5. Title: Analaysis of Drinking Water from Different Parts of Thailand

Principal Investigators: Sakorn Dhanamitta, M.D.
Aree Valyasevi, M.D.
Robert Van Reen, Ph.D.

Assistant Investigator: Jaratbhan Yooktatat, B.Sc.

Objectives

To study the chemical compositions of drinking water obtained from Ubol village (hyper-endemic) Ubol city (hypo-endemic) and Bangkok and its surrounding provinces (non-endemic).

Description

Twenty eight water samples from four cities in Thailand, Ubol (North-eastern), Bangkok, Pratoomtani and Samutprakarn (Central) were collected in 3 different seasons of the year 1966-1967. The first collection was in September 1966 (Rainy season), the second was in December 1966 (Winter season) and the third in May 1967 (Summer season). The water samples were sent to U.S. Geological Survey, Quality of Water Laboratory, Washington, D.C. after each collection for the analyses. In each season eighteen samples were sent for routine analyses and the other ten samples were sent for complete analyses.

The routine analyses required 1000 ml water sampies and were assayed for pH, residue, hardness as $CaCO_3$, non-carbonate hardness, specific conductance, alkalinity as $CaCO_3$, CO_2 calcium, SiO_2, Ca, Mg, Na, K, HCO_3, CO_3, SO_4, Cl, F, and NO_3. The complete analyses required one bottle of 2000 ml and two 100 ml bottles with a few drops of conc. HCl added and were assayed the same as those in routine analyses plus the determination of trace elements, Al, Cu, Pb, Zn, Sr, Ba, Li, B, Fe, Mn, and P as PO_4.

Progress

Table I. shows the numbers of water sample collected from various locations in 3 different seasons of the year. Twenty-one water samples were from Ubol Province and seven were from Bangkok and surrounding provinces.

Figure I indicates the locations of the water samples. From Ubol province, in north-eastern Thailand, 16 samples were collected from village wells 10 to 50 kilometers from Ubol city; 4 were collected from the city wells and one was from the Mekong River at the border. One tap water sample was from Bangkok, in the central part of the country; 3 samples collected from Pratoomtani were 30 kilometers north-west of Bangkok and 3 samples were from Samutprakarn located at the gulf of Thailand about 20 kilometer south-east of Bangkok.

Since the sources of drinking water in different parts of the country were different according to the geography and the way of living, the water samples collected here were from different sources which represented the types of drinking water in each location as well and are reported in Table 2.

Most of the sources of drinking water from Ubol villages were from soil wells about 4-8 meters in depth. There were only few villages where drinking water was obtained from stone wells, brick wells or concrete wells. However the sources of drinking water from Ubol city were either from concrete or brick wells only. The drinking water in Pratoomtani were either from canals or deep wells while those from Samutprakarn were from deep wells only.

Table 2 demonstrates the pH, residue, hardness as $CaCO_3$, non--carbonate hardness, specific conductance, alkalinity as $CaCO_3$ and CO_2 calcium. Most of Ubol village samples, especially the soil wells, show acid pH and lowest amount of residue, hardness as $CaCO_3$, non-carbonate hardness, alkalinity as $CaCO_3$ and specific conductance. However, one village concrete well (V_2) showed higher pH and amounts of all constituents.

The samples from Ubol city (concrete and brick wells) show higher pH and higher residue as well as specific conductance. One Ubol city brick well (C_2) showed a higher amount of hardness as $CaCO_3$, non—carbonate hardness while the other 3 samples did not show any definite differences.

The alkaline pH, higher residue, hardness as $CaCO_3$, non-carbonate hardness, specific conductance and alkalinity as $CaCO_3$ were all found higher in the sample from Mekong River and from Bangkok tap water. These findings were markedly higher in samples from Pratoomtani canals and deep wells and were highest in all three samples from deep wells at Samutprakarn.

The CO_2 calcium did not show any definite differences among various sources of the water samples.

Table 3 demonstrates part per million of SiO_2, Ca, Mg, Na, K, HCO_3, CO_3 SO_4, Cl, F, and NO_3. These minerals were generally lower in samples from Ubol province and higher in samples from Samutprakarn, Pratoomtani, Mekong River and Bangkok. The only exception was the Ubol village concrete well (V_2) that showed higher amounts of these minerals also.

The amounts of Ca, Mg, HCO_3, SO_4, and F were obviously higher in water samples from Pratoomtani, Samutprakarn, Mekong River and Bangkok while SiO_2 were higher in all 4 samples from deep wells (1 from Pratoomtani and 3 from Samutprakarn). The Na, K, and Cl, were higher in Ubol city samples as well as the samples from Pratoomtani and were very high in 4 samples from deep wells of Pratoomtani and Samutprakarn. CO_3 was undetectable in all samples and the NO_3 was generally low except in one sample from Ubol city brick well (C_2) that showed high amount of NO_3 and also showed higher amounts of Ca and Mg (this well demonstrated a high degree of hardness as $CaCO_3$ and non-carbonate hardness also).

Table 4 shows amounts of trace elements which were generally low in most of the samples. However the one Ubol city brick well (C_2) which was mentioned previously showed more or less higher amounts of Ca, Pb, Sr, B, and Mn in various seasons of the year. The Al was high in the sample from the Mekong River while the Zn was very high in Bangkok tap water in one season of the year. Sr was lower in Ubol village wells than those from other locations in all 3 seasons. However, the Fe was consistently higher in Ubol village samples as well as the sampls from Samutprakarn deep welles and the Mekong River. The Mn and P as PO_4 were higher in Samutprakarn deep wells but generally were low in other samples.

Table 1. Number of Water Samples Collected from Various Locations in Thailand in 3 Different Seasons of 1966-1967*

Locations	Number of Water Samples		
	Routine Analyses	Complete Analysis	Total
Ubol Villages	11	5	16
Ubol City	3	1	4
Ubol Border (Mekong River)	-	1	1
Bangkok	-	1	1
Pratoomtani	2	1	3
Samutprakarn	2	1	3
Total	18	10	28

* September 1966 (Rainy Season), December 1966 (Winter Season), May 1967 (Summer Season).

FIGURE 1. MAP SHOWING THE LOCATION OF THE WATER SAMPLE

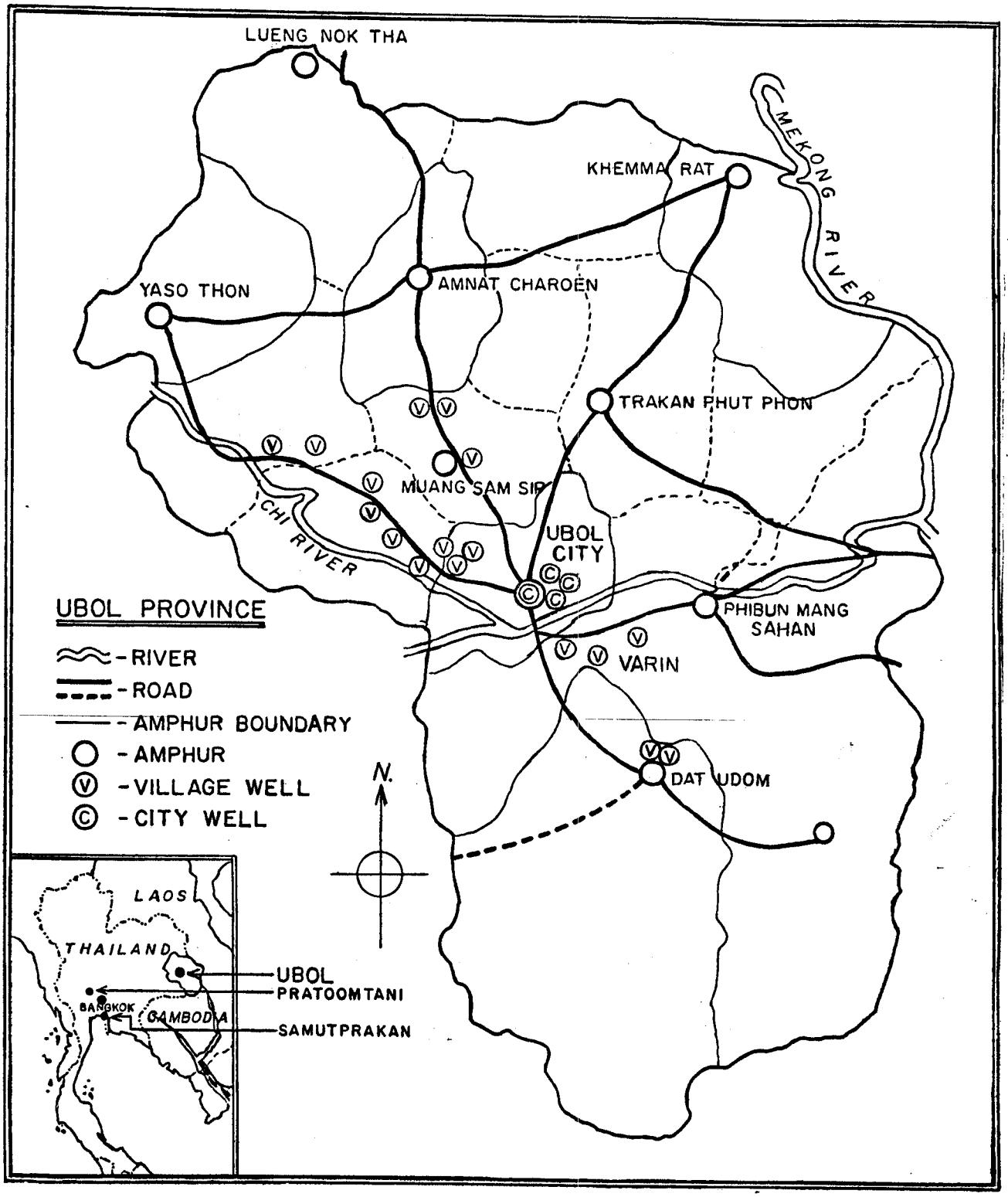

Table 2. Composition of Drinking Water in Different Seasons and Locations Thailand 1966—1967

Number	Sources	Appearance			pH			Parts per million: Residue (calculated sum)			Parts per million: Hardness as $CaCO_3$			Parts per million: Non-carbonate Hardness			Specific conductance (micromhos at 25°C)			Parts per million: Alkaline as $CaCO_3$			Parts per million: CO_2 Calcium		
		Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy
V_1	Soil Well	clear	clear	cloudy	6.7	5.1	5.4	36	48	66	8	9	13	5	7	8	51	80	112	2	1	4	1.0	31	33
V_3	" "	clear	clear	clear	4.25	4.6	5.0	26	30	32	2	2	2	2	2	1	45	38	29	0	0	2	0	-	42
V_5	" "	slightly cloudy	cloudy	cloudy	4.20	6.0	5.65	51	34	44	4	6	5	4	2	2	77	49	57	0	4	3	0	7.5	17
V_{17}	" "	cloudy	rather cloudy	cloudy	6.8	5.0	5.2	75	38	48	7	3	4	3	1	1	123	56	83	14	1	2	4.3	42	34
V_{19}	" "	clear	clear	cloudy	5.7	6.3	6.3	38	24	33	5	2	4	2	0	0	50	20	34	3	3	6	10	3.2	5.6
V_{22}	" "	cloudy	clear	clear	5.8	5.9	6.5	23	22	17	3	4	3	0	2	0	29	21	18	3	2	3	10	4.2	2.0
V_{23}	" "	clear	clear	cloudy	4.8	4.7	4.8	22	34	52	1	1	4	1	0	2	33	57	106	1	1	2	49	71	75
V_{24}	" "	clear	clear	cloudy	5.0	5.3	6.25	23	28	42	3	2	7	2	0	2	24	30	58	1	2	6	26	18	7.0
V_2	Concrete Well	clear	rather clear	cloudy	7.5	6.9	7.05	213	72	152	148	27	74	0	10	8	342	101	238	157	17	66	10	4.2	13.0
V_9	Brick Well	cloudy		cloudy	6.3	6.3	6.3	53	48	46	4	3	5	0	0	0	74	72	74	6	6	7	5	6.3	6.4
V_{12}	Stone Well	clear	clear	clear	5.5	6.5	6.5	147	28	29	20	2	4	18	0	0	268	28	35	2	6	7	16	3.4	4.0
V_4	Soil Well	rather clear	cloudy	clear	5.4	5.5	4.65	19	22	25	2	2	4	1	1	3	14	15	28	1	2	1	7.9	11	101.0
V_{11}	" "	cloudy	rather clear	clear	4.7	5.5	6.4	33	32	29	8	7	7	7	6	2	39	36	31	1	1	5	71	6.0	38
V_{25}	" "	clear	clear	clear	5.2	5.6	5.8	21	22	44	1	1	3	0	0	0	22	23	56	1	2	3	24	8.6	10
V_{15}	Concrete Well	clear		clear	5.8	6.0	6.7	47	51	50	7	8	10	3	4	2	66	84	73	4	3	7	13	6.4	2.9
V_{26}	" "	rather clear	clear	clear	5.8	6.2	7.15	38	30	58	14	2	34	0	0	0	44	24	77	8	3	36	56	4.0	4.4
C_1	" "	clear	clear	clear	6.4	6.7	6.9	73	83	116	4	5	17	0	0	0	127	145	203	7	2.9	19	51	2.9	4.6
C_4	" "	clear	clear	rather clear	5.8	6.5	6.9	108	104	108	8	7	12	4	1	2	196	175	184	4	7	11	13	4.0	2.6
C_2	Brick Well	very clear	clear		5.1	6.1	5.4	131	176	194	23	35	32	22	33	29	229	294	333	1	2	3	19	2.5	21
C_3	" "	very clear	clear	rather clear	4.8	5.1	6.6	71	63	72	5	4	10	4	2	5	120	101	115	1	2	5	49	31	2.4
P_1	Canal		cloudy	clear	6.9	7.4	6.6	173	160	86	105	113	36	24	1	15	297	262	126	80	112	21	20	8.6	10
P_2	"	cloudy	cloudy	cloudy	6.8	7.1	7.1	174	143	108	112	67	12	33	18	7	300	230	176	79	49	45	24	7.6	6.9
P_3	Deep Well	clear	clear		7.7	8.0	-	426	426	-	103	107	-	0	0	-	654	660	-	293	294	-	11	5.7	-
S_1	" "	clear	clear	clear	7.8	7.9	7.9	436	438	439	86	84	84	0	0	0	693	674	678	210	313	310	94	7.6	7.6
S_2	" "	clear	clear	clear	7.7	7.8	8.0	719	880	770	174	218	179	0	0	0	1310	1560	1320	276	253	271	11	7.7	5.3
S_3	" "	clear	clear	-	7.3	7.6	-	505	498	-	103	105	-	0	0	-	848	834	-	259	259	-	25	13	-
R_1	River	cloudy	cloudy	cloudy	7.0	7.4	7.8	143	137	80	98	99	57	8	6	0	244	226	125	90	93	61	17	7.2	1.8
B_1	Tap Water	clear	clear	clear	6.9	7.2	7.1	149	129	115	93	77	56	44	10	43	244	218	174	49	67	13	12	8.2	2.0

Table 3. Composition of Drinking Water in Different Seasons and Locations, Thailand 1966–1967

Number	CHEMICAL COMPONENT (Parts Per Million)																																
	SiO_2			Ca			Mg			Na			K			HCO_3			CO_3			SO_4			Cl			F			NO_3		
	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R
V_1	12	12	13	0.8	1.0	2.2	1.3	1.4	1.7	5.0	8.6	13	1.5	3.0	3.3	3.0	1.8	5	0	0	0	0.0	0.2	0.0	13	21	28	0.1	0.1	0.0	0.6	0.3	1.7
V_3	11	17	18	0.6	0.5	0.4	0.3	0.3	0.4	3.6	3.5	3.5	0.5	0.4	0.2		0.2	2	0	0	0	0.2	0.2	1.8	9.5	8.1	6.1	0.1	0.0	0.1	0.1	0.0	0.2
V_5	24	10	13	0.3	0.5	0.5	0.9	1.1	1.0	7.6	5.8	7.9	0.2	1.4	0.4		4.7	4	0	0	0	0.4	1.4	1.2	17	11	11	0.1	0.0	0.1	0.9	0.5	1.8
V_{17}	12	12	12	5.8	0.9	0.2	0.6	0.1	0.1	17	7.6	7.4	0.8	0.4	0.1	17	1.6	7	0	0	0	0.0	0.2	0.0	30	12	7.2	0.0	0.0	0.1	0.5	3.7	0.1
V_{19}	13	15	16	1.4	0.3	1.3	0.3	0.2	0.3	7.4	3.1	4.7	0.2	0.5	0.3	3.4	4.0	7	0	0	0	0.4	0.0	0.8	13	3.3	6.9	0.1	0.0	0.1	0.1	0.0	0.0
V_{22}	8.7	13	6.5	1.1	1.0	0.9	0.1	0.2	0.2	3.6	2.1	2.5	0.4	0.3	0.0	3.7	2.0	4	0	0	0	0.0	0.4	0.8	6.8	4.3	4.0	0.2	0.0	0.1	0.0	0.0	0.0
V_{23}	10	11	8.7	0.3	0.2	1.0	0.1	0.1	0.3	3.9	8.2	16	0.4	0.1	0.1	0.8	1	2	0	0	0	0.2	0.0	0.4	6.8	14	2.4	0.2	0.0	0.1	0.2	0.0	0.0
V_{24}	12	14	14	0.8	0.4	1.9	0.1	0.1	0.6	3.2	4.5	8.1	0.2	0.0	0.6	1.2	2	7	0	0	0	0.0	0.4	1.4	6.0	7.2	12	0.1	0.0	0.1	0.0	0.0	0.0
V_2	27	23	27	56	8.2	23	2.0	1.5	4.0	11	5.9	15	5.1	4.0	5.6	191	21	81	0	0	0	0.2	2.6	5.6	17	17	27	0.0	0.0	0.1	0.4	0.2	4.8
V_9	13	11	6.7	0.6	0.6	1.2	0.5	0.4	0.4	12	11	12	2.9	3.0	2.4	6.9	7.9	8	0	0	0	0.0	0.4	0.8	19	17	18	0.0	0.0	0.0	1.2	1.0	0.9
V_{12}	12	13	11	2.4	0.5	1.0	3.4	0.1	0.2	40	4.4	5.0	3.1	0.9	0.8	3	6.8	8	0	0	0	0.2	1.0	0.0	64	4.0	5.7	0.1	0.1	0.1	20	0.5	1.1
V_4	13	15	14	0.4	0.4	0.8	0.2	0.2	0.4	1.1	1.0	1.9	0.3	0.5	0.5	1.3	2.0	1	0	0	0	0.4	1.0	1.4	2.1	1.9	4.3	0.1	0.0	0.1	0.7	0.9	1.2
V_{11}	13	13	12	2.3	2.1	2.0	0.5	0.5	0.4	3.0	2.5	2.9	1.2	0.9	0.7	0.8	1	6	0	0	0	0.4	0.0	0.0	6.3	4.7	4.3	0.0	0.0	0.1	5.7	7.2	3.0
V_{25}	11	11	14	0.1	0.2	0.8	0.1	0.1	0.2	3.0	3.5	9.9	0.3	0.4	0.3	1.7	2	4	0	0	0	0.2	0.0	0.2	4.8	5.0	15	0.1	0.0	0.0	0.2	0.1	0.0
V_{15}	15	13	14	2.3	2.6	3.5	0.2	0.3	0.3	9.2	11.0	10.0	0.6	0.7	0.8	4.8	4	9	0	0	0	0.0	0.0	0.0	17	20	17	0.1	0.0	0.1	0.4	1.8	0.0
V_{26}	15	15	14	5.0	0.2	14	0.2	0.2	0.2	2.9	3.8	2.3	1.3	0.7	0.3	22	4	44	0	0	0	0.0	2.4	2.4	2.5	5.1	2.1	0.1	0.0	0.1	0.2	0.1	0.6
C_1	8.8	8.9	11	1.3	1.6	6.3	0.2	0.2	0.3	20	24	29	4.6	4.8	5.8	8	9	23	0	0	0	0 .0	2.4	2.4	3.4	37	44	0.0	0.0	0.0	0.1	0.2	6.0
C_4	11	11	12	2.2	2.1	4.1	0.6	0.5	0.5	28	27	27	8.0	7.4	7.2	5	8	13	0	0	0	3.0	3.4	3.6	48	40	39	0.1	0.0	0.1	5.5	8.4	9.0
C_2	14	14	20	4.5	6.8	6.8	2.8	4.2	3.5	30	38	47	3.1	3.4	3.8	1.3	2	3	0	0	0	0.2	3.2	0.0	49	60	70	0.1	0.0	0.0	26	45	41
C_3	12	13	13	1.3	0.9	3.0	0.5	0.4	0.5	19	16	17	0.6	0.5	0.9	1	2	6	0	0	0	0.6	1.4	0.2	26	21	25	0.1	0.0	0.1	10	8.6	8.9
P_1	14	15	16	30	35	9.8	7.2	6.2	2.8	14	10	8.7	6.1	3.2	1.7	98	137	26	0	0	0	36	9.4	26	16	12	7	0.3	0.2	0.0	1.4	0.3	0.1
P_2	15	13	11	32	16	17	7.6	6.5	4.7	12	19	9.3	6.0	5.2	2.4	96	60	55	0	0	0	39	31	30	14	21	6.6	0.2	0.2	0.0	1.7	1.0	0.0
P_3	27	25	-	31	31	-	6.2	7.1	-	117	116	-	2.7	2.8	-	357	358	-	0	0	-	62	63	-	3.0	3.9	-	0.5	0.4	-	0.3	0.3	-
S_1	32	32	38	20	19	20	8.7	8.7	8.2	130	131	125	5.5	5.2	5.1	378	382	378	0	0	0	31	33	35	22	21	21	0.4	0.3	0.3	0.3	0.1	0.0
S_2	31	31	38	43	51	27	16	22	27	200	252	222	7.0	7.4	6.7	336	308	330	0	0	0	17	19	19	240	346	266	0.3	0.2	0.2	0.0	0.9	1.9
S_3	33	32	-	23	22	-	11	13	-	145	148	-	6.1	5.8	-	316	316	-	0	0	0	20	19	-	111	103	-	0.2	0.2	-	0.7	0.2	-
R_1	13	15	11	29	29	18	6.1	6.5	2.8	10	7.9	2.9	1.7	1.4	1.0	110	114	74	0	0	0	19	15	4	10	6.2	1.5	0.2	0.1	0.1	0.2	0.2	0.0
B_1	9.5	13	11	29	22	17	5.0	5.8	3.3	8.4	11	9.6	3.3	3.4	2.0	60	82	16	0	0	0	49	21	54	13	12	8.5	0.2	0.1	0.1	1.0	0.6	0.0

Table 4. Composition of Drinking Water in Different Seasons and Locations Thailand 1966–1967

Number	CHEMICAL COMPONENT (Part per Million)																														
	Al			Cu			Pb			Zn			Sr			Ba			Li			B			Fe			Mn			P as PO_4		
	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	S	R
V_4	0.1	0.0	-	0.02	0.0	-	0.00	0.00	-	0.14	0.33	-	0.00	0.00	-	0.00	0.00	-	0.00		-	0.00	0.00	-	1.2	0.34	-	0.05	0.00	-	0.09	0.01	-
V_{11}	0.4	0.1	0.0	0.02	0.0	0.00	0.00	0.00	0.0	0.08	0.02	0.00	0.00	0.03	0.02	0.00	0.00	0.07	0.01	-	0.00	0.00	0.00	0.00	0.93	0.36	0.66	0.01	0.06	0.00	0.28	0.00	0.08
V_{25}	0.0	0.0	0.0	0.02	0.0	0.04	0.00	0.00	0.004	0.30	0.22	0.08	0.00	0.00	0.01	0.00	0.00	0.06	0.00	-	0.00	0.00	0.00	0.00	0.78	0.00	1.6	0.01	0.01	0.06	0.00	0.00	0.05
V_{15}	0.0	0.1	0.0	0.00	0.05	0.02	0.00	0.00	0.0	0.12	0.15	0.10	0.00	0.03	0.01	0.00	0.00	0.06	0.00	-	0.00	0.00	0.00	0.00	0.49	0.22	0.55	0.11	0.08	0.00	0.16	0.02	0.01
V_{26}	0.1	-	-	0.01	-	-	0.00	-	-	0.12	-	-	0.01	-	-	0.00	-	-	0.01	-	-	0.00	-	-	0.80	-	-	0.06	-	-	0.11	-	-
C_2	0.3	0.3	0.0	0.03	0.03	0.08	0.00	0.00	0.011	0.08	0.05	0.03	0.02	0.07	0.01	0.00	0.00	0.07	0.00	-	0.01	0.00	0.00	0.23	0.14	0.08	0.10	0.28	0.15	0.10	0.00	0.00	0.04
P_3	0.1	0.0	-	0.01	0.05	-	0.00	0.00	-	0.23	0.13	-	0.08	0.17	-	0.00	0.00	-	0.01	-	-	0.01	0.00	-	0.42	0.30	-	0.14	0.04	-	0.00	0.01	-
S_3	0.1	0.0	-	0.02	0.02	-	0.00	0.00	-	0.10	0.40	-	0.06	0.15	-	0.04	0.00	-	0.01	-	-	0.07	0.07	-	1.40	1.9	-	0.50	0.20	-	0.31	0.03	-
R_1	0.4	0.9	0.1	0.02	0.03	0.02	0.00	0.00	0.0	0.26	0.02	0.00	0.10	0.19	0.07	0.00	0.00	0.07	0.02	-	0.00	0.02	0.00	0.00	0.94	1.7	2.8	0.00	0.02	0.10	0.09	0.00	0.04
B_1	0.4	0.1	0	0.02	0.03	0.00	0.00	0.00	0.0	2.3	0.60	0.82	0.11	0.14	0.07	0.00	0.00	0.07	0.00	-	0.01	0.01	0.00	0.00	0.19	0.28	0.41	0.00	0.02	0.01	0.09	0.03	0.05