Chemical Contamination in a Typical Independent Water Scheme (IWS) Catchment

T. Imo, P. Amosa, V. Vaurasi, and F. Latu

***Abstract*—Surface fresh waters including rivers, streams and lakes are a major source of drinking water and are habitats for plants and animals. Surface waters are often contaminated with chemicals such as pesticides, nutrients, heavy metals and dissolved inorganics. The sources of these chemicals include agricultural and anthropogenic activities. The occurrence of chemical contaminants in drinking water has become a problem of increasing concern. Samoa, the baseline information on the contamination problems in a typical Independent Water Scheme (IWS) catchment is very limited. Hence, this article will provide detail information on the past and current status of drinking water by chemical contaminants.**

***Index Terms*—Catchment, drinking water, nitrate, pollutants.**

I. Introduction

Declining drinking water quality has become a global concern due to anthropogenic activities such as agricultural activities, land development, population growth as well as climate change [1]. Drinking water comes from two basic sources: surface waters such as rivers/lakes, 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 [2]. Although there are natural processes such as volcanic eruptions, evaporation and condensation sometimes can cause water ground water pollution but most water pollution originates from land-based activities. 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 [3]. Chemical contaminants, specifically inorganic and organic contaminants, concerning health can be present in the waters or the sources. Arsenic has been famous as an agent of death for many years and is of great health problems worldwide [4]. Heavy metals, like lead (Pb), copper (Cu), chromium (IV) (Cr) and mercury (Hg) are dangerous for human health since they are toxic and can be carcinogenic. They have been used in a variety of electrical products and as preservatives. Fluoride is a mineral that is naturally found in drinking water and can occur in water sources from insignificant to dangerously high concentrations. At slightly higher consumption levels fluoride causes discoloration of tooth enamel and skeletal fluorosis [5]. Nitrate in drinking water is undetectable without laboratory testing because it is tasteless, odourless and colourless. Nitrates are usually present in water contaminated with septic tank sewage effluents, livestock or agricultural runoff [6]. Pesticides are widely used in modern agriculture in most countries throughout the world and in a large range of environments. Although the uses of pesticides have resulted in increased food production and other benefits [7] it has raised concerns about potential adverse health effects on human and the impact on the aquatic and coastal environment. A pesticide may also be classified as broad-spectrum when used to control a wide range of species or as narrow-spectrum when used to control a small group of species. However, the most common classification of pesticides is based on the type of pest they are used to control [8]. These include insecticides (control insects), herbicides (control weeds) and fungicides (control fungi). Pesticides are used in agriculture to maintain high production efficiency and there is a constant demand for stable crop production to support the growing human population. Pesticides are transported into aquatic systems through processes such as direct applications, surface runoffs, spray drifts, agricultural returns and groundwater intrusions; either as single chemicals or complex mixtures [9]. Mercury is a toxic heavy metal and a persistent environmental pollutant. Exposure to mercury is associated with serious adverse health and developmental effects, especially in pregnant women, developing fetuses, and young children [10]. Industrial activity results in releases of millions of pounds of mercury into the environment each year, primarily in the form of air emissions from coal-fired power plants. Mercury also is released into the environment by municipal and medical waste incineration, mining, and smelting. Once in the environment, elemental mercury can be transformed by microorganisms to organic forms, most notably methylmercury. The World Health Organization [11] and the Ministry of Health [12] in Samoa have set standards for these chemical pollutants in drinking water. In spite of the toxicity of these chemical pollutants, several studies have been conducted to evaluate and monitor their concentrations in drinking water in developing countries including Samoa. Protection of ground and surface water quality requires careful monitoring. There is a need for tighter ground and

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surface water monitoring requirements in the Water and Sanitation Sector guidelines globally and locally. Thus keeping surface free of pollution is a high priority in environment policies. The Independent Water Scheme Association (IWSA) is a Civil Society registered as an Incorporated Society (NGO). It was formed in 2007 to represent interests and support the developments of 24 independent water schemes. The IWSA was established with funding from the European Union (EU) with continued core funding being provided by the Ministry of Women Community and Social Development (MWCSD). The IWS represent and support 31 independent water schemes covering 53 villages that are not currently part of the Samoa Water Authority (SWA) network [13]. The IWS provide water to approximately 17% of the total population [14]. In Samoa, the information on the distribution and occurrence of chemical contaminants in a typical IWS drinking water is limited. This study presents a baseline data on the distribution and occurrence of potential chemical contaminants in drinking water from the selected IWS catchments in Samoa.

II. Methodology

A. Study Sites

This study was conducted from the selected IWS catchments (Letogo 13°85'25" N, 171°72'16" E, Aufaga 13°98'00" N, 171°40'00" E; Falelatai 13°55'00" N, 171°59'00" E; (Fig. 1.). The details about sampling sites are presented in Table I.

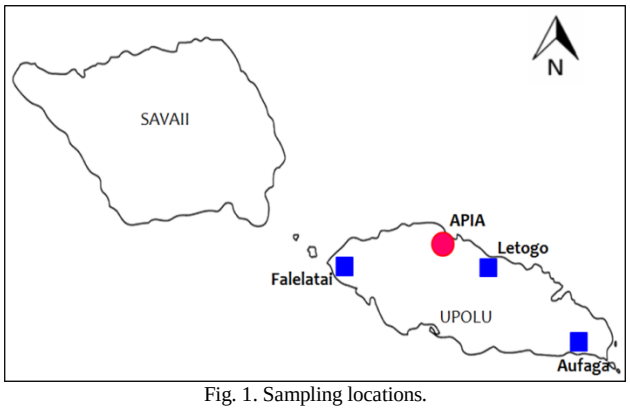

Fig. 1. Sampling locations.

TABLE I: Detailed Description of Sampling Sites

IWS site	Samples	Possible pollution source/s
Letogo	LT1-LT5	Settlement/vegetation
Aufaga	AA1-AA5	Vegetation/ plantation
Falelatai	FL1-FL5	Vegetation/ plantation

B. Sampling and Sample Preparation

Water samples were collected from the three IWS catchment sites during seven months of the dry season (August to October) and similarly for the wet season (November to February) in glass bottles of 1L capacity. Water samples were pre-filtered through 0.45 µm fiber filters (WHATMAN) to remove debris and suspended materials.

C. Quantitative Analyses

Pesticides (organochlorine/organophosphorus) and other 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.

D. Pesticides Analyses

A 1L filtered water sample from each site was extracted by liquid-liquid extraction in a separatory funnel using *n*-hexane. The combined solvent extracts were demoisturised using anhydrous granular sodium sulphate and concentrated in a rotary evaporator to a final volume of 2mL. All samples were analyzed for different pesticides on Gas Chromatography Mass Spectrometry (GC-MS) [15] [16].

E. Nitrate Analyses

Each sample was measured out to 150 mL in a volumetric flask. Then 15mL of the nitrate buffer solution was added. This sample was thoroughly mixed and then added to the top of the column. The sample was collected at a rate of about 6 mL per 5 minutes. The first 15 mL of sample to come off of the column will be discarded. After collecting a fraction, 0.5 mL of sulfanilamide solution was added to the sample and mixed thoroughly. After 5 minutes, but not exceeding 8 minutes 0.5 mL of the naphthyl ethylenediamine dihydrochloride solution will be added to the fraction. After mixing, the sample developed a pink/ purple coloration. The intensity of the coloration directly related to the concentration of nitrate in the water. The sample was then analyzed with the diode array spectrophotometer, with a focus on the absorbance at the 542 nm wavelength [17].

F. 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 was 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 was analyzed using a UV Spectrophotometer at a wavelength of 700-880 nm [18].

G. Lead Analyses

A 100 mL water sample was transferred into a 250mL beaker and the pH will be adjusted to about 3 with nitric acid. A 5mL 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 [19].

H. 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.

III. Results

The mean pH of the investigated samples ranged from 7.12 to 7.25 indicates that all water samples are slightly alkaline. The mean temperature variations at different IWS ranged from 18.5°C to 20.8°C. The mean concentrations of the different chemical contaminants are shown in Table IV and Table V.

TABLE II: WHO GUIDELINE STANDARDS (DRINKING WATER QUALITY) - 2010

Chemical contaminants	Limited Level (mg/L)
Lead	0.01
Iron	0.30
Arsenic	0.01
Mercury	0.006
Copper	2.0
Fluoride	1.50
Chloride	250
Pesticides/Herbicides	<0.01
Nitrates	50

TABLE III: MOH GUIDELINE STANDARDS (DRINKING WATER QUALITY) - 2008

Chemical contaminants	Limited Level (mg/L)
Lead	0.01
Iron	0.30
Arsenic	0.01
Mercury	0.001
Copper	1.0
Fluoride	1.5
Chloride	250
Pesticides/Herbicides	0.001-0.04
Nitrates	50

TABLE IV: MEAN CONCENTRATIONS OF DETECTED CONTAMINANTS

IWS sites	Samples	Nitrate	Fluoride	Chloride
Falelatai	FL1	1.20 ±0.01	0.41 ±0.01	15 ±.0.44
	FL2	1.21 ±0.04	0.42 ±0.01	15 ±0.42
	FL3	1.20 ±0.02	0.45 ±0.01	15 ±0.40
	FL4	1.20 ±0.01	0.40 ±0.01	15 ±0.39
	FL5	1.20 ±0.02	0.32 ±0.01	15 ±0.24
Aufaga	AA1	1.50 ±0.11	0.49 ±0.01	15 ±0.14
	AA2	1.51 ±0.11	0.47 ±0.02	15 ±0.14
	AA3	1.70 ±0.31	0.47 ±0.02	15 ±0.25
	AA4	1.70 ±0.31	0.47 ±0.02	15 ±0.96
	AA5	1.70 ±0.22	0.49 ±0.01	15 ±0.26
Letogo	LT1	1.40 ±0.12	0.43 ±0.08	11 ±0.54
	LT2	1.40 ±0.12	0.49 ±0.03	11 ±0.54
	LT3	1.90 ±0.38	0.59 ±0.03	11 ±0.15
	LT4	1.90 ±0.41	0.59 ±0.03	11 ±0.24
	LT5	1.90 ±0.41	0.49 ±0.08	11 ±0.19

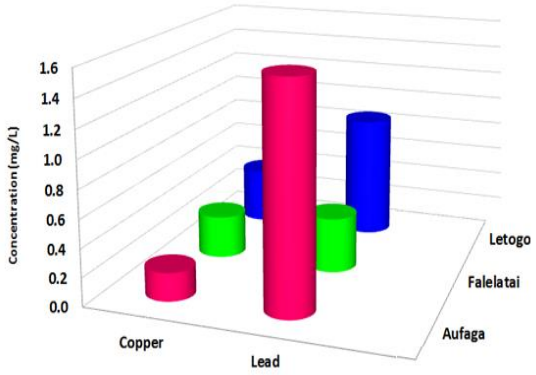

Fig. 2. Concentrations of copper & lead, August.

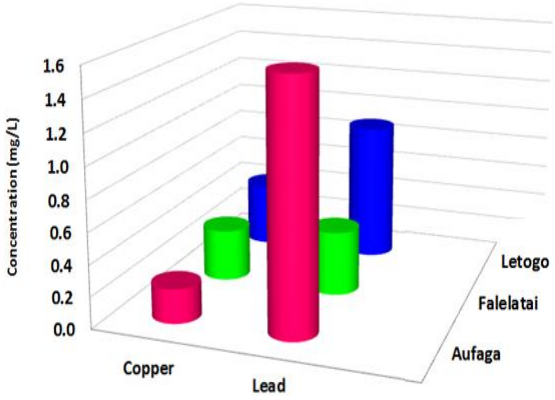

Fig. 3. Concentrations of copper & lead, September.

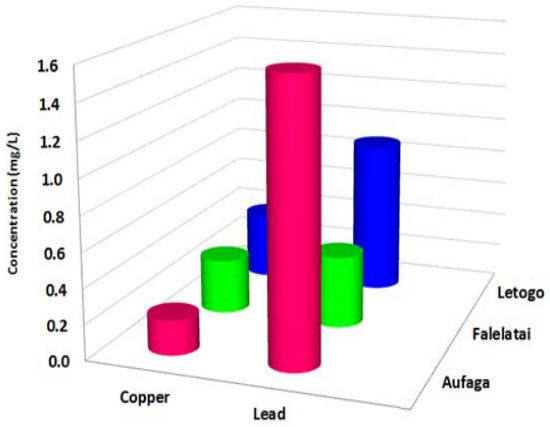

Fig. 4. Concentrations of copper & lead, October.

TABLE V: MEAN CONCENTRATIONS OF DETECTED CONTAMINANTS

IWS sites	Samples	Phosphorus
Falelatai	FL1	0.18 ±0.05
	FL2	0.17 ±0.05
	FL3	0.18 ±0.05
	FL4	0.18 ±0.04
	FL5	0.18 ±0.04
Aufaga	AA1	0.16 ±0.05
	AA2	0.16 ±0.05
	AA3	0.18 ±0.04
	AA4	0.18 ±0.04
	AA5	0.16 ±0.05
Letogo	LT1	0.19 ±0.01
	LT2	0.19 ±0.04
	LT3	0.19 ±0.01
	LT4	0.19 ±0.01
	LT5	0.19 ±0.01

IV. Discussion

The chloride concentration ranges from 11 to 15 mg/L indicates the possible sources can be from the accumulation of chlorine in the water pipes. Similarly, the concentration of fluorides is in the ranges of 11 to 15 mg/L. The increase in concentration ranged from 1.20 to 1.90 mg/L for nitrate and the highest concentration was detected at the Letogo IWS. It was suggested that this could be due to the runoff from nearby settlements. The highest concentration of phosphorus was 0.19 mg/L (Letogo IWS) followed by 0.18 mg/L (Falelatai and Aufaga). It was suggested that the source of phosphorus could be from agricultural activities. There were no pesticides and mercury detected from all three IWS. 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 the Falelatai IWS (0.29 mg/L) followed by 0.28 mg/L from Letogo IWS. The possible sources could be from past usage of lead based paints in the catchment or soil containing pesticides that were used near the catchment decades ago. The highest concentration of lead was found in the first three months of sampling from the Aufaga site followed by Letogo and Falelatai sites (Figures 2, 3, 4). On the other hand, the concentration of copper was in the ranges of 0.11 to 1.39 mg/L. All the concentrations are below the WHO and the MoH standards (Tables II & Table III) except for lead; however long term exposure of these chemical contaminants might have detrimental impacts on human health and the environment as well. Further monitoring studies are needed on the analysis of chemical contaminants in the IWS catchments seems unlikely to advance our knowledge of the occurrence and the sources of these contaminants in the IWS catchments.

V. Conclusion

This paper describes a monitoring survey carried out in the three selected IWS catchments to evaluate the physical-chemical quality of drinking water supply by the IWS to the three villages. This research provided a baseline water quality data for the IWS catchments in Samoa. The analyses of chemical contaminants in IWS systems are commonplace for drinking water to ensure compliance with regulatory limits. The results from this survey will provide more insight to chemical contaminants which is a necessary objective in minimizing the exposure to these contaminants in drinking water.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

T.Imo wrote the paper and conducted chemical analyses; P.Amosa analysed the data, V.Vaurasi and F.Latu conducted sampling collection and field activities. All authors had approved the final version.

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