Assessment of Chemical Contamination in the Loimata o Apaula (LoA) Watershed Catchment in Samoa

T. Imo-Seuoti, P. Amosa, F. Lātu, A. Taise, and S. Taua'a

***Abstract*—The objective of this study was the river water quality assessment of Loimata o Apaula (LoA) watershed catchment in Samoa. River water samples from upstream and downstream are were collected and analyzed for heavy metals and nitrates/phosphorus. Among various heavy metals examined lead in upstream river water was higher than in downstream. Similarly to cyanide and nitrate concentration were higher in upstream than downstream with some concentration below the permissible maximum concentration of environment quality standard (WHO).**

***Index Terms*—Contaminants, watershed, heavy metals, Samoa.**

I. Introduction

Water pollution is a serious environmental problem that has attracted the attention of many researchers. Drinking water is derived from two basic sources: surface waters such as rivers and reservoirs and groundwater. All natural contaminants, particularly inorganic contaminants that arise from the geological strata through which the water flows and to a varying extent, anthropogenic activities by both microorganisms and chemicals [1]. In addition, ground water contamination causes degradation of from the water quality. It becomes important when the concentrations of one or more of the constituents reach levels that reduce the water unsuitable for its intended use. Among the point sources that have the potential to contaminate ground water are agriculture, sewage disposal, solid waste disposal sites, mining, industrial processing and product storage and transportation [2]. Surface fresh waters (rivers, streams, lakes) are a major source of drinking water, and are habitats for plants and animal life and they also provide opportunities for transportation and recreation [3]. Surface water has a higher level of suspended matter than groundwater. Thus surface water requires more processing to make it safe to drink. Groundwater tends to be less contaminated than surface water because organic matter in the water has had time to be decomposed by soil bacteria [4]. Surface waters are often contaminated with organic and inorganic chemicals such as pesticides and herbicides, nutrients, heavy metals, dissolved in organics. The sources of these substances include industrial, commercial and natural sources, agricultural and anthropogenic activities [5]. Heavy metals, like lead, chromium (IV), cadmium and mercury are dangerous for human health since they are toxic and can be carcinogenic. Protection of ground and surface water quality requires careful monitoring. There is a need for tighter ground and surface water monitoring requirements in the Water and Sanitation Sector guidelines globally and locally. Arsenic is widely distributed in small quantities in waters around the worlds. However, past studies revealed that thirty years ago in Bangladesh millions of shallow surface wells were drilled to reduce the risk of gastrointestinal diseases from highly polluted surface water. It has been estimated that over 40 million people in Bangladesh are exposed to potentially risky levels of arsenic in water [6]. In the aquatic ecosystems, heavy metals are detected in low concentrations, normally at the nanogram to microgram per liter level. However, the occurrence of chemical contaminants, especially heavy metals in excess of natural loads has become a problem of increasing concern. This situation has arisen as a result of; the increasing growth of population, increased urbanization, industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices, as well as non-enforcement of environmental regulations [7]. The major sources of heavy metal uptake by man are food, drinking water and air [8]. For instance, aquatic biota especially fish are the most important source of mercury (Hg). As trace elements some heavy metals (example of copper and zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. The heavy metals linked most often to human poisoning are lead (Pb), mercury (Hg), arsenic (As) and Cadmium (Cd). Others including copper (Cu), Zinc (Zn) and Chromium (Cr) are actually required by the body in small amounts, but can also be toxic in higher amount [9].

Fluoride is another natural water component that has caused serious consequences when it is present in excessive amounts. At slightly higher consumption levels fluoride causes discoloration of tooth enamel and at even higher levels [10]. As sources of freshwater, rivers are generally low in fluoride but due to various factors affect the concentration of fluoride in river waters such as temperature, pH and the porosity of the rocks and soils over which they pass [11]. Nitrate in excess are a particular risk to infants causing methaemoglobinaemia which may result in morbidity and death from short exposures. Nitrates are usually present in water contaminated with sewage, septic tank effluent or agricultural runoff [12]. The intensification of agriculture is the main cause of the increase in nitrate concentration in many

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rivers in temperate countries over recent last decades. Comparisons of nitrogen concentrations in catchments covering much contrasted land uses showed a relationship between dominant land use and the mean nitrogen concentration in the stream: concentrations increased from woodland to grassland and arable land [13]. Cyanide were widely used in gold production and electroplating industries [14]. Cyanide could be entered into human body by the way of respiratory tract, digestive tract and skin touch, combined with ferric iron of cytochromeoxidase, and resulted in the cutting of the oxygen transfer and the death of organism. The wastes of the industries above were rich in cyanide, and had caused various environmental problems [15].

The LoA catchment is part of the four Apia Catchments. The LoA watershed water resource served two water intakes. The land use activities of the LoA watershed catchment are dominated by forests and livestock cattle farm covers the rest of the land within LoA watershed areas. Samoa, the baseline information on the pollution problems on some catchment areas is very limited. Thus this study will provide baseline information on the ecotoxicological impact of chemical contaminants in the LoA watershed catchment. The objective of this study is to evaluate and assess the levels of chemical contaminants from the LoA watershed catchment.

II. Details Experimental

A. Materials and Procedures

Loimata o Apaula watershed catchment is located in the island of Upolu (173°59'W, 18°39'S) (Fig. 1). It is part of the four Apia Catchments that is bordered by Gasegase Watershed on the west and Vaisigano Watershed on the east, with a total area of approximately 630 hectares from ridge to reef. The average annual rainfall for LoA Watershed is 3,000 mm. In the wet season, the average rainfall is about 3,700 mm and 1,700 mm during dry periods.

B. Quantitative Analyses

Chemical parameters (nitrates, phosphorus, lead, cyanide) in water samples were quantitatively determined by Gas Chromatography Mass Spectrometry (GC-MS), Atomic Absorption Spectrometry (AAS) and UV Spectrometry.

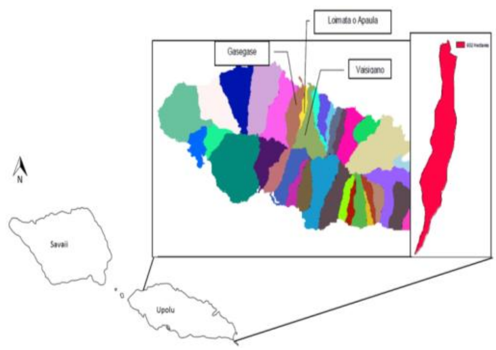

Fig. 1. Geographical map of Upolu. Insert: Mask map of Loimata o Apaula [Source: MNRE, 2012].

C. Phosphorus Analyses

Phosphorus in river water was determined using the Ascorbic acid method. A combined liquid consisting of sulphuric acid, potassium antimonyl tartrate, ammonium molybdate and ascorbic acid will be added to 25 mL of the water sample. This colors the sample blue in direct proportion to the amount of orthophosphate in the sample. The sample will be analyzed using a UV Spectrophotometer at a wavelength of 700-880 nm [16].

D. Lead Analyses

A 100 mL water sample was transferred into a 250 mL beaker and the pH was adjusted to about 3 with nitric acid. A 5 mL of APDC solution was added and the mixture was slowly shaken for 1 min. The solution was passed through SDS-coated alumina packed column with the aid of a suction pump. The lead–APDC complex was absorbed in the 586 TALEBI and SAFIGHOLI column. The column was washed with 10 mL distilled de-ionized water. The lead complex was finally eluted from the column by washing with 4.5 mL of nitric acid (4M). The eluent were collected in a 5 mL volumetric flask and made to the volume with distilled de-ionized water. A Varian atomic absorption spectrometer, Model AA-220, equipped with a deuterium background correcting system was used for the determination of the lead concentration [17].

E. Cyanide Analyses

A 1L subsurface water sample were collected from 5 sites. The method for the determination of cyanide in water samples was the Ion Selective Electrode using an Ion Selective Electrode, Multiparameter Bench Photometers, HI 83000 Series [18], [19].

F. Statistical Analyses

The Statistical Package for Social Sciences (SPSS) was used for all statistical calculations such as determination of basic statistical parameters (mean, geometric mean, median, maximum, minimum variance and standard deviations) for all the data from the three sites. All tests were performed at least twice to calculate the average value.

TABLE I: Detailed Description of Sampling Sites

Samples	Possible pollution sources	Locality
P1	livestock cattle/forest	upstream
P2	livestock cattle/forest	upstream
P3	livestock cattle /forest	upstream
P4	vegetation/crop plantation	upstream
P5	vegetation/ crop plantation	mid-stream
P6	vegetation/ crop plantation	mid-stream
P7	vegetation/ crop plantation	mid-stream
P8	settlement/vegetation	downstream
P9	settlement/vegetation	downstream
P10	settlement/vegetation	downstream

TABLE II: Physico-chemical Parameters (Mean Values)

Samples	**Water temp. /°C**	**pH**	**EC µS cm^{-1}**
P1	19.10 ± 0.10	7.20 ± 0.01	427.1 ± 82.9
P2	19.10 ± 0.10	7.21 ± 0.04	419.7 ±90. 2
P3	19.10 ± 0.10	7.21 ± 0.04	421.5 ± 80.1
P4	19.10 ± 0.10	7.21 ± 0.04	324.9 ±81.2
P5	19.10 ± 0.10	7.21 ± 0.04	445.3 ± 91.2
P6	18.70 ± 0.24	7.39 ± 0.01	553.2 ± 78.9
P7	18.70 ± 0.24	7.38 ± 0.01	446.1 ± 93.5
P8	18.70 ± 0.24	7.39 ± 0.01	462 ± 86. 6
P9	18.70 ± 0.24	7.39 ± 0.01	435.2 ± 91.2
P10	18.70 ± 0.24	7.39 ± 0.01	412.4 ±79.3

III. Results

The physic-chemical parameters (water temperature, pH, EC (µS cm^{-1}) are presented in Table II. The mean concentrations of the different chemical contaminants are shown in Table III.

TABLE III: MEAN CONCENTRATIONS OF CONTAMINANTS

Samples	Nitrate (mg/L)	Pb (mg/L)	Cyanide (mg/L)
P1	0.50 ± 0.01	0.29 ± 0.03	0.005±0. 002
P2	0.60 ± 0.04	0.29 ± 0.04	0.005±0. 002
P3	0.30 ± 0.01	0.24 ± 0.03	0.002±0. 001
P4	0.50 ± 0.01	0.24 ± 0.04	0.002±0. 001
P5	0.60 ± 0.04	0.24 ± 0.04	0.004±0. 002
P6	0.40 ± 0.11	0.25 ± 0.05	0.004±0. 001
P7	0.40 ± 0.11	0.25 ± 0.05	0.004±0. 001
P8	0.50± 0.21	0.25 ± 0.05	0.003±0. 001
P9	0.50 ± 0.21	0.25 ± 0.08	0.003±0. 001
P10	0.50 ± 0.22	0.25 ± 0.08	0.003±0. 001

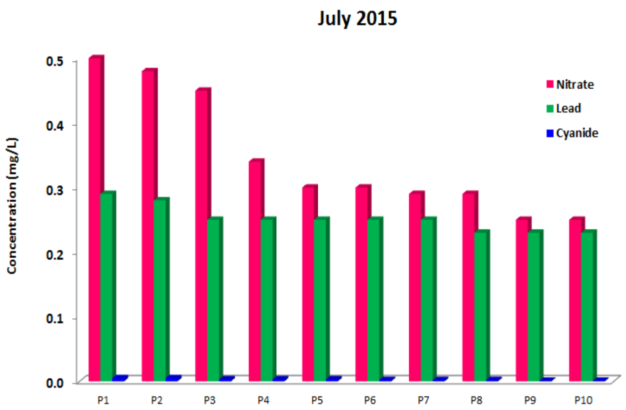

Fig. 2. Concentration of chemical contaminants, July 2015.

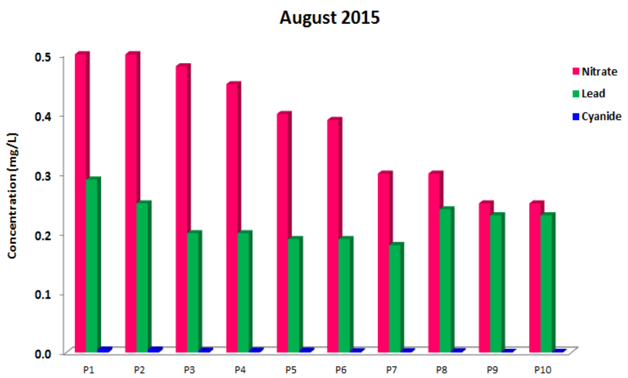

Fig. 3. Concentration of chemical contaminants, August 2015.

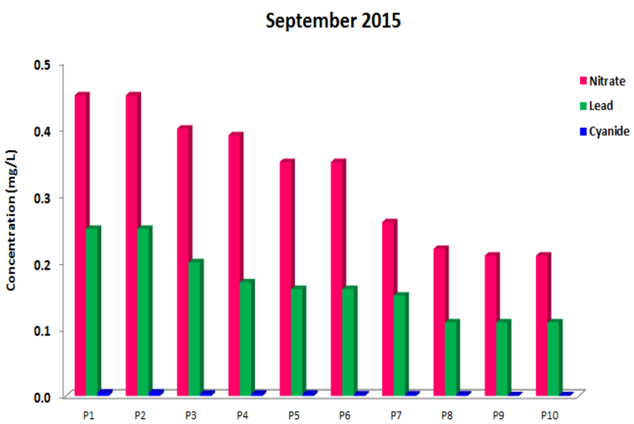

Fig. 4. Concentration of chemical contaminants, September 2015.

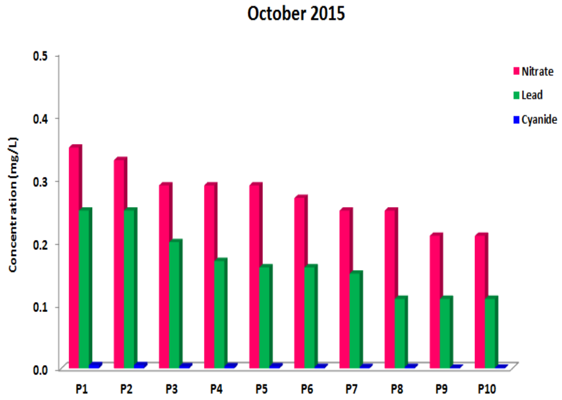

Fig..5. Concentration of chemical contaminants, October, 2015.

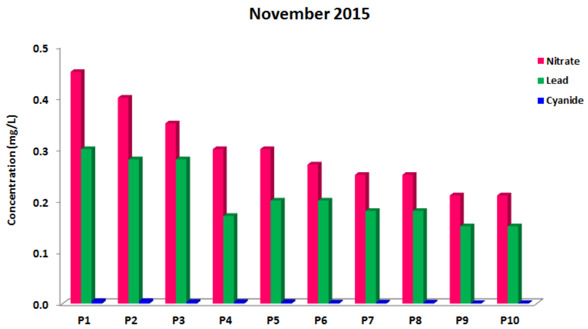

Fig. 6. Concentration of chemical contaminants, November, 2015.

IV. Discussion

The mean pH of the investigated samples ranges from 7.20 to 7.39 indicates that all water samples are slightly alkaline. The mean temperature variations at different sites indicated by the in situ readings are given in Table II. The nitrate concentration ranges from 0.30 to 0.60 mg/L indicates the possible sources can be from livestock cattle. The increase in concentration ranged from 0.24 to 0.29 mg/L for lead and the highest concentration was detected at P1 and P2 (Fig. 2). This could be due to the runoff from nearby livestock cattle and settlement. The highest concentration of cyanide was 0.005 mg/L (P1 & P2) followed by 0.004 mg/L (P5, P6, P7). There were no pesticides detected from all three sites. This suggests that crop plantations surrounding the catchments had used other alternatives instead of pesticides. For the heavy metals, the highest concentration of lead was detected at P1 & P2 (0.29 mg/L) followed by 0.25 mg/L at P6-P10. The possible sources could be from the livestock cattle or nearby settlement.All the concentrations are below the WHO and MOH guideline standards, however long term exposure of these chemical contaminants might have detrimental impacts on human health and the environment as well.Further studies are needed on the analysis of IWS catchments for other priority pollutants and monitoring the area of influence in each water scheme catchments. Increased knowledge has shown the complexity of many of the issues that are related to drinking water and health. Overall, however, it is evident that the supply and maintenance of safe drinking water remain key requirements for public health.

V. Conclusion

This report describes a survey carried out in the LoA watershed catchment in Upolu Island. As a consequence, this research provided baseline water quality data for the LoA watershed catchment in Samoa. Furthermore, it contributed to identify the main concerns regarding the quality of river water in order to suggest appropriate solutions to reduce the observed contaminations and to motivate communities and villages to plan future involvements in the water sector. Only by identifying the sources of chemical contamination will it be possible to select and implement the most correct and appropriate solution to these quality issues.

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