Marine Pollution Bulletin 116 (2017) 501–507

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Land-based sources of marine pollution: Pesticides, PAHs and phthalates in coastal stream water, and heavy metals in coastal stream sediments in American Samoa

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ARTICLE INFO

Article history:
Received 12 August 2016
Received in revised form 19 December 2016
Accepted 21 December 2016
Available online 4 January 2017

Keywords:
Water pollution
Toxic metals
Pesticides
Plastics
Pacific islands
Contaminants

ABSTRACT

The island nations and territories of the South Pacific are facing a number of pressing environmental concerns, including solid waste management and coastal pollution. Here we provide baseline information on the presence and concentration of heavy metals and selected organic contaminants (pesticides, PAHs, phthalates) in 7 coastal streams and in surface waters adjacent to the Futiga landfill in American Samoa. All sampled stream sediments contained high concentrations of lead, and some of mercury. Several coastal stream waters showed relatively high concentrations of diethyl phthalate and of organophosphate pesticides, above chronic toxicity values for fish and other aquatic organisms. Parathion, which has been banned by the US Environmental Protection Agency since 2006, was detected in several stream sites. Increased monitoring and initiatives to limit non-point source land-based pollution will greatly improve the state of freshwater and coastal resources, as well as reduce risks to human health in American Samoa.

The island nations and territories of the South Pacific are facing a number of environmental and humanitarian concerns, including preparing for the impacts of climate change, solid waste management and harnessing cost-efficient and sustainable energy sources, among others (Morrison and Munro, 1999; Craig et al., 2005; McCarroll et al., 2015). Tens of thousands of tons of goods and materials are shipped annually to island nations (e.g. furniture, electronics, packaged foods, clothing, medicines, etc.), but very few, if any, nations have means to recycle or properly dispose of solid and other wastes (Morrison and Munro, 1999). As a result, landfills are quickly reaching capacity, especially on small islands or atolls where the total land area might be as little as a few square kilometers. As the costs of shipping long oceanic distances often prohibits removal or recycling of wastes off island, island states are extremely vulnerable to increased contamination of freshwater and coastal resources, especially in light of potentially increasing sea-level rise and storm activity from climate change (Walsh et al., 2012).

The US island territory of American Samoa, located approximately 4200 km south of Hawai'i is the southernmost of all U.S. possessions and the only U.S. jurisdiction in the South Pacific. American Samoa comprises seven islands (five volcanic islands and two coral atolls) with a total combined land area of approximately 200 km^2. The largest island of Tutuila (140 km^2) is the center of government and business, and supports a population of >56,000 residents. With a population density of >1350 people/km^2 along the coast and growth rate of 2.1% per year, the most pressing environmental concerns include extensive coastal alterations, fishing pressure, loss of wetlands, soil erosion, coastal sedimentation, solid and hazardous waste disposal, and pollution (Craig et al., 2005).

As in much of the Pacific, local streams in American Samoa serve as temporary waste receptacles, and contain plastics, household and agricultural waste, and other trash that is eventually deposited downstream in nearshore coastal areas, deteriorating freshwater and marine habitats. Particularly during storm events, household and industrial waste and debris often end up in streams and coastal beaches as landfills, stream and coastal litter, and infrastructures are eroded and washed away. Historical industrial, commercial, and military activity in the main Pago Pago harbor on Tutuila has also contributed to coastal pollution, including degradation of water quality and local reef habitats. Coral reefs in American Samoa support a high diversity of Indo-Pacific corals (over 200 species), fishes (890 species), and high numbers of invertebrates (Craig et al., 2005). Overfishing, point and non-point source pollution from storm water run-off, erosion from agricultural plots and urban development have been identified as the primary threats contributing to the decline of American Samoa's coral reef resources (Craig et al., 2005).

In addition to solid waste, stream water quality in American Samoa is also affected by riparian development causing changes in hydrology and shading, by watershed development causing erosion and increased turbidity, and by nutrient and bacterial pollution from poorly constructed human and pig waste disposal systems (Tuitele et al., 2014). The

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http://dx.doi.org/10.1016/j.marpolbul.2016.12.058
0025-326X/

American Samoa Environmental Protection Agency (ASEPA) is actively engaged in long term stream and beach water quality monitoring. Monthly assessments of water hydrography (pH, turbidity, temperature, dissolved oxygen), water chemistry (total nitrogen, total phosphorus, nitrate, ammonium) and fecal bacterial contamination are conducted in selected perennial streams on Tutuila (Craig et al., 2005).

Given the nature of solid waste observed in coastal streams and associated beaches (comprised of plastics, electronics, fabrics, furniture, etc.), as well as documented agricultural runoff (that can contribute pesticides, fertilizer, and sediments) and urban/industrial runoff (that can contribute toxic metals and petrochemicals), there is great potential for coastal streams to be a source of organic and heavy metal pollutants to near-shore coastal resources. However, no studies are known to have examined the presence of organic or elemental pollutants in American Samoa coastal streams or near-shore sediments. Therefore, the objective of this study was to provide a baseline information for the presence and concentration of selected organic contaminants (pesticides, PAHs, and phthalates) and toxic metals in selected coastal streams and sediments in American Samoa for the purposes of determining if increased monitoring, regulatory policy and conservation actions are needed.

In June 2015, seven coastal streams were selected for sampling based on observations of high solid waste content (Fig. 1). The majority of these sampled streams are within close proximity of the main town and harbor of Pago Pago. An eighth sampling site was included in an area of perched surface water that is thought to be draining from Tutuila's main landfill, located in Futiga. With the exception of the Futiga landfill, all streams were sampled very close to the mouth of the stream within the near-shore environment, where there was observed potential mixing with marine waters during extreme high tide or storm events. It is important to note, the sampling occurred during and just after a major storm event, with high rainfall, stream discharge and tidal surges.

At each surface water site, 3 composite sediment samples were randomly taken from 0–10 cm depth. Composite sediment samples were air-dried, homogenized and passed through a 2 mm sieve to remove rocks and other debris. Approximately 3 g of each sample were prepared for microwave digestion using nitric acid and hydrofluoric acid followed by a boron quench, and analyzed for 30 different elements using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) at Arizona State University's Goldwater Environmental Laboratory. Results are reported in mg/kg dry weight. The National Institute of Standards and Technology's Trace Elements in Soil Containing Lead from Paint (SRM 2587) was used as the Certified Reference Material for sediment elemental analyses.

Water sampling consisted of collecting two 1-liter water samples from each stream. Within 12 h, each 1-liter water sample was pre-filtered with 47 mm glass fiber filters, and then extracted with solid-phase extraction C18 disks (Empore 3M, 47 mm) conditioned with acetone. Immediately after extraction, all C18 disks were frozen until arrival at Arizona State University. For Gas Chromatography-Mass Spectrometry (GC–MS) analyses, C18 disks were eluted with 5 mL acetone, 5 mL acetonitrile and 8 mL of hexane and concentrated to a volume of about 0.5 mL. Concentrated sample extracts were passed through a sodium sulfate column with hexane, and then concentrated to a final volume of 0.5 mL with nitrogen gas. Method recoveries for detected organic contaminants ranged from 60% to >100% for pesticides, from 40% to 94% for phthalates, and from 15% to 40% for PAHs. All surface water samples, including two field and two laboratory blanks, were analyzed for organic contaminants using a Varian 3800 gas chromatograph in tandem with a Saturn 2200 electron ionization mass spectrometer. A complete list of potential contaminants searched for, with minimum detection limits, is shown in Table S1 (Supplemental materials). Minimum detection limits (MDL) were estimated by doubling the lowest standard concentration that showed a peak, with a signal-to-noise ratio >3.

Maximum elemental concentrations detected in composite sediment samples at each of the sites are shown in Table 1, along with selected screening level limits based on modelled amphipod toxicity in marine sediments (Field et al., 2002; Buchman, 2008). Screening levels were available for only 9 of the 30 elements quantified, and for these,

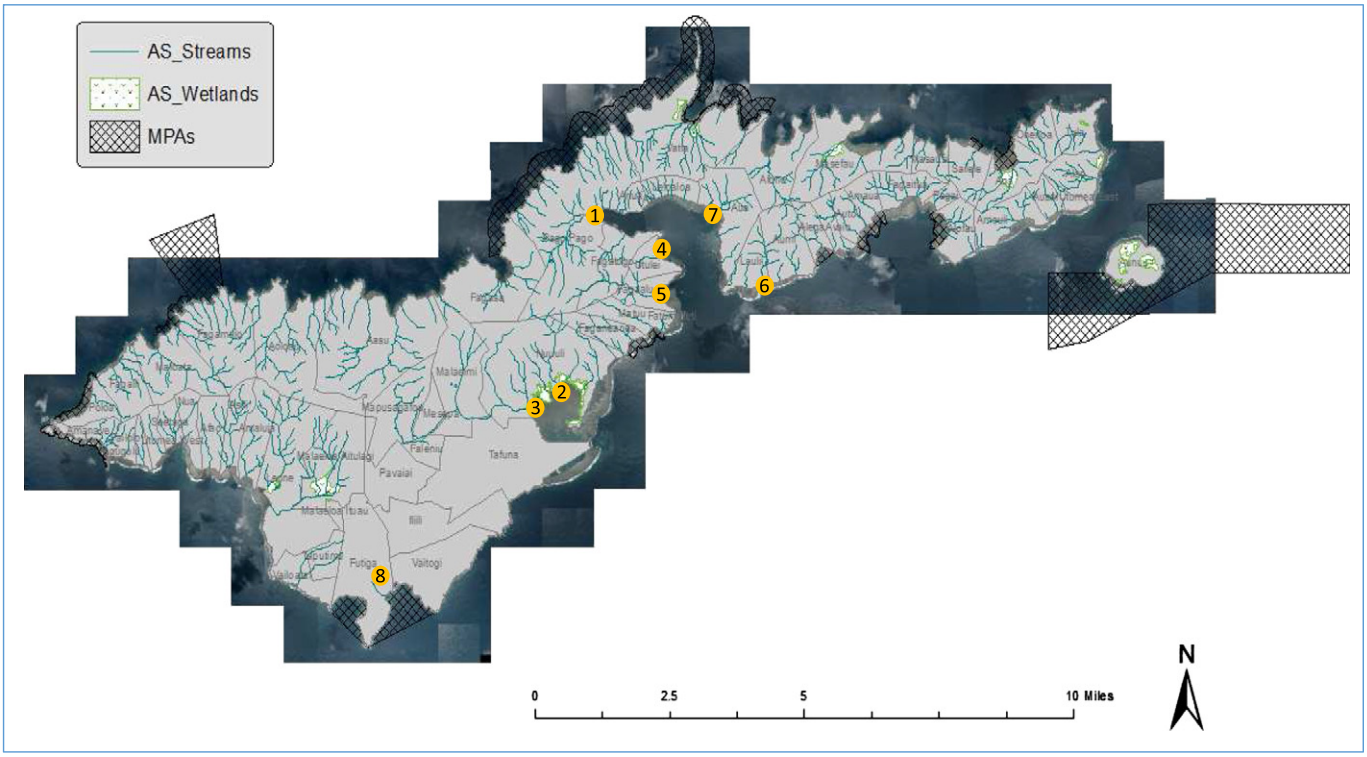

Fig. 1. Location of coastal stream sampling sites on Tutuila, American Samoa. Village names given in parentheses. 1) Vaipito (Pago Pago), 2) Papa (Nuuli), 3) Jail or Vitele (Lauliituai), 4) G'atavai or Vailoa (Utulei), 5) Faga'alu (Faga'alu), 6) Visa (Lauli'i), 7) Lalolamauta (Aua), and 8) Landfill Leachate (Futiga). MPAs = marine protected areas.