DRINKING WATER QUALITY OF SOME WELLS IN THE INTENSIVE VEGETABLE GROWING AREAS IN THE UPCOUNTRY INTERMEDIATE ZONE

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ABSTRACT

An investigation was conducted to study the extent of drinking water contamination by plant nutrients due to fertilizer and manure use in the intensive vegetable growing areas in the upcountry intermediate zone. Monthly water samples were analysed from 20 wells for a period of 12 consecutive months commencing February 1995. They were analysed for pH, EC, Na, K, Ca, Mg, P and NO_3-N. The pH values in the drinking water were between 6.3 - 7.4 (mean 6.5). These pH values agreed with recommended pH range of 6.5 - 9.0 for drinking water standards. However, a majority of the wells had pH below 7. The electrical conductivity of water was low and it ranged from 0.09 to 0.36 dS/m (mean 0.2 dS/ m). This indicates that the drinking water in the upcountry intermediate zone contain low quantities of salts. In general, the sodium content in well water was high and it ranged between 4.0 - 38.1 mg/ l (mean 13.2 mg/ l). An appreciable amount of potassium was found and its range was between 1.4 - 11.5 mg/ l (mean 4.0 mg/ l). These values were higher than the K values reported even in some irrigation waters in some parts of the country. The calcium content in well water ranged from 0.1 to 5.6 mg/ l (mean 2.8 mg/ l). Generally, the magnesium contents were high and ranged from 2.5 to 10.9 mg/ l (mean 6.5 mg/ l). Phosphorus was extremely low and the phosphorus values reported in this region were less than the maximum P values of 0.65 mg/ l recommended by the National Water Supply and Drainage Board of Sri Lanka. In general, the nitrate contents were lower than the permissible level of 11.3 mg/ l NO_3-N stipulated by WHO for drinking water. The lowest and the highest NO_3-N levels were 0.44 and 2.23 mg/ l (mean 1.15 mg/ l) respectively. Results of this study indicates that there is an appreciable amount of some plant nutrients in the drinking water in the upcountry intermediate zone of Sri Lanka where intensive agriculture is being carried out.

KEY WORDS: Drinking water quality, Intensive vegetable growing areas, Plant nutrients, Upcountry intermediate zone.

INTRODUCTION

The up country intermediate zone of Sri Lanka refers to the region which lies between 600 - 1400 m above mean sea level. The topography comprises of steeply dissected hills with rolling terrain. The mean air temperature ranges from 15 to 27°C, while the average annual rainfall varies from 1100 to 1400 mm. The soils are mainly Ultisols (Panabokke, 1967) with a pH range of 4.0-5.5 (Wijewardena *et al.*,1996). Therefore, the climate and other environmental factors in the region are ideally suitable for year-round cultivation of high quality, high priced vegetables. With intensive potato cultivation in the upcountry, the cropping intensity within the available lands for agriculture had increased by 250-300 per cent.

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The food crops cultivated in these areas include rice, potato and vegetables. Tomato, cabbage, bean, radish, brinjal and capsicum are the main vegetable crops which represents a major part of the cropping sequence. Unlike the general pattern of low fertilizer used in Sri Lanka, many farmers in this region use large quantities of poultry manure together with high rates of chemical fertilizers (Wijewardena, 1993, 1995, 1997a, 1997b). This has resulted in the accumulation of high quantities of many plant nutrients in the soil of this region (Wijewardena, 1996a; Wijewardena *et al.*, 1996). In addition, inappropriate fertilizer management practices are also prevalent among the upcountry farmers. Due to the hilly nature and high rainfall in the area, applied fertilizer could easily get washed out resulting in pollution of drinking water with many plant nutrients.

Most of the wells in the upcountry intermediate zone are situated in the vegetable growing lands. Potato and vegetables are grown in these lands under rainfed conditions with supplementary irrigation. Consequently, there is a tendency to use more water for crops than necessary. Many of these wells are not properly protected with cement walls. Therefore, water in these wells could easily be polluted even by the run-off water.

Agriculture is often accused of being one of the main factors responsible for pollution of drinking water. Mobile components such as nitrate and other anions as well as potassium and other univalent cations may leach out to the ground water. This affects the quality of drinking water sources (Cooper *et al.*, 1984). Nagarajah *et al.* (1988) and Kuruppuarachchi (1995) previously reported that well water is polluted due to agricultural activities in Jaffna and North-Western province, respectively.

Nitrogen fertilizer use has been shown to strongly affect NO_3-N concentrations in ground water by Baker and Johnson (1981). Similarly, Hargert (1986) reported that fertilization and irrigation contribute to higher NO_3 -N leaching particularly in sandy soils. There are reports that Nitrate levels in groundwater increased following the intensive use of animal waste and fertilizers (Ballance and Olsen, 1980; Gervy, 1986). Similarly, many plant nutrients could be leached to drinking water due to high cropping intensity and regular fertilizer application are practiced in high intensive vegetable growing areas. Though, P is the nutrient most restricted to leaching through the soil there are some evidence that even P could be leached in to ground water in different fractions (Anderson *et al.*, 1974). This indicates that application of animal manure, crop residues and chemical fertilizers and also the over irrigation practiced by farmers in the up country intermediate zone could lead to pollution of drinking water by various plant nutrients.

However, monitoring of well-waters has not been undertaken in the upcountry intermediate zone where intensive vegetable cultivation is common. A study was therefore, carried out and water samples from 20 selected wells in the upcountry intermediate zone were analysed to determine some important chemical components. This paper discusses the results of this study during a period of 12 months from February 1995 to January 1996.

MATERIALS AND METHODS

Water samples were collected monthly from 20 wells selected randomly in the intensive vegetable growing lands in the upcountry intermediate zone commencing February 1995 over a period of 12 consecutive months. The sampling sites are shown in Table 1.

Table 1. Sampling sites.

Well no	Location	DS division
1	Kahagolla	Bandarawela
2	Kumbalwela	Ella
3	Kumbalwela	Ella
4	Demodera	Ella
5	Baddewela	Ella
6	Haputalegama	Haputale
7	Haputalegama	Haputale
8	Haputalegama	Haputale
9	Walgahawela	Haputale
10	Bogahakumbura	Welimada
11	Erabadda	Welimada
12	Idama	Lunuwatta
13	Idama	Lunuwatta
14	Mudanawa	Lunuwatta
15	Mudanawa	Lunuwatta
16	Ganetenna	Lunuwatta
17	Gabadagama	Lunuwatta
18	Kumarapattiya	Lunuwatta
19	Mirahawatte	Welimada
20	Ellathota	Bandarawela

DS Division – Divisional Secretariat Division

Water samples were collected between 0 - 30 cm depth from the water surface using a plastic bucket. Each sample was poured into a 500 ml polythene bottle (previously washed with chromic acid followed by distilled water) after rinsing it 2-3 times with the same water and covered with the lid. The samples were then transported to the laboratory at the Regional Agricultural Research and Development Centre, Bandarawela, for chemical analysis. As soon as the samples reached the laboratory, water was filtered using Whatman filter paper No.5 and the filtrate was used for analysis. In the case of water samples needed to be stored for long periods, a few drops of chloroform were added to prevent any algal growth and then stored in the refrigerator.

Immediately, pH measurements were taken using pH meter model Fisher Scientific Model 5 with a glass electrode and electrical conductivity using a conductivity meter model YSI-32. Nitrate was determined colorimetrically using a spectrophotometer model Spectronic-21 by the Brucine method (Taras, 1958). Phosphorous was also ascertained colorimetrically by the molybdenum blue method using ascorbic acid (Watanabe and Olsen, 1965). Sodium and potassium were determined using a Jenway Flame Photometer model PFP-7 while calcium and magnesium were determined by a GBC Atomic Absorption Spectrophotometer,

RESULTS AND DISCUSSION

The analysis of the water samples from 20 wells are given in Table 2.

pH

The mean pH value of drinking water in the upcountry intermediate zone was 6.5. The lowest and highest pH values recorded were 6.3 and 7.3 respectively. In general, Ultisol which is the main soil group in the upcountry intermediate zone is acidic and pH ranges between 4 - 5.5 (Wijewardena, 1996a; Wijewardena *et al.*, 1996). According to Lehr *et al.* (1994) normal pH range for drinking water standards in USA is from 6.5 to 8.5. Similarly, Ayers and Westcot (1985) reported the same range of pH values for irrigation water too. The National Water Supply and Drainage Board of Sri Lanka in 1983 recommended the pH range between 6.5 - 9.0 as a suitable range for drinking water in Sri Lanka. In addition high rainfall in the area also may be the reason for the low pH in the drinking water. Amarasiri (1965) observed that a close relationship exists between pH of irrigation water and the degree of rainfall. This may be the reason for high pH of water with pH values over 7 (Amarasiri, 1973) in irrigation tanks which are situated in the dry zone of Sri Lanka. Similarly, Nagarajah *et al.* (1988) and Kuruppuarachchi (1995) reported high pH values in well waters in Jaffna and North-Western province respectively.

Electrical Conductivity (EC)

Salt concentration in water is indicated by the electrical conductivity. Based on the standards developed by Nagarajah *et al.* (1988) the water of majority of wells sampled in the upcountry intermediate zone could be categorized as low salinity water having range between 0 and 0.25 dS/ m (Table 2). However, there were a few number of wells which had water with medium salinity that ranged between 0.25 - 0.75 dS/ m. Overall, the water of 70% and 30% of the wells sampled in the upcountry intermediate zone had low and medium salinity levels respectively. Low salinity of the drinking water in majority of wells could be attributed to the low salt concentration in the soil and the low infiltration rates of the Ultisols. However, electrical conductivity values in the upcountry intermediate zone well water (mean 0.20 dS/ m) were very much less compared to values reported in Jaffna (Nagarajah *et al.*, 1988) and North-Western province (Kuruppuarachchi, 1995).

Sodium

Sodium content of drinking waters in the upcountry intermediate zone ranged from 4.0 to 38.1 mg/ l (mean 13.2 mg/ l). In general, the drinking water in the region contained high levels of Na (Table 2). The Na values reported by Amarasiri (1965, 1973) and Nagarajah *et al.* (1988) in irrigation waters were much lower than these values.

Table 2. Water analysis of selected wells in the upcountry intermediate zone (Average of 12 monthly samples).

Well No.	pH	EC	N	K	Ca	Mg	P	NO_3-N
	dS/m ←				mg/l →			
1	6.7	0.1	4	2.6	0.1	3.4	0.035	0.44
2	7.4	0.27	23.2	3.3	3.7	10.7	0.026	0.68
3	6.7	0.12	8.8	1.4	1.6	4.7	0.018	1.08
4	7.3	0.32	19.9	3.4	4.3	8.4	0.016	1.81
5	6.8	0.16	7.8	2.1	1.7	2.7	0.025	0.91
6	6.6	0.2	22.6	6.1	2.2	5.5	0.012	2.01
7	6.6	0.16	7.7	3.0	2.4	5.2	0.054	1.45
8	6.5	0.28	30.8	6.1	2.9	9.8	0.025	1.85
9	6.3	0.14	8.0	4.4	1.8	3.3	0.017	1.25
10	7.1	0.24	7.5	2.9	2.9	10.1	0.143	0.62
11	6.6	0.17	6.6	4.0	2.6	7.2	0.042	0.74
12	6.7	0.363	8.1	11.5	4.1	10.9	0.122	1.22
13	6.5	0.25	8.9	2.7	3.9	7.7	0.021	1.90
14	6.5	0.16	7.0	3.1	2.8	5.4	0.032	2.23
15	6.3	0.09	5.7	2.5	1.5	2.5	0.039	1.43
16	6.7	0.19	8.6	5.2	2.7	6.8	0.021	1.14
17	6.9	0.23	15.3	5.9	3.8	6.7	0.014	0.50
18	7.3	0.35	17.9	1.7	5.6	8.7	0.141	0.50
19	6.8	0.16	7.5	5.6	2.7	5.2	0.013	0.59
20	7.0	0.13	7.8	3.3	2.0	4.9	0.053	0.70
Mean	6.8	0.2	13.2	4.0	2.8	6.5	0.043	1.15

Potassium

Potassium content in the drinking water in the upcountry intermediate zone ranged from 1.4 to 11.5 mg/ l (mean 4.0 mg/ l). One well (No.12) had a value of 11.5 mg/ l (Table 2). High values of potassium in drinking water in this area could be attributed to high level of potassium fertilizer used for the crops grown in this region. In general, farmers in the upcountry use high rates of chemical and organic fertilizers for potato and vegetables (Wijewardena, 1996 a). The level of fertilizer applied by the farmers to the vegetable crops is almost two to three times the quantity recommended by the Department of Agriculture (Rezania, *et al.*, 1989; Wijewardena and Amarasiri, 1997). This normally results in high level of potassium accumulation in the soil. (Wijewardena *et al.*, 1996). In addition, Ultisols which are the main soil group in this region are high in potassium (Wijewardena and Amarasiri, 1993,1997; Wijewardena, 1996 b).

Long-term field experiment conducted by Wijewardena (1993) revealed the accumulation of exchangeable potassium by affecting 10 t/ha poultry manure in Ultisols. In general, farmers in this region use poultry manure in combination with high levels of chemical fertilizers. Hence, these practices could also be attributed to the high potassium content in the drinking water in this region.

In some cases potassium levels in well water reported by Nagarajah *et al.* (1988) were higher than potassium values found in this study. However, potassium values reported in North-Western province well-water were much lower (Kuruppuarachchi, 1995) than well-water in the upcountry intermediate zone.

Calcium

Calcium content in the upcountry intermediate zone well-waters ranged from 0.1 to 5.6 mg/ l (mean 2.8 mg/ l). An appreciable amount of calcium in drinking water (Table 2) may be due to use of lime and dolomite in the upcountry farming. The application of lime and dolomite for potato and vegetable cultivation is a common practice in this region (Rezania *et al.,* 1989; Wijewardena, 1996a). In addition, the use of poultry manure is also common among the farmers in this region. Generally, poultry manure contains large amount of calcium as 2.9% (Wijewardena, 1994). Experiments conducted by Wijewardena (1994) showed that drainage water from pots treated with poultry manure had high calcium compared to that from untreated pots. Therefore, applied poultry manure for crops grown in this region could also be a reason for the high content of calcium in drinking water in this region. Further, long-term experiments conducted by Wijewardena (1993) and Wijewardena and Yapa (1996) revealed soil pH increase with application of poultry manure which contains high calcium levels. The calcium values reported by Nagarajah *et al.* (1988) and Navaratne and Susantha (1996) in Jaffna well water and in Gampaha irrigation waters respectively, were much higher than the calcium values reported in this study.

Magnesium

Magnesium content in the upcountry intermediate zone well water ranged 2.5 - 10.9 mg/ l (mean 6.5 mg/ l). This may be attributed to the use of high rate of organic manures such as poultry and cattle manure. This could have been also due to the high leaching of Mg in acid soils (Mikkelsen *et al.*, 1963). Use of dolomite for crops grown in this region is a common practice. Also, dolomite is used in large quantities in this area for plantation crops like tea may have been washed down to the drinking water in this region.

High rainfall and soil acidity together with low cation exchange capacity increases the mobility of magnesium and cause heavy losses by leaching (Hobt and Kemmler, 1986). Similar conditions prevailing in the upcountry may have aggravated the high magnesium content in the well water as found in this study.

Phosphorus

Phosphorus content in the drinking water in the upcountry ranged from 0.012 to 0.143 mg/ l (mean 0.043 mg/ l)). In general, phosphorus in the drinking water was extremely low with the exception of 3 wells (No. 10, 12 and 18) in all other wells had P below 0.1 mg/l (Table 2). Amarasiri (1965) and Nagarajah *et al.* (1988) reported very low levels of P even in rice irrigation and Jaffna well water respectively (<0.05 mg/ l). Phosphorus levels in drinking water in the upcountry intermediate zone were less than the maximum P value (0.65 mg/l) in drinking water accepted by the National Water Supply and Drainage Board of Sri Lanka (1983). Low P in water could be expected because of the movement of any soluble P to ground water is restricted due to ready P fixation by soil minerals. Low pH of the Ultisols would have encouraged the fixation of P in this soil. It is well known that P fixation is high in acid soils. In fact Vighi *et al.* (1991) reported that phosphorus losses are independent of fertilizer P application rate; even in intensive cropping systems. Many workers previously reported that in the absence of erosion little P could reach the surface water (Loher, 1974; Dillon and Kirchner, 1975; Miller *et al.*, 1982; Heise, 1984). Wijewardena (1994) reported of extremely low P leaching even in soils fertilized with organic manure and phosphorus fertilizers. Therefore, low P was also found in the well-water in the upcountry.

Nitrate

Nitrate content in the drinking water in the upcountry intermediate zone ranged from 0.44 to 2.23 mg/l NO_3-N (mean 1.15 mg/ l). The WHO recommended the following standards for drinking water in Europe (Olsen, 1978).

0.0 -11.3 mg/l NO_3-N- Recommended

11.3 -22.6 mg/l NO_3-N- Acceptable

> 22.6 mg/l NO_3-N- Not recommended

According to USA, Environmental Protection Agency (EPA) primary drinking water standards, a permissible level of NO_3-N has been established for drinking water no more than 10 mg/l (Jervy, 1986; Lehr *et al.*, 1994). According to the standards established for drinking water by the National Water Supply and Drainage Board of Sri Lanka (1983) maximum NO_3-N level was also 10 mg/l.

Nitrate which is considered as the most important plant nutrient could influence human health (Russell, 1978; Nagarajah *et al.*, 1988) and in particular the health of babies up to about four months of age. Babies may be unable to detoxify NO_2 which combines with hemoglobin and reduces the absorption of oxygen into the blood resulting in a clinical condition called "methaemoglobinaemia". In general infants suffering from this condition are sometimes referred to as "blue babies". In addition, a high NO_3 intake is undesirable for adults because some of the NO_2 produced may be converted to nitrosamines causing gastric cancer and diarrhea (Hill *et al.*, 1973). However, results of this experiment suggest the low nitrate pollution of the drinking water in the upcountry intermediate zone. In contrast, nitrogen fertilizer use has been shown to strongly affect NO_3 concentrations in drainage water (Baker and Johnson, 1981; Wijewardena, 1994) and well waters. (Nagarajah *et al.*, 1988). However low NO_3 in the drinking waters in the upcountry intermediate zone may be attributed to heavy textural fraction in Ultisols. This may have restricted the leaching of nitrate to the drinking water. Gamberell *et al.* (1975) reported that losses of nitrate to ground water were regulated by the amount of infiltration occurring in the soil, being high for a moderately well-drained soil and low for a poorly drained soil. In addition, crops grown in the upcountry such as cabbage, tomato, potato, etc., have been considered as high nutrient removers (FAO, 1984). Therefore, nitrate leaching would have been controlled by the high removal of nitrogen (Wijewardena, 1997c) from the cultivated fields in this region. On the other hand, it is also relevant to note that throughout this study period this area had unusually low rainfall as in the rest of the country. Hence, low rainfall may have restricted the leaching of nitrates as well as other nutrients to the drinking water. Overall, the results suggest that it is important to monitor the quality of water over a long period to cover even heavy and average rainfall periods in this region.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. R. Seneviratne and Mr. A. A. Yasawardena for their support in calcium and magnesium analysis at HORDI, Gannoruwa, Peradeniya and Mrs. P.H. Sumanawathie for her excellent job in typing.

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