Pollution in Surface Sediments in Faga'alu Bay, Tutuila, American Samoa 2025 Update

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Abstract

This addendum to the original technical memorandum presents findings from a follow up study of sediment metal concentrations in Faga'alu watershed/bay. Five sites that previously had elevated metals levels (in 2014) were re-sampled in 2021 to determine if best management practices (BMPs) at the quarry had an impact on sediment metals. Other than silver, metals concentrations either didn't change or increased since 2014. These data suggest that metals input to the watershed and Bay are likely coming from sources other than the quarry.

Background

Faga'alu is a small coastal watershed located on the southern shore on Tutuila Island in American Samoa. Within the watershed lies the village of Faga'alu (population 731, US Census 2020), a hospital which serves the entire territory, a popular public beach park, an elementary school, and a variety of small businesses – including Samoa Maritime Company, an open pit rock quarry located upslope from the village. See pages 1-3 of the original report for a more in-depth description of the study area.

In 2014, NOAA scientists sampled Faga'alu Bay for sediment contaminants and water column nutrients as part of a larger effort to characterize the environmental status of the Bay (Holst et al. 2016). This work found some elevated concentrations of contaminants (silver, arsenic, chromium, copper, zinc, nickel, chlordane) and we hypothesized that one potential explanation for elevated concentrations of metals could be accelerated erosion associated with quarry activities (i.e., liberating crustal elements at a higher than natural rate).

Following this environmental assessment, best management practices were installed at the quarry in order to reduce sediment loss to the stream, and subsequent transport downstream to the Bay. These best management practices included: groundwater diversions to intercept clean ground water and prevent its flow across haul roads and operational areas, road stabilization using large gravel to minimize erosion of surface sediments, and sediment retention ponds. In 2021, a subset of the original sites was re-sampled to quantify sediment metals to examine whether BMPs in the quarry may have been effective in reducing concentrations of sediment metals in the Bay.

Methods

Sampling Design and Field Methods

The original sampling design involved a stratified random design for the sites within the Bay and a targeted (based on position in the watershed and ability for field crews to access the sites) approach for the watershed (stream) sites. For this follow up study, five sites (Figure A1) that demonstrated elevated metals concentrations in the original study were re-sampled in 2021. Budgetary constraints made replicate sampling of sites prohibitive, so only one sample at each site was collected/analyzed for metals. Three of these sites were in the watershed and two of them were in the inner bay. Field personnel collected sediment directly into certified clean glass jars. Nitrile gloves were worn to minimize the potential for cross contamination between sites. Jars were stored on ice and in the dark until returning to the lab where they were kept frozen until analysis.

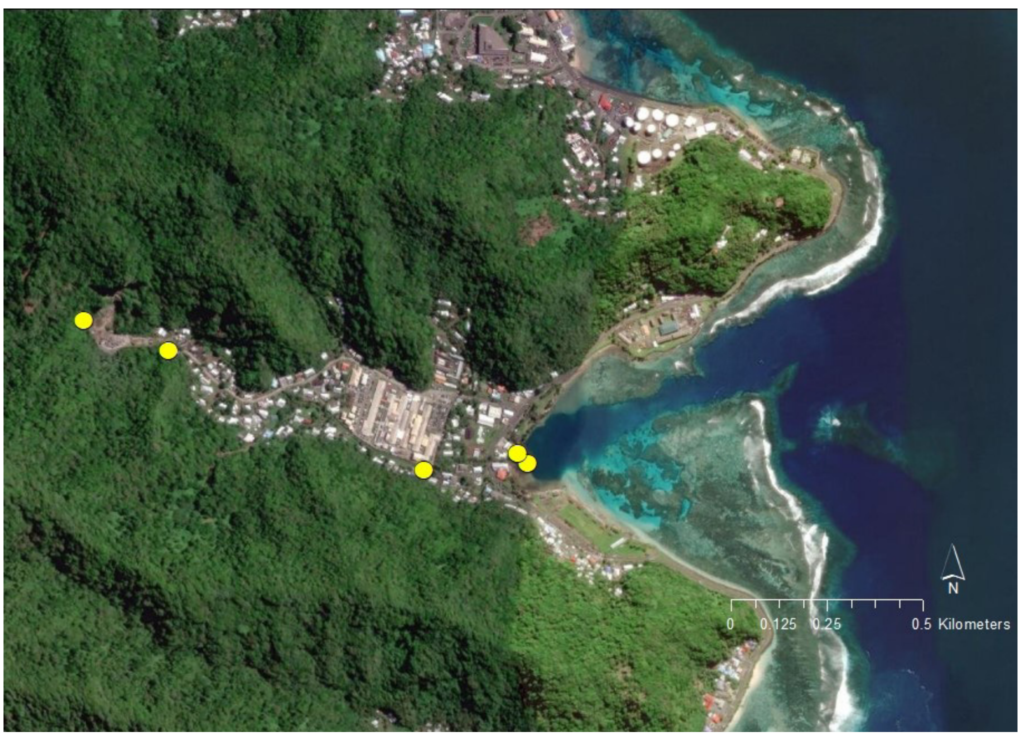

Figure A1: Sampling sites 2021. WS01 is most western site (farthest upstream); WS03 is farthest downstream. The two marine sites are IB05 and IB06 (most eastern sites).

Analytical Methods

Each sample was analyzed for a suite of metals (Ag, Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Se, Si, Sn, Zn). The values reported are total metals in microgram per gram. The same analytical laboratory from the original study (TDI Brooks, College Station, TX) was used for these analyses.

Statistics

Because there were not replicate samples taken from each site, the statistical approach was to compare the before and after across all five sites. Because these data are not normally distributed, a Wilcoxon analysis was applied to these data using the JMP statistical software package.

Results and Discussion

Statistically significant differences between the 2014 and 2021 sampling were observed for five metals (Figures A2-A6). Silver was the only metal to decrease between samplings, with aluminum, arsenic, cadmium and zinc increasing. In all cases, patterns were fairly consistent among all five sites (e.g. all five sites had increased arsenic concentrations). Before and after concentrations for all metals are shown in Table A1.

Table A1: Sediment metals concentrations by site (mg/g) for before (2014) and after (2021) best management practices were installed at the quarry.

	Before						**After**				
Analyte	*WS01*	*WS02*	*WS03*	*IB05*	*IB06*		*WS01*	*WS02*	*WS03*	*IB05*	*IB06*
Ag	1.28	1.67	2.74	0.987	1.25		0.0874	0.087	0.081	0.0812	0.103
Al	65700	66600	64200	54500	54800		76500	80000	79900	68300	73200
As	2.06	1.58	1.52	4.08	3.91		3.93	5.88	4.26	5.29	7.11
Cd	0.221	0.194	0.195	0.123	0.134		0.292	0.362	0.256	0.24	0.237
Cr	67.5	28.2	25.7	87.9	75.6		9.15	66.1	11.7	77.9	52.1
Cu	14.7	5.74	8.79	12.7	12.7		8.03	16.9	5.18	11.6	10.8
Fe	70600	56000	50600	53200	50300		47200	76200	56200	65500	65100
Hg	0.00349	0.0028	0.00296	0.0103	0.00695		0	0.003	0	0	0.00795
Mn	1180	1250	1180	798	978		1180	1180	1160	890	786
Ni	77.2	40.5	12.6	57.9	62.3		7.94	60.3	7.68	79.5	52.5
Pb	13.2	8.46	13.1	14.2	18.4		9.2	8.75	8.83	12.3	11.7
Sb	0.235	0.136	0.15	0.198	0.363		0.18	0.165	0.137	0.199	0.228
Se	0	0	0	0	0		0.271	0.388	0	0	0.211
Si	221000	235000	256000	143000	161000		301000	2E+05	3E+05	244000	226000
Sn	6.57	4.98	6.17	4.84	4.86		5.71	4.31	5.45	5.02	5.77
Zn	246	214	239	203	197		221	256	243	259	253

It had been proposed that activities at the quarry could have been responsible for elevated metals concentrations in the streams and near shore waters; mining activities that liberated metals and exacerbated erosional issues could have led to increased flux of metals downstream. If this was true, it might have been expected that metals

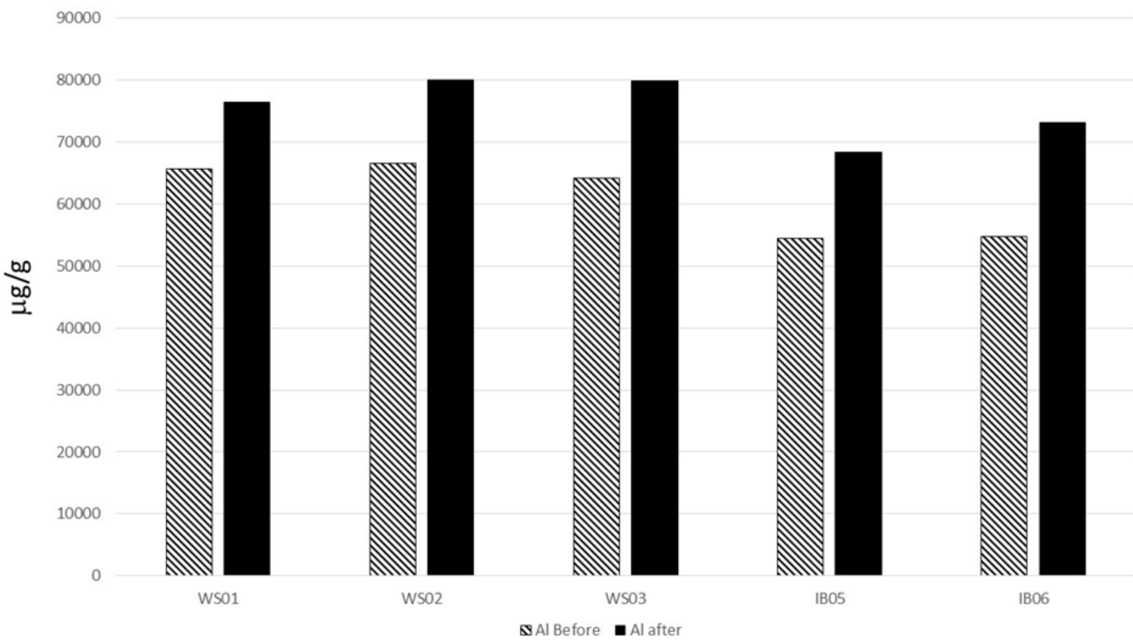

Figure A2: Sediment aluminum concentrations by site for 2014 (hatched bars) and 2021 (solid bars). 2014 is before best management practices at the quarry and 2021 is after.

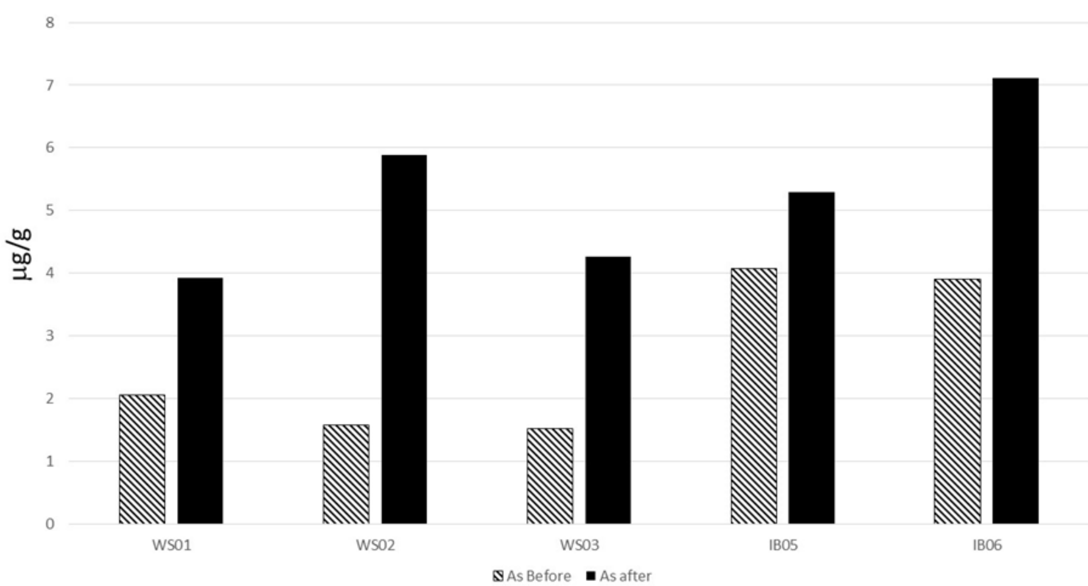

Figure A3: Sediment arsenic concentrations by site for 2014 (hatched bars) and 2021 (solid bars). 2014 is before best management practices at the quarry and 2021 is after.

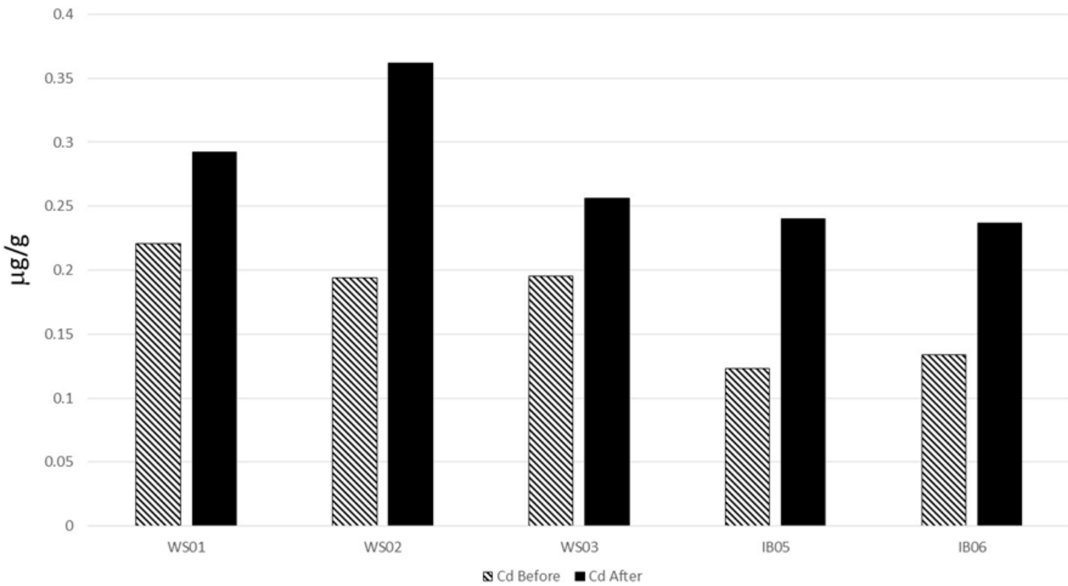

Figure A4: Sediment cadmium concentrations by site for 2014 (hatched bars) and 2021 (solid bars). 2014 is before best management practices at the quarry and 2021 is after.

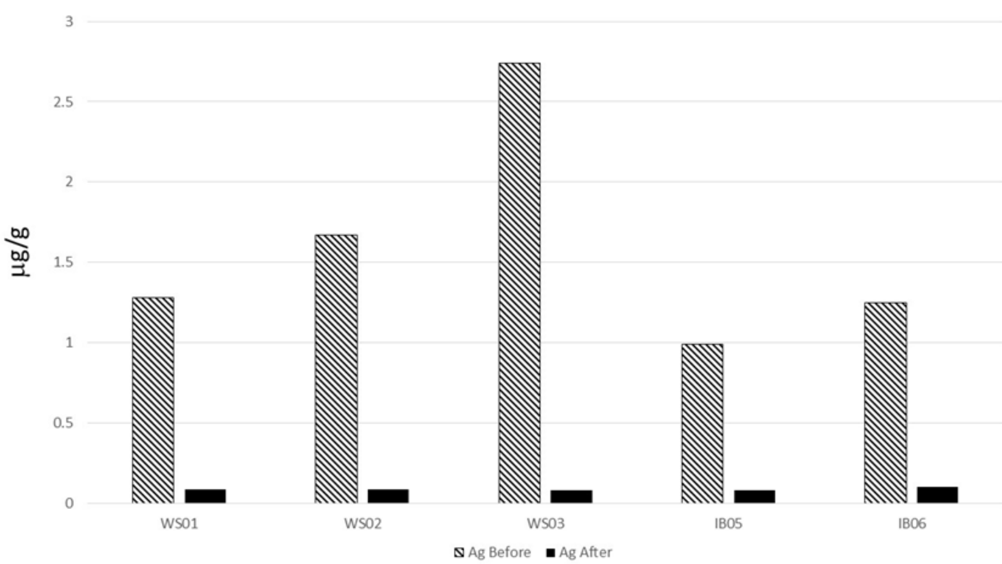

Figure A5: Sediment silver concentrations by site for 2014 (hatched bars) and 2021 (solid bars). 2014 is before best management practices at the quarry and 2021 is after.

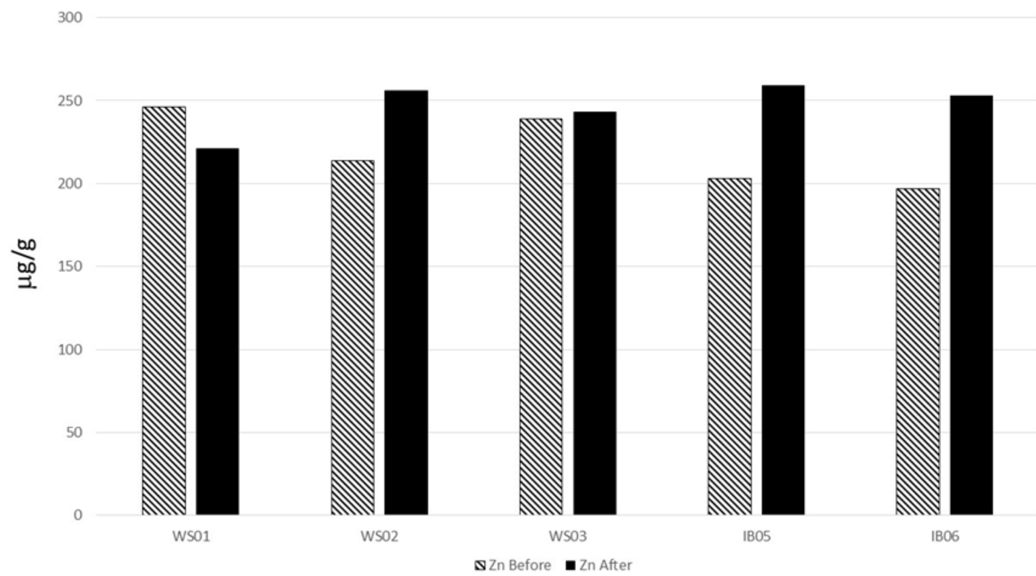

Figure A6: Sediment zinc concentrations by site for 2014 (hatched bars) and 2021 (solid bars). 2014 is before best management practices at the quarry and 2021 is after.

analysis after the BMPs were implemented would have shown a decrease in metals concentrations. Other than for silver, this was not observed. There are multiple possible explanations for this, which are discussed below.

First, unlike organic pollutants, which degrade into simpler constituents, metals are elemental and remain in that form. The only ways for metals to be "removed" from the surface sediments are via transport (e.g. a storm washes out a system), burial (i.e. new sediment is deposited on top of them) or biological uptake. Therefore, it is possible that increases in some metals are due to this geochemistry. However, because new deposition is occurring (Holst et al. 2016) and there is a decrease in silver, this explanation does not seem likely.

A second possible explanation is that small scale spatial variability at sampling sites could be introducing random error into these data. In other words, when field teams return to a given site, the precision of the hand-held GPS units is approximately 3 m, so it is unlikely that they are sampling at *exactly* the same location as before. It is therefore possible that spatial variability is confounding attempts to compare before and after. However, this too seems unlikely because on a site-by-site basis, the patterns are consistent, e.g., every site has higher cadmium in the after sampling than in the before. This consistency within analytes doesn't support sampling bias as a reasonable explanation

A third possible explanation is that the BMPs did not work as well as expected. This is refuted by recent work showing decreases in sediment transport (Biggs et al. 2023), and is similarly not supported by the decrease in silver values. However, local partners have observed that the BMPs are not being consistently maintained (American Samoa Coral Reef Advisory Group, personnel communication).

Final explanation: metals are coming from a source other than the quarry. For example, arsenic may be coming from treated wood (construction), zinc from automobile tire wear particles, and cadmium from improper battery disposal. The authors have observed improper battery disposal (i.e., as marine debris) across the island, including in Faga'alu watershed.

One potential hypothesis to explain the decrease in silver concentrations would be decreased use of silver products at the hospital. Silver was historically used in X-ray film development, but as modern methods have shifted to digital, we would expect that potential waste stream to approach zero. Additionally, the primary provider of dental care on the island is at the hospital. Silver has historically been used in dental amalgams, but has been phased out in favor of ceramic fillings. This shift in silver use may mean less silver is making it into the environment. However, the highest concentration of silver observed in 2014 was at site WS03 which is upstream from the hospital. As such, this hypothesis is not supported by these data and it is unclear why the silver concentrations decreased.

Conclusions

The hypothesis that the quarry was a source of metals to Faga'alu Bay was not supported by the data. Although there are potential confounding factors (e.g., small scale spatial variability), these data support the conclusion that metals pollution in the Bay is coming from watershed sources other than the quarry. It's important to note that BMPs were effective in reducing sediment pollution to the Bay, so these findings should not detract from that successful management action. While Faga'alu Bay is not highly polluted, coastal managers can use the data from this before and after study to target the most likely sources of metals pollution in this ecologically important system.

Additional References Not Contained in Original Document

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