

How safe is the drinking water in Tonga?

VILI A FUAVAO PHD *
 SILVEINUSI TIUETI BSc **
 SALESI FINAU DPH ***
 SENGILI MOALA DSM****

Abstract

Survey of the standard of drinking water quality was carried out in the Kingdom of Tonga. Constituents determined include faecal coliform count, total hardness, pH, and chloride and heavy metal concentrations. With the exception of high count of faecal coliform in some areas in Tongatapu drinking water samples from Tonga generally had values within the WHO maximal safety limits for the above constituents. In addition, total hardness and chloride concentrations in some locations in Tonga were well above the Tonga Ministry of Health maximal limits yet still within the WHO desired limits. This study showed some faecal contamination and emphasised the need for continuous monitoring of water quality.

Introduction

The government policies of most of the Pacific islands have been amended recently to encourage foreign investment supporting local industrial development. The detrimental effects on the environment of such developments have been swamped by the promise of economic gains and have usually gone unchecked. This shift in national policies and its possible adverse effects on the environment have led to a renewed effort directed towards monitoring the environmental changes. It is important to design a surveillance system to evaluate the effects of the development projects being implemented in the various

Pacific nations. In some part of the world baseline chemical data on environmental samples, such as drinking, waste and coastal water, have been well documented. These analytical data are essential for monitoring pollution. Measurement and control of these pollutants should be integral parts of the activities of water authorities, development companies and health departments.

There are two categories of water quality standards. They are primary and secondary. Primary standard deals with basic safety standard of water quality whereas secondary standard is more specific with regard to radiation level, concentrations of heavy metals, etc. The quality of drinking water can be assessed accurately when components of both categories are known.

Little published information is available on water quality in Tonga. In an attempt to determine whether the drinking water in Tongatapu complies with the World Health Organisation (WHO) primary water quality standards^{1,2} a survey was done in January 1987 for pH, turbidity, chloride content and total hardness. The WHO standards for drinking water require: colour 5–50 units, turbidity 5–25 units, pH 7.0–8.0, chloride concentration 200–600 mg/L, and total hardness 100–500 mg/L calcium carbonate. The health authorities in Tonga have set the following standards for drinking water: pH 5.8–6.8, turbidity <2 units, chloride concentration <200 mg/L, and total hardness <300 mg/L calcium carbonate.

“ The detrimental effects on the environment of such developments have been swamped by the promise of economic gains and have usually gone unchecked. ”

The survey of the concentrations of heavy metals in drinking water in Tongatapu, Vava'u and Ha'apai was carried out and compared with the WHO guidelines. Tonga uses the WHO limits for the concentration of heavy metals in the drinking water. WHO and the US Department of Interior Committee on Water Quality Criteria³ has produced similar criteria. Unfortunately, essential baseline data for natural waters in Tonga were non-existent. This report presents data for the well water from the Vava'u group, two locations in Ha'apai (Pangai and Faleloa), and Tongatapu. This is the only data of this nature known to the authors.

* Dr Fuavao was lecturer, School of Pure and Applied Sciences, University of the South Pacific. ** Mr Tiueti was a science student at USP. ** Mr Finau was Senior Environmental Health Officer, Ministry of Health, Tonga. **** Dr Moala is Senior Medical Officer, Ministry of Health, Tonga.

Method

The water samples from Vava'u and Ha'apai were collected from Ha'alaufuli, Tu'anekeviale, 'Ene'io, Mangia, Tu'anuku, Longomapu lagoon, Neiafu and Holonga in Vava'u; and Pangai and Faleloa in Ha'apai.

In Tongatapu, water samples were collected from water taps located in various areas on 13, 19 and 27 January, and 3 and 16 February 1987. Samples were collected in plastic bottles and taken immediately to the laboratory for analysis. Water samples for trace heavy metals analyses were collected on the third week of April 1988. The areas are listed on tables 1 and 2.

All samples were drawn directly from the well where possible; otherwise, they were taken from the taps immediately leading out to the tanks where the water is stored prior to distribution. The samples were collected in acid washed plastic bottles and acidified with analytical grade concentrated hydrochloric acid to give a final hydrochloric acid concentration of 0.04 mol/L. Other standard analytical procedures for sampling were also followed.

All the analyses for primary standard water quality were carried out at the Central Health Laboratory, Ministry of Health, Nuku'alofa, Tonga. The pH values were determined using a pH meter calibrated with appropriate buffer solutions. Turbidity was determined using the Hach DR-EL test reagents and procedures. Chloride contents were determined by silver nitrate titration using potassium chromate as indicator. Total hardness was determined using EDTA titration using Erichrome Black T indicator. The detection limit by this procedure was 0.5 mg CaCO₃/L.

A Plasma Scan 2000 Inductively Coupled Plasma Emission Spectroscopy (ICP) located at the University of New South Wales was used in the analysis for heavy metals in the samples from Tongatapu. A Perkin Elmer HG 2380 Atomic Absorption Spectrophotometer with accessories: HGA 300 graphite furnace atomizer (FAAS), a laboratory made hydride generator (AAS), and air-acetylene and acetylene-nitrous oxide flames were used to analyse for trace of heavy metals in water samples from Vava'u and Ha'apai. Pre-concentration steps such as extraction of the metal with complexing agent 1-pyrrolidine carbodithioic acid ammonium salt (APDC) and methyl isobutyl ketone (MIBK) organic solvent, prior to the determination by FAAS, and coating the surface of the graphite tubes with solution of either zirconium or lanthanum salts, which are known to form low volatile carbides with graphite at high temperature, were used. The latter minimised the loss of analyte through the graphite porous walls. The complete coating can be found elsewhere⁴. Optimum conditions were used throughout.

All standards were of the highest purity grade chemicals available and stock solutions prepared were typically 1,000

mg/L. High purity de-ionised water was used in the preparation of all solutions. Working solutions were prepared immediately prior to each day's run.

Results and discussion

The results of the analyses for primary standards and biological tests in Tongatapu are given in Tables 1 and 2,

Table 1. Results of microbiological test for Tongatapu drinking water samples

Sampling location	Date of sampling	Total Coliform/100 ml	Faecal Coliform/100 ml
Talafo'ou	18/4/87	460	93
Haveluliku	18/4/87	>= 2400	240*
Fatumu	18/4/87	>= 2400	240*
Pelehake	18/4/87	1100	150
Veitongo	18/4/87	150	150
Sia'atoutai	18/4/87	1100	1100*
Puke	18/4/87	1100	1100*
Hofoa	18/4/87	460	240*
Halaleva	18/4/87	> 2400	28
Kiteau Topui	18/4/87	240	240*
	26/4/87	0	0
Dateline Hotel	18/4/87	93	43
	26/4/87	15	0
Popua	18/4/87	460	460*
	26/4/87	0	0
Queen Salote Wharf	18/4/87	9	0
Coconut factory	18/4/87	0	0
Vaiola Hospital	18/4/87	0	0
Houma	26/4/87	4	0
Vaotu'u	26/4/87	43	9
Fahefa	26/4/87	93	0
Kala'au	26/4/87	240	0
Fo'ui	26/4/87	23	0
Ha'avakatolo	26/4/88	240	0
Masilamea	26/4/88	43	0
Te'ekiu	26/4/88	43	0
Hala'ovave	26/4/88	9	0

* Above WHO limits

Table 2. Water quality data for Tongatapu drinking water samples						Table 2. Water quality data for Tongatapu drinking water samples (cont.)					
Sampling location	Date of sampling	pH	Turbidity	Chloride (mg/L)	Hardness (mg CaCO ₃ /L)	Sampling location	Date of sampling	pH	Turbidity	Chloride (mg/L)	Hardness (mg CaCO ₃ /L)
Lab. Water (before ion exchange)	13/1/87	7.0	0	132	340*	Vaotu'u	27/1/87	7.2	0	180	380*
	16/2/87	7.3	0	9	not done	Houma	27/1/87	7.2	0	116	340*
Lab Water (after ion exchange)	13/1/87	7.0	0	24	36	Ha'akame	27/1/87	7.2	0	100	328*
	13/1/87	7.1	0	128	380*	Ha'alalo	27/1/87	7.2	0	72	304*
Queen Salote Wharf	13/1/87	7.1	0	140	336*	'Utulau	27/1/87	7.4	0	100	324*
	19/1/87	7.1	0	132	368*	Matangiake	27/1/87	7.4	0	40	304*
Toni Newland factory	13/1/87	7.1	0	116	364*		3/2/87	7.5	0	216*	340*
Dateline Hotel	13/1/87	7.1	0	128	344*	Tokomololo	27/1/87	7.2	0	84	304
	19/1/87	7.1	0	116	364*	Pea I	3/2/87	7.5	0	72	290
Kiteau Topui bakery	13/1/87	7.1	0	140	356*	Pea II	3/2/87	7.5	0	72	290
	19/1/87	7.2	0	128	368*	Ha'ateiho I	3/2/87	7.2	0	136	320*
Tutomu factory	13/1/87	5.6*	0	132	200	Ha'ateiho II	3/2/87	7.2	0	128	330*
	19/1/87	7.1	0	128	364*	Veitongo	3/2/87	7.2	0	104	200
Fakava'inga factory	13/1/87	7.1	0	132	360*	Folaha	3/2/87	7.2	0	536*	400*
	19/1/87	7.2	0	132	368*	Nukuhetulu	3/2/87	7.1	0	200*	410*
Desicated coconut factory	13/1/87	7.0	0	132	344*	Longoteme	3/2/87	7.2	0	324*	380*
	19/1/87	7.0	0	132	348*	Vaini I	3/2/87	7.2	0	168	300*
Vaiola hospital	13/1/87	7.1	0	200*	452*	Vaini II	3/2/87	7.4	0	164	312*
	19/1/87	7.1	0	80	380*	Malapo	3/2/87	7.4	0	128	288
Hofoa	19/1/87	7.2	0	148	352*	Holonga	3/2/87	7.4	0	268*	392
Puke	19/1/87	7.1	0	640+	588+*	'Alakifonua	3/2/87	7.3	0	56	340*
Matafonua	19/1/87	7.1	0	200*	452*	Tatakamotonga I	3/2/87	7.4	0	440*	440*
Nukunuku I	19/1/87	7.1	0	80	380*	Tatakamotonga II	3/2/87	7.4	0	460*	450*
Nukunuku II	19/1/87	7.2	0	80	352*	Hoi	3/2/87	7.4	0	3088	407*
Te'ekiu	19/1/87	7.1	0	232*	480*	Nukuleka	3/2/87	7.4	0	184	312*
Masilamea	19/1/87	7.1	0	336*	520+*	Talafo'ou	3/2/87	7.4	0	208*	337*
Fo'ui	19/1/87	7.0	0	676*	628+*	Haveluliku	16/2/87	7.4	0	769+*	485*
Ha'avakatolo	19/1/87	7.2	0	1384+*	908+*	Fatumu I	16/2/87	7.6	0	160	345*
'Ahau	19/1/87	7.0	0	554*	604+*	Fatumu II	16/2/87	7.2	0	160	340*
Lakepa	27/1/87	7.2	0	116	356*	Lavengatonga	16/2/87	7.2	0	84	315*
Matahau	27/1/87	7.1	0	140	376*	Ha'asini	16/2/87	7.2	0	62	295
Kala'au	27/1/87	7.2	0	248*	424*	Hamula	16/2/87	7.4	0	44	310*
Fahefa	27/1/87	7.2	0	212*	400*	Nakolo	16/2/87	7.2	0	63	310*
Ha'utu	27/1/87	7.4	0	184	388*	Fua'amotu I	16/2/87	7.6	0	20	275

Table 2. Water quality data for Tongatapu drinking water samples (cont.)

Sampling location	Date of sampling	pH	Turbidity	Chloride (mg/L)	Hardness (mg CaCO ₃ /L)
Fua'amotu II	16/2/87	7.4	0	20	265
Fua'amotu Airport	16/2/87	7.4	0	not done	290
Pelehake I	16/2/87	7.5	0	34	280
Pelehake II	16/2/87	7.5	0	34	270
Tupou College	16/2/87	7.5	0	34	270
Beulah College	16/2/87	7.4	0	200*	350*
Tonga College	16/2/87	7.4	0	144	365*
Lapaha	16/2/87	7.4	0	452*	475
Hu'atolifoli	16/2/87	7.4	0	129	295

+ Above WHO Desirable Maximal International Standard for drinking water
* Above Tonga health authorities limit for drinking water

Table 6. Methods of analysis and precision by elements

Elements	Methods	Precision *
Fe	Zr-coated graphite furnace AAS	4.3
Al	Zr-coated graphite furnace AAS	3.5
Ca	FAAS	3.0
Cd	FAAS	3.0
Cr	FAAS	3.0
As	HGAAS	4.0
Se	HGAAS	3.1
Mg	FAAS	4.0
Mn	FAAS	4.0
Pb	La-coated graphite furnace AAS	3.0
Cu	Hg Generator	3.0
Na	FAAS	5.0
K	FAAS	5.0
Zn	FAAS	5.0

* Relative standard deviation of at least 4 consecutive analysis

Table 3. Detection limits* (mg/L) of heavy metal in ICP

Element	Detection limits
Al	0.019
As	0.029
B	0.009
Ba	0.002
Bi	0.012
Cd	0.004
Co	0.0018
Cr	0.0011
Cu	0.003
Fe	0.003
K	1.55
Mg	0.004
Mn	0.003
Mo	0.002
Na	0.68
Ni	0.002
Pb	0.011
Sb	0.024
Se	0.003
Sn	0.034
Ti	0.002
V	0.004
W	0.005
Zn	0.005
Zr	0.06

* Concentration giving a signal-to-noise of 2

respectively. In addition to the data given, all samples were checked for colour and were found to be clear. As can be seen from Table 2, all samples were free from turbidity.

Examination of the data in Table 2 shows that while most samples were within the WHO desirable maximal limits, many samples had chloride and hardness levels above the limits set by the Tonga health authorities. Of the 73 samples tested, 4 had chloride contents above the WHO limit and 22 had chloride contents above the Tonga health authority

limits. Since many of the water supplies are drawn from wells near coastal areas, high levels of chloride due to sea water intrusion are to be expected. For hardness, however, 5 samples were above the WHO limit and 58 (i.e. 79%) were above the Tonga health authority limit. Since the water samples are drawn from a limestone substratum, high levels of dissolved calcium carbonate (CaCO₃) are expected. Assuming an average temperature of 25°C, under normal atmospheric conditions, the saturated calcium carbonate concentration in water would be of the order of 400 mg/L (ignoring the influence of other salts). Thus it can be seen that a major portion of the hardness is related to the contact of

Table 4. Concentration (mg/L) of heavy metals in drinking water from Tongatapu

Element	Sites									
	Ha'atafu	Te'ekiu	Puke	'Utulau	Foloha	Fua'amotu	Haveluiku	Navutoka	Niutoua	Nuku'alofa
Al	0.41	0.34	0.44	0.18	0.27	0.25	0.28	0.35	0.28	0.17
As	0.062	nd	nd	nd	0.095	0.08	0.053	nd	nd	nd
B	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ba	0.007	nd	0.002	n.d.	nd	nd	nd	nd	nd	nd
Bi	nd	nd	nd	0.012	nd	nd	nd	nd	nd	0.012
Cd	0.004	nd	nd	0.004	nd	nd	nd	nd	nd	nd
Co	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cr	nd	nd	nd	0.001	nd	nd	nd	nd	nd	nd
Cu	nd	nd	0.003	nd	nd	nd	nd	nd	nd	nd
Fe	0.011	nd	0.003	nd	nd	0.009	0.089	nd	0.624	0.05
K	15.9	5.6	12.4	3.9	13.2	1.5	21.9	22.4	7.9	10.7
Mg	51.7	21.2	37.4	10.4	31.5	4.2	53.7	61.9	19.2	30.0
Mn	nd	nd	nd	nd	0.029	0.003	0.006	nd	nd	nd
Mo	0.005	0.004	0.08	0.003	0.002	0.041	0.041	0.041	0.034	0.034
Na	428.5	159.9	302.5	63.4	236.7	15.5	428.3	558.7	169.5	170.2
Ni	nd	nd	nd	nd	nd	0.002	nd	nd	nd	nd
Pb	nd	nd	nd	0.034	nd	0.011	nd	nd	0.023	nd
Sb	0.009	0.048	nd	nd	0.024	nd	0.024	nd	0.023	nd
Se	0.004	0.003	0.004	0.014	0.01	0.010	0.007	0.029	0.03	0.031
Si	17.5	18.4	4.3	14.3	8.7	6.9	7.8	11.4	9.7	11.1
Sn	nd	0.034	0.069	nd	nd	nd	nd	0.34	0.34	nd
Sr	1.5	1.5	1.5	0.59	0.58	0.53	0.68	1.3	1.3	1.5
Ti	0.004	0.002	0.004	0.002	nd	nd	nd	nd	nd	nd
V	0.004	0.017	0.031	0.081	0.024	nd	0.40	0.49	0.16	nd
W	0.005	nd	0.005	nd	nd	nd	nd	nd	nd	nd
Zn	0.32	0.048	0.043	0.02	0.038	0.034	0.20	0.086	0.027	0.035
Zr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd Not detected i.e. below the detection limit

ground water with the calcium carbonate substratum⁵.

Table 1 indicates that, while most samples have low total coliform and faecal coliform counts, seven samples have faecal coliform count higher than the WHO limit. These high values indicate possible sewerage contamination. Table 3 shows the detection limits of the ICP. Table 4 shows the results of the survey of concentrations of trace heavy metals in drinking water samples from Tongatapu.

Samples from ten sites were analysed for 27 elements. The precision of the analysis were accepted with values of less than 5% and all concentrations were blank corrected. Table 4 shows that all water samples from Tongatapu were within the WHO limits. With the exception of sodium, magnesium, and possibly potassium and silicon, no significant variation of metal concentration was observed in the samples.

The concentrations of various metals in water samples from Vava'u and Ha'apai are shown in Table 5. The respective

Table 5. Metal concentration (mg/l) in well water samples from Vava'u and Ha'apai

Sites	Elements and their WHO limits *														
	Fe	Al	Ca	Cd	Cr	As	Se	Mg	Mn	Pb	Cu	Hg	Na	K	Zn
	0.3-1.0	0.2	75 - 200	0.005	0.05	0.05	0.02	50 - 150	0.1 - 0.5	0.05	1.0 - 1.5	0.01	200		5 - 15
Ha'alaufuli	0.08	0.05	46.6	0.014	0.008	0.002	0.002	16.1	0.1	0.010	0.034	0.002	64.3	15.0	0.004
Tu'anekeviale	2.1	0.060	71.1	0.014	0.008	0.005	0.005	156.3	0.1	0.012	0.016	0.002	156.8	52.1	0.030
'Ene io	0.11	0.65	70.3	0.011	0.002	0.002	0.009	242.5	0.1	0.009	0.018	nd	nd	85.9	0.006
'Ene io (seawater)	0.72	0.73	486.8	0.012	0.008	0.002	0.010	127.2	0.1	0.113	0.028	0.002	nd	60.2	0.012
Longomanpu-Ano	0.50	0.76	46.8	0.018	0.002	0.001	0.007	266.3	0.1	0.054	0.006	nd	nd	85.0	0.018
Neiafu	0.40	nd	60.0	nd	nd	0.001	0.002	30.0	0.1	nd	nd	0.002	nd	70.1	nd
Holonga	0.60	nd	52.0	nd	0.001	0.002	35.0	0.1	nd	nd	nd	nd	nd	77.0	nd
Mangia	0.40	nd	55.9	0.014	0.008	0.001	0.002	26.0	0.1	0.009	0.005	nd	nd	60.2	0.006
Tuanuku	0.40	nd	54.3	0.014	0.008	0.002	0.001	97.1	0.1	0.046	0.010	0.002	nd	30.2	0.004
Pangai	0.30	nd	80.6	nd	nd	0.002	0.004	192.5	0.1	nd	nd	0.002	nd	64.2	nd
Faleloa	0.14	nd	51.8	0.014	0.008	0.001	0.001	26.9	0.1	0.028	0.018	0.002	371.3	18.7	0.012

* The limits are the maximum allowable concentration in water (Ref. 2)

methods of analysis and precision are presented in Table 6. The pH of all samples at the time of collection was in the range of 7.0–7.5. The chloride concentration of water samples from these sites had been determined two weeks prior to sampling by the Tonga Water Board to be between 200–400 mg/L CaCO₃ and the total hardness were within acceptable international standards of 100–500 mg/L. Table 5 shows that while elements such as arsenic, selenium and mercury concentrations are well below the desirable limits, calcium and others are on the borderline safe limits suggested by WHO¹.

The validity of the analysis both by ICP and AAS was confirmed by the analysis of National Bureau of Standards Water Sample No.1643 B. Triplicate analyses of this water sample for copper, lead, manganese, selenium, and zinc gave good agreement of +10% within the certified values.

Conclusions

Drinking water samples in Tongatapu generally have pH values in the range 7.0–7.5, are clear of coloured material, have little turbidity, but contain appreciable amounts of chloride and dissolved calcium carbonates. While the latter two parameters are usually within the WHO desired limits for drinking water, they often exceed the limits set by the Tongan health authorities. Care must be exercised in pumping to avoid increased saline intrusion. Regular monitoring of chloride and hardness levels in drinking water should be established and maintained.

Drinking water samples in Tongatapu, Vava'u and Ha'apai generally have trace metals concentrations within the WHO

desired limits. The opening of new industries and intensive use of agricultural chemicals will effect the limited water supply in Tonga. The fact that some elements are on the borderline of WHO safe limits indicates clearly that regular monitoring of trace metals and chemicals in drinking water should be established and maintained. This study provides baseline data for monitoring water standards in Tonga and a reminder that similar testing needs to be done urgently and regularly throughout the Pacific.

Acknowledgements

The authors thank Mr S.Maka of the Tonga Ministry of Health and the late Mr F. Koloi of the Tonga Water Board for assistance with this project. The assistance of Prof R.J. Morrison is greatly appreciated. Funding support was received from the University of the South Pacific Research Committee and the Commonwealth Fund for Technical Co-operation.

References

1. WHO. *International Standards for Drinking Water*, 3rd Edition. WHO, Geneva; 1971.
2. WHO. *Guidelines for Drinking Water Quality*, Vol. I. WHO, Geneva; 1984.
3. US Department of Interior. *Report of Committee on Water Quality Criteria*. Washington D.C: 1968.
4. Sneddon J and Fuavao VA. *Anal. Chem. Acta*; 1987.
5. Stumm W and Morgan J. *Aquatic Chemistry: An Introduction Emphasizing Chemical Equilibrium in Natural Waters*. Wiley-Interscience, N.Y.; 1970. □