics. Fish species used as bio-monitors confirmed sediment contamination, with arsenic levels in fish exceeding FAO/WHO safety limits. Statistical analyses (correlation and PCA) indicated that the contaminants originate from mining activities.

The study recommends public awareness and immediate mitigation measures to prevent further degradation of river systems around the Gold Ridge area.

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