Trace metal levels in drinking water on Viti Levu, Fiji Islands

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ABSTRACT

Drinking water samples from several major source intakes and reticulation end points on Viti Levu, Fiji Islands were analysed for trace metal (As, Cd, Cr, Cu, Hg, Pb, Zn) content. The objective of the study was to determine if metal concentrations were within the World Health Organisation (WHO) guidelines. The concentrations of metals were determined using various atomic absorption techniques (flame, graphite furnace, hydride generation). In the source waters, concentrations of trace metals were generally very low (<0.5 mg/L) indicating that there are only small inputs of metals from anthropogenic or natural sources. Some of the reticulation end points were found to have higher levels of metals such as Cu. This is likely due to the leaching of metals from metal pipes and fittings within the distribution system. The majority of samples were within WHO guidelines indicating that Viti Levu's water appears safe for drinking from a trace metal perspective. A relatively high value for As was found at one site which was located downstream of a gold mine tailings pond discharge.

***Keywords**: Trace metals, Fiji, anthropogenic, reticulation*

1 INTRODUCTION

Good drinking water quality is essential for the well being of all people. Unfortunately in many countries around the world, including the Pacific Islands, some drinking water supplies have become contaminated, which has impacted on the health and economic status of the populations. Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have found their way into water supplies as a result of inadequate treatment and disposal of waste (human and livestock), industrial discharges, and over-use of limited water resources.

There have been few published studies of drinking water quality in the Pacific islands (e.g. Lee and Brodie, 1982; Brodie *et al.* 1983). Most of the limited data available is mainly held by water utilities and health agencies on parameters such as faecal and total coliforms, pH, conductivity, turbidity, and nitrate. There has been insufficient investigation of the levels of metals and other possible contaminants such as pesticides in drinking water. This is probably due to the inability of many Pacific Island countries to accurately measure these parameters in water, and lack of funding to send samples elsewhere for analysis. The shortage of data is of concern given the increasing development and industrial activity on many islands (UNESCAP, 2000).

The waste products of industrial activities such as mining, factory discharges to air and water, and urban runoff can contain significant levels of metals which may enter water sources directly or indirectly (Stumm and Morgan, 1996). Once metals are in the reticulation system, corrosion of metal pipes and tanks can also occur under certain conditions (low pH and hardness) releasing metals into the water supply (Gray, 1994). Even if no sources of anthropogenic contamination exist there is potential for natural levels of metals to be harmful to human health. This was highlighted recently in Bangladesh where natural levels of arsenic in groundwater were found to be causing harmful effects on the population (e.g. Anawara *et al*., 2002). Unfortunately, this problem arose because the groundwater was extracted for drinking without a detailed chemical investigation.

The purpose of this study was to determine the concentration of trace metals in source water and at the end of the reticulation system for various public water systems in Viti Levu in order to determine if values were within the World Health Organisation (WHO) recommended limits.

2 METHODS

2.1 STUDY AREA AND SAMPLE SITES

Viti Levu is Fiji's largest island (10,388 km^2), and is also the most populated with over 75% of Fiji's total population of ca. 800,000 (1996 census data). Viti Levu's main urban population (approximately 210,000) is concentrated in the Suva-Nausori area with the rest of the population distributed in much smaller towns and rural areas. The water supplies for all major urban and semi-urban areas in Fiji are Government owned and managed by the Water and Sewerage Section of the Public Works Department (PWD). Most of the water supplied is drawn from reservoirs, rivers and small creeks, with relatively few boreholes. Many of the water supply intakes are quite isolated geographically from the locations they supply.

Rainfall on Viti Levu is highly variable due to the presence of several high mountains and the impact of the prevailing easterly maritime airstream, known as the 'South East Trade Winds'. In eastern areas, rainfall is high (4000-5000 mm/yr) and mainly orographic as the trade winds reach the mountains of Viti Levu. In leeward western areas, the annual rainfall is considerably lower (<2000 mm/yr) and more dependent on localised low pressure systems moving through the area. Fiji experiences distinct wet (November to April) and dry (June-November) seasons (Twyford and Wright, 1965).

Most of the Fiji Islands are of volcanic origin and there is a large variety of soil types as a result of differences in topography, climate, substratum, erosion rates and vegetation cover (Twyford and Wright, 1965). Hence the inorganic content of the water is variable and it requires varying degrees of treatment to remove particulate matter and dissolved metals such as iron and manganese. Most water is chlorinated before distribution. The PWD (National Water Quality Laboratory) regularly monitors microbiological quality. and parameters such as chlorine, turbidity, pH, conductivity and nitrate.

Sample sites in the present study were at the intakes of major sources for government owned piped water system around Viti Levu and also at selected reticulation endpoints. The water supply locations and source types (e.g. dams, rivers, boreholes) sampled are listed in Table 2, with Figure 1 showing the general location of the reticulation endpoints (exact sampling locations are available on request). All major cities and towns were included in this study as well as several smaller supplies.

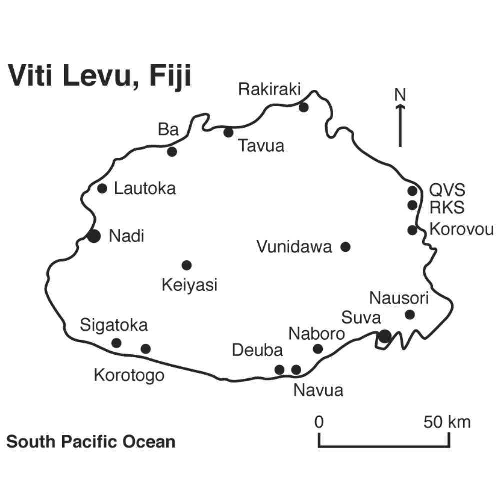

Figure 1 Map of Viti Levu, Fiji Islands showing locations of the reticulation endpoints sampled for trace metal content

2.2 SAMPLING AND ANALYSIS

Care was taken during sampling and analysis to minimise any external contamination of the samples with metals. This is very important for trace metal studies as there are many metal-containing materials (e.g., dust, car exhaust particulates, rust) in the field and laboratory that may contaminate samples. Sample bottles (polyethylene) were cleaned by soaking in acid (25 % aqua regia) for at least 24 hours, rinsed with deionised water (Milli-Q), filled with 1 % nitric acid (Baker ultrapure grade) and stored in individual sealed plastic bags. At the sampling sites, the acid was removed, the bottles rinsed three times with the sample prior to filling, capping, and being returned to the plastic bag. Clean powder-free Latex hand gloves were worn during sample collection and source water samples taken with the bottle upstream of the person collecting the sample. At reticulation endpoints, standpipe taps were run for at least 1 minute before samples were collected. At the Vaturu Dam, samples were taken at three depths (0, 15, 25 m) using an acid-cleaned Niskin bottle.

Upon return to the laboratory, the samples were acidified with nitric acid (Baker ultrapure grade) to reach a concentration of 0.2 % *v/v* and stored in a refrigerator until analysis. Because very little visible particulate matter was present in the samples, filtering was not considered necessary. No further sample digestion was performed. The results therefore reflect total dissolved and easily extractable (from any particles present) metal concentrations.

All laboratory equipment (autosampler cups, pipette tips, glassware) used for sample analysis were acid-cleaned in 10 % nitric acid and rinsed several times with deionised water prior to use. Each sample was analysed for arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb) and zinc (Zn) using a variety of techniques. Cd, Cr, Cu, and Pb were analysed using a graphite furnace atomic absorption spectrophotometer (Perkin Elmer Analyst 100 and HGA-800 graphite furnace) with deuterium arc background correction. The typical sample injection size was 20 µL. Zn was analysed using flame atomic absorption spectroscopy with a 10 cm air-acetylene burner head replacing the graphite furnace unit. The instrument conditions and matrix modifiers used for the determination of the above elements were those specified by Bosnak and Grosser (1996). The remaining metals, As and Hg, were analysed by hydride generation Atomic Absorption spectroscopy (Perkin-Elmer 3100 with a quartz cell and FIAS 100 flow injection unit) using standard methods (Perkin-Elmer flow injection mercury/hydride analyses manual).

Method accuracy was assessed by analysis of a certified Standard Reference Material (NIST 1643d) and measuring the recovery of metals following the spiking of samples (see Table 1). The values obtained from analysing the reference material were within (Cd, Cu) or very close (As, Cr, Pb, Zn) to the certified values, suggesting that the methods were accurate. The average percentage recoveries for the spiked samples were also satisfactory with all falling between 87-107 % (Table 1). Method detection limits (DL) were calculated from the standard deviation of seven replicates of a low level standard multiplied by 3.14, and these are also listed in Table 1. As the study objectives were only concerned with whether metal levels were hazardous to human health, the samples were not pre-concentrated prior to analysis. This gave detection limits sufficient for determining whether levels were below WHO guidelines (see Table 1).

Table 1 Results for analysis of NIST Standard Reference Water 1643d, % recovery of spikes of the samples with metals, method detection limits (DL) and World Health Organisation drinking water guideline limits (WHO 1996)

Metal	**Reference Water Results**		**Spike Recovery (%)**	**DL (µg/L)**	**WHO limit**
	Analysed (µg/L)	**Certified (µg/L)**			
As	25.6	26.67±0.41	92	0.5	10
Cd	6.19	6.47±0.37	89	0.1	3
Cr	18.1	18.53 ±0.2	99	0.3	50
Cu	20.7	20.5 ± 3.8	87	0.5	2000
Hg	N/a[a]	N/a[a]	88	0.5	10
Pb	19.1	18.15±0.64	107	0.3	1
Zn	78.0	72.48±0.65	107	7.0	3000[b]

[a] No certified value was available for Hg on the NIST 1643d water

[b] Levels likely to give rise to consumer complaints but not toxic

3 RESULTS AND DISCUSSION

The concentrations of trace metals in drinking water samples are presented in Table 2. In the source waters, trace metal levels were low with the majority of samples being below detection limits. Where the metal concentrations were above detection limits they still fell below WHO guidelines for safe drinking water (Table 1). Therefore our findings suggest that Fiji's main sources of drinking water have very little trace metal contamination and there does not appear to be any natural levels of any concern. Previous studies in a few of Viti Levu's rivers (Gangaiya *et al.*, 1988; Tamata *et al.*, 1996) have found low metal levels, which is in agreement with the present study's findings. Most of Viti Levu's drinking water supply sources are isolated from potential contamination sources such as industries.

Table 2 Trace metal concentrations in drinking water sources and reticulation endpoints on Viti Levu, Fiji.

Water Supply Sample Location	Sample Type	As mg/L	Cd mg/L	Cr mg/L	Cu mg/L	Hg mg/L	Pb mg/L	Zn mg/L
SUVA/NAUSORI								
Tamavua Water Supply								
Wailoku Dam	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Sovunisacau Creek	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	137
Savura Creek	Source	<0.5	<0.1	<0.5	2.8	<0.5	<0.5	10
Savura Dam	Source	<0.5	<0.1	<0.5	6.0	<0.5	<0.5	<7
Lami Shell Service Station Standpipe	Reticulation	<0.5	<0.1	0.8	15.9	<0.5	<0.5	<7
Waila Water Supply								
Waimanu River	Source	<0.5	<0.1	<0.5	6.5	<0.5	<0.5	266
Nadave Centre Standpipe	Reticulation	<0.5	<0.1	<0.5	19.9	<0.5	<0.5	12
NADI								
Vaturu Dam surface (0 m)	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Vaturu Dam Middle (15 m)	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Vaturu Dam Bottom (25 m)	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Sonasali Resort Standpipe	Reticulation	<0.5	<0.1	<0.5	13.3	<0.5	<0.5	<7
LAUTOKA								
Varagi Stream	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Nalau Stream	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Buabua Stream	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Lomolomo Village Standpipe	Reticulation	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
SIGATOKA								
Matovo Water Supply								
Matovo borehole 2	Source	<0.5	<0.1	0.5	2.1	<0.5	<0.5	<7
Matovo Borehole 3	Source	<0.5	<0.1	<0.5	6.1	<0.5	<0.5	<7
Matovo Borehole 4	Source	<0.5	<0.1	1.0	2.1	<0.5	<0.5	<7
Nayawa Village Tap	Reticulation	<0.5	<0.1	<0.5	64.1	<0.5	<0.5	34
Lawaqa Water Supply								
Lawaqa Stream	Source	<0.5	<0.1	<0.5	1.3	<0.5	<0.5	<7
Qereqere Water Supply								
Qereqere Borehole 2	Source	<0.5	<0.1	<0.5	1.3	<0.5	<0.5	<7
Qereqere Borehole 3	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	17
Fijian Resort Standpipe	Reticulation	<0.5	<0.1	0.7	1.8	<0.5	<0.5	<7
BA								
Waiwai River	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Varaciva Creek	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
RAKIRAKI								
Waimari River	Source	<0.5	<0.1	<0.5	2.1	<0.5	<0.5	<7
Narara River	Source	<0.5	<0.1	<0.5	3.9	<0.5	<0.5	<7
Nakasia Stream	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Rakiraki Hotel Standpipe	Reticulation	<0.5	<0.1	0.6	4.3	<0.5	<0.5	24
KOROVOU								
Korovou River	Source	<0.5	<0.1	<0.5	49.5	<0.5	<0.5	<7
Korovou PWD Depot Standpipe	Reticulation	<0.5	<0.1	<0.5	6.1	<0.5	<0.5	<7
NABORO								
Wainaboro Stream	Source	<0.5	<0.1	<0.5	4.5	<0.5	<0.5	<7
Naboro Primary School Standpipe	Reticulation	<0.5	<0.1	<0.5	13.7	<0.5	<0.5	47
NAVUA								
Wainikavika Stream	Source	<0.5	<0.1	<0.5	6.3	<0.5	<0.5	21
Naitonitoni Shop Standpipe	Reticulation	<0.5	<0.1	<0.5	5.2	<0.5	0.7	58
DEUBA								
Taunovo Creek	Source	<0.5	<0.1	<0.5	5.9	<0.5	<0.5	44
Deuba Foresty Office Standpipe	Reticulation	<0.5	<0.1	<0.5	1.5	<0.5	<0.5	70
KOROTOGO								
Korotogo borehole	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	88
Malevu Village Standpipe	Reticulation	<0.5	<0.1	<0.5	5.9	<0.5	<0.5	<7
TAVUA								
Tavua River (intake)	Source	<0.5	<0.1	<0.5	8.4	<0.5	<0.5	<7
Tavua River downstream of mine discharge	Source	6.6	<0.1	0.5	15.0	<0.5	1.9	<7
Tavua College Standpipe	Reticulation	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
VUNIDAWA								
Vunidawa Stream	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Vunidawa School Standpipe	Reticulation	<0.5	<0.1	<0.5	1.2	<0.5	<0.5	<7
KEYASI								
Keyasi River Intake	Source	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
Keyasi Village Standpipe	Reticulation	<0.5	<0.1	<0.5	<1.0	<0.5	<0.5	<7
QUEEN VICTORIA SCHOOL (QVS)								
Naimasi Creek	Source	<0.5	<0.1	<0.5	1.0	<0.5	<0.5	<7
QVS School Ground Standpipe	Reticulation	<0.5	<0.1	<0.5	11.0	<0.5	<0.5	122
RATU KANDAVULEVU SCHOOL (RKS)								
RKS Stream	Source	<0.5	<0.1	<0.5	2.4	<0.5	<0.5	<7
RKS School Main Gate Standpipe	Reticulation	<0.5	<0.1	<0.5	6.6	<0.5	<0.5	<7

Interestingly, higher levels of zinc were found in some of the source water supplies for Fiji's main urban area of Suva/Nausori than some of the other source water supply locations (Table 2). It is unclear whether this is due to anthropogenic inputs (e.g., emissions to air from industries, waste discharges, urban runoff) or from a localised natural source.

In some of the reticulation endpoint samples, the metal concentrations (in particular copper) were greater than that found in the source water. However, the increased metal concentrations were still not high enough to pose a potential health risk. The increase may be due to corrosion of pipes or pipe fittings in the reticulation system, or from periodic use of copper sulfate as an algicide at some water treatment plants (PWD pers. comm.). Metal solubility increases with decreasing pH, particularly in 'soft' (low in major ions such as calcium and magnesium) waters (Stumm and Morgan, 1996). In a reticulation system, metals (e.g., copper and lead) are commonly used in pipes and fittings and if pH levels drop sufficiently (pH<7) they begin to be dissolved into the water (Gray, 1994). Previous analysis by the PWD (unpublished data) showed the pH is generally in the range of 6.8-8 and hardness in the range 35-120 mg $CaCO_3$/L which can be considered as 'medium' hardness. These values suggest that there is a low risk of metals solubilising from pipes and fittings in the reticulation systems on Viti Levu but it is still recommended that several supply and household pipes be examined for corrosion. Lead concentrations in the present study were low at the reticulation endpoints (Table 2) which is encouraging as lead can be toxic at relatively low levels, particularly for infants (WHO, 1996). It is noted that more reticulation endpoints should be sampled in the future as there may be considerable variability in the condition of pipes and fittings.

Cadmium levels were very low in the present study with all samples below the detection limit (Table 2). Cadmium concentrations in unpolluted natural waters are usually minimal and the levels found in the present study suggest that no corrosion of cadmium containing pipe fittings was occurring. Elevated cadmium levels in water have also been associated with runoff from agricultural land where fertilisers are used (WHO, 1996) but the water catchment areas in the present study did not have a significant proportion of these types of land uses.

Mercury and arsenic levels were mostly below detection limit (Table 1) indicating that local mineral deposits in the catchment areas studied do not have high levels of these metals. Elevated levels of arsenic, copper and lead were found in one sample taken 500 m downstream from the Tavua River intake (Table 2). This is where input from a creek carrying discharge from the tailings pond of a gold mine occurs. The river below the pumping station is not used regularly for drinking, which is encouraging from a human health standpoint but there have been anecdotal reports of skin lesions (a common symptom of arsenic poisoning) on people who have swum in the river. The arsenic input may also be a concern for aquatic organisms in the river as there have also been anecdotal reports of fish deaths in the vicinity of the discharge.

This study was concerned with measuring trace metals in the government owned supplies. While this is the majority of water users, a substantial number (ca. 12%) of Viti Levu's population is estimated to be dependent on water from hand-dug wells, boreholes or rainwater collection systems (Gale and Booth, 1993). In order to assess the health risks for this population group, samples should be taken for trace metals and other parameters from these supplies. Sampling of Fiji's other islands should also be a priority. Study of metals in drinking water in Fiji should be repeated at least every 5 years to monitor if any changes in contamination levels are occurring. Further research on other Pacific Islands for drinking water trace metal content is also required, as levels may vary considerably due to different soil types, water chemistry (e.g., pH, hardness), and industrial activities.

In summary, the concentrations of trace metals (As, Cd, Cr, Cu, Hg, Pb, Zn) in the major drinking water supplies of Viti Levu, Fiji were found to be low in this study and no risk to human health was detected.

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