6.3 CHRONIC RENAL FAILURE IN MEDAWACHCHIYA – PADAVIYA AREAS OF ANURADHAPURA DISTRICT A GEO-ENVIRONMENTAL STUDY

Chronic renal failure in the Medawachchiya - Padaviya areas of Anuradhapura District

A geo-environmental study

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EXECUTIVE SUMMERY

During the last two decades alarmingly high incidences of kidney failure and associated deaths have become very significant in certain parts of the Anuradhapura District. A Proposal prepared by a team of scientists from the University of Peradeniya and the National Water Supply and Drainage Board for studying the problem closely was accepted by the Research committee of the Notational Water Supply and Drainage Board which provided the necessary funding. This resulted in commencement of the present research project "Chronic *Renal Failure in the Medawacchiya-padaviya areas-A geo-environmental study*" at the Faculty of Science, University of Peradeniya. Extensive studies were carried out in the Padaviya and Medawachchiya areas of the Anuradhapura district where the renal failure problem was recorded with a high degree of prevalence. The main objective of the project was to determine the geo-environmental causative factors of the CRF problem and to propose remedial action to alleviate this problem.

A large number of environmental factors of the affected areas were examined, consisting of Water quality, Water use practices, Agrochemical use, Geo-hydrology of the area, Biochemical status of water sources, Social health and Economic status of the affected communities etc. In addition, a limited number of human blood, kidney and bone samples were also subjected to analysis.

The study revealed that the occurrence of CRF in the north-central province can be attributed to geo-environmental factors of the region and not due to a prevalence of other health conditions such as hypertension and diabetes. It has a direct relationship to the presence of high fluoride in drinking water. This investigation established the fact that leaching of aluminum is enhanced in the presence of excessive fluoride and in the presence of acidic conditions. Formation of Alumino-fluoro complexes which can penetrate the blood brain barrier is the major reason for the synergistic enhancement of the toxicity of these two elements when present together. This type of leaching is increased by a factor of 4 for inferior quality aluminum pots and pans used for cooking in the affected areas. The presence of lead in these pots has been confirmed and leaching of lead is also shown especially under the typical acidic conditions used in cooking.

Since there is a direct correlation between CRF and the presence of high fluoride in drinking water, regular monitoring of all drinking water sources for fluoride is an urgent necessity and use of fluoride filters should be encouraged in such areas. Use of poor quality cooking pots and pans should be avoided and SLS certification about the quality of such utensils should be made compulsory Cooking with acidic spices such as tamarind, lime juice and tomato in aluminum pots should be avoided and the use of a fluoride filter is highly recommended.

CHRONIC RENAL FAILURE IN THE MEDAWACCHIYA - PADAVIYA AREAS
A GEO-ENVIRONMENTAL STUDY

1.0 BACKGROUND

During the last two decades alarmingly high incidences of kidney failure and some associated deaths have become very significant in certain parts of the Anuradhapura District. In the Padaviya AGA division alone, 184 such cases and 22 deaths due to the same reason have been reported since January 1999. During the same period and for the whole Anuradhapura district, the number of incidences was 4095 while the number of deaths was 577. (Provincial Ministry of Health, North Central Province)

Although chronic renal failure is commonly associated with high blood pressure, diabetes, alcoholism etc., the present problem in the Anuradhapura district has not shown any noticeable relation to any of those. Therefore, it was quite likely that CRF in the north-central province could be due to be the result of the intake of some toxic and detrimental constituents in the drinking water (or food). There are a number of such elements and constituents that can be present in the water and prolong exposure to these in drinking water may result in damage to the kidney.

Anuradhapura district being a part of the dry zone of the country, the vast majority of (rural) population depend both on groundwater and surface water sources such as dug wells, hand pump-tube wells, irrigation tanks and channels etc. for their domestic water supplies.

Water pollution is a serious environmental problem faced by people not only in Sri Lanka but also in the entire world. Increase in human population, increased pesticide use and fertilizers have all contributed to this situation. Outbursts of algal blooms occurring in the north-central and north-western provinces are a common feature and the algal toxins produced by some of these algae; hepatotoxins, endotoxins and neurotoxins are extremely toxic.

Another potential hazard highlighted was the heavy use of pesticides in this region which is primarily an agricultural area. These are accumulative poisons and the health effects will manifest only after prolonged exposure. Shallow water sources including tank water are likely to be contaminated. The possibility of pesticide residues finding their way into the underground water table is also likely and this can contaminate dug well as well as tube well waters.

The other major possibility is the geological composition of the underlying rocks and soil. It is possible and it has been reported in certain instances too, that there are toxic elements such as cadmium, arsenic and fluoride in ground water and the presence of arsenic is a major health hazard reported from Bangladesh where people rely heavily on ground water mainly from shallow tube wells.

In view of the above facts, this collaborative research study was carried out by a team of researchers from the Peradeniya University and the National water Supply and Drainage Board since March 2003, with the aim of determining causative factors and finding remedial actions to minimize/stop the exposure of rural communities to those. The Research Project was funded by the Research Committee of the National Water Supply and Drainage Board.

2.0 INTRODUCTION

Chronic renal failure (CRF) affecting the north-central province results in the premature deaths of otherwise healthy people. People affected are mostly farmers who live in rural areas of the district. Once detected there is no curing other than a transplant which too is not an ideal cure? Admission of patients to the Anuradhapura hospital with CRF which was 13% of all cases increased gradually to 23% in 2003. Recognizing the gravity of this situation, a meeting was convened in February 2003 convening all concerned and the future strategy to combat this deadly disease was discussed. As a consequence of this, the Water Board granted funds to the Investigators to carry out the research required to establish the geo-environmental reasons for the occurrence of CRF.

While in most countries CRF is generally attributed to hypertension and diabetes, there is no association of CRF in the north-central province to any of these conditions. While Balkan Endemic Nephropathy has received intense international attention and the causative agents have been identified as toxic organic compounds leached from Pliocene lignite, Endemic Nephropathy in this part of the world has received little or no attention. Some of the medical and epidemiological features of this type of nephropathy are quite similar to Balkan endemic nephropathy such as; incubation period with a rapid onset of end-stage renal disease, at least 15-25 years of residence in an endemic village, occurrence mostly in adults in the age group of 30-45 years while no children or individuals above 65 years develop the disease and no association with hypertension or diabetes. Although originally it was thought to affect only males, most of them farmers, subsequent studies show no such gender preference.

3.0 OBJECTIVES

The objectives of the research project were:

- To demarcate the problematic areas and to determine the geographic distribution of the problem
- To ascertain the domestic water use practices of the affected communities
- To determine the geo-environmental causative factors of the CRF problem
- To propose remedial action to minimize the problem

4.0 GEOGRAPHICAL DISTRIBUTION OF CRF IN THE ANURADHAPURA DISTRICT

A considerably large number of patients of renal failure have been admitted to the Anuradhapura hospital over the last few years. The actual number of patients can be much higher than this amount because many patients tend to get admitted into the central hospitals in Kandy, Kurunegala and Colombo and therefore are not registered at the Anuradhapura hospital. Table 1 gives the geographic distribution of patients from the different areas of the Anuradhapura district admitted to the Anuradhapura base hospital in 2001.

Table 1 The Geographic Distribution of Renal Failure Patients Admitted to the Anuradhapura Base Hospital in 2001.

Area	Number of patients	Percentage of the total
Medawachchiya	53	17
Kahatagasdigiliya	19	6
Padaviya	16	5
Galendindinuwewa	14	5
Nochchiyagama	12	4
Tirappane	12	4
Mihintale	12	4
Talawa	11	4
Kebitigollawa	9	3
Rajanganaya	9	3
Horwopathana	9	3
Kekirawa	4	1

While some areas such as Medawachchiya are more affected than the others there is hardly any area in this district without the occurrence of CRF. More recently, CRF patients have been detected from other dry zone areas such as Mahaweli System C, Giradurukotte and Trincomalee.

5.0 STUDY OF THE GEO-ENVIRONMENTAL FACTORS

While the etiology of the chronic renal failure in the Medawachchiya - Padaviya areas still remains a mystery some results on the geo-environmental factors of the region reveal some significant findings. Several possible factors were investigated.

1. The water used by people is contaminated with some toxic agents such as pesticides and also possible contamination of the body during spraying of pesticides which is commonly practiced by the people affected.
2. Genetic and other geological factors such as heavy metals.

5.1 Results of pesticide analysis

There is widespread use of pesticides in these agricultural communities. Occupational hygiene practices are quite unsatisfactory and contamination of the human body with pesticides through the skin is a common occurrence. There is also the potential for drinking water contamination through agricultural runoffs. Pesticides are accumulative poisons and the common adverse health effects include chronic pulmonary diseases and bronchitis while there are only a few reports on the effects of pesticides on kidneys. Exposure to low levels of pesticides over a long period of time may result in damage to renal tubules. Due to these reasons, pesticide monitoring was also undertaken with a number of representative drinking water samples from this area. The representative samples were analyzed for the presence of pesticides at the Agriculture Department's laboratory (Pesticide Registrar's division) and the results are given in table

2. The water samples were collected in glass bottles and immediately extracted with dichloromethane to extract the pesticides. These extracts were then subject to high pressure liquid chromatography and quantitatively estimated for the presence of dimethoate and chloropyrifos and diazenon which are commonly used in this area.

Table 2 Pesticide Levels in Drinking Water Samples from Mahadivulwewa, Yakawewa and Padaviya Areas

Sample no.	Chloropyriphos/ppb	Dimethoate/ppb	Diazinone/ppb
BK1	ND	ND	ND
BK2	ND	ND	ND
BK3	ND	ND	ND
BK4	ND	ND	ND
GK1	ND	ND	ND
KD1	ND	ND	ND
KD2	0.535	ND	1.175
MC2	ND	ND	2.225
MH2	ND	ND	1.25
PD1	0.585	ND	ND
SK3	0.825	ND	2.06
TE2	0.875	ND	ND
UG2	0.690	ND	2.34

(ND=not detected)

These results showed that detectable levels of pesticides are present only in a very few instances and the commonest pesticide detected was diazenon. This is also difficult to explain since it is an organophosphate pesticide which normally degrades fairly rapidly in the environment. Similar observations have been made from studies conducted in the Polonnaruwa and Amparai areas (Personal communication, Dr. GK Manuweera, Registrar of Pesticides, Department of Agriculture). The levels of pesticides in these samples were well below the stipulated WHO water quality standards for pesticides. Field investigations further revealed that many of the dug /tube wells that have been used by the renal failure patients were situated well away from the paddy fields or other vegetable plots and therefore risk of contamination of water due to pesticides was almost absent.

5.2 Water quality examination

Samples of drinking water from the affected areas of the Anuradhapura district in the north-central Province were collected and subjected to routine water quality analysis. Parameters determined were; pH,EC,COD,BOD, nitrate, sulphate and fluoride. They were analysed by the standards methods and fluoride was determined using an ion-selective electrode.

Water samples were collected in cleaned plastic bottles and analyzed at the Department of Chemistry, University of Peradeniya. A large number of water samples were collected from a wide area in the affected region. The results of the chemical analysis are given in table 2. Since survey samples during the pilot study were found to show no abnormalities in these drinking water sources, some standard parameters such as EC, BOD, COD etc., were not carried out with the full set of samples.

Table 3 Some representative water analysis from the affected areas

Sample	Location no.	Type of well	pH	Fluoride/ppm	Al/ppb	EC .ms m^{-1}
1	AK.01	DW	8.0	0.84	71.6	620.24
2	AK.02	DW	7.6	1.01	57.3	238.55
3	AK.03	TW	8.6	1.59	60.1	954.21
4	BK.01	AW	8.2	0.79	91.7	583.01
5	BK.02	AW	8.4	0.98	45.9	757.91
6	BK.03	AW	8.6	1.50	63.0	505.27
7	BK.04	AW	8.4	4.13	<5.0	728.76
8	DW.01	DW	8.0	1.03	34.3	680.17
9	DW.02	DW	8.0	0.95	17.2	583.01
10	GK.01	AW	8.0	0.89	8.6	743.36
11	GK.02	TW	8.0	0.85	5.7	1049.44
12	GK.03	DW	8.0	0.58	14.3	402.29
13	KD.01	AW	8.4	0.81	<5.0	489.74
14	KD.02	AW	8.4	0.65	12.5	437.27
15	KD.03	DW	8.4	0.69	<5.0	437.27
16	MC.01	DW	8.0	0.55	<5.0	687.03
17	MC.02	AW	8.2	1.69	<5.0	801.54
18	MC.03	TW	8.0	1.61	<5.0	896.96
19	MD.01	TW	8.2	0.63	25.5	533.47
20	MD.02	DW	7.6	0.56	29.8	1486.71
21	MD.03	DW	7.8	0.53	19.2	1136.90
22	MD.04	TW	8.0	0.48	17.0	795.83
23	MH.01	DW	8.0	1.51	25.8	906.50
24	MH.02	AW	8.0	1.06	29.9	1908.42
25	PD.01	AW	8.0	0.96	<5	1263.18
26	PD.02	DW	7.8	0.15	14	971.68
27	PD.03	TW	8.2	0.44	8.7	699.61
28	SK.01	DW	8.8	1.09	61.7	884.23
29	SK.02	DW	8.4	0.95	31.9	631.59
30	SK.03	AW	8.0	0.96	12.8	971.68
31	TE.01	DW	8.2	0.35	<5	477.11
32	TE.02	AW	7.8	0.91	6.1	1049.63
33	TE.03	TW	8.4	1.08	<5	954.21
34	UG.01	TW	8.4	0.53	21.3	658.40
35	UG.02	AW	8.0	0.59	34.0	725.20
36	UG.03	DW	8.4	0.82	19.2	1049.63
37	YK.01	DW	8.0	0.87	6.4	689.89
38	YK.02	DW	8.2	2.25	10.6	757.91
39	YK.03	DW	8.0	0.96	21.3	1263.18
40	Nurse's ample			1.27		
41	Peradeniya	Tap water		0.26		

Note:

DW=Dugwell AW=Artesian well
Locations: AK=Atambagaskade, BK=Bellankadawala, GK=Gurukandegama, KD= Kodiyabandawewa, MC=Magichchawa, YK=Yakawewa, MD=Mahadivulwewa, MH= Minhettigama, PD=Puhudivula, SK=Siyambalagaskada, TE=Tammenna Elawaka

The results revealed that the water quality is quite good with all these samples except for fluoride. The range of fluoride concentrations observed was 0.15-4.13 with a median of 0.98 ppm.

Frequency Distribution of fluoride in the groundwater of the Padaviya area is shown in figure 1.

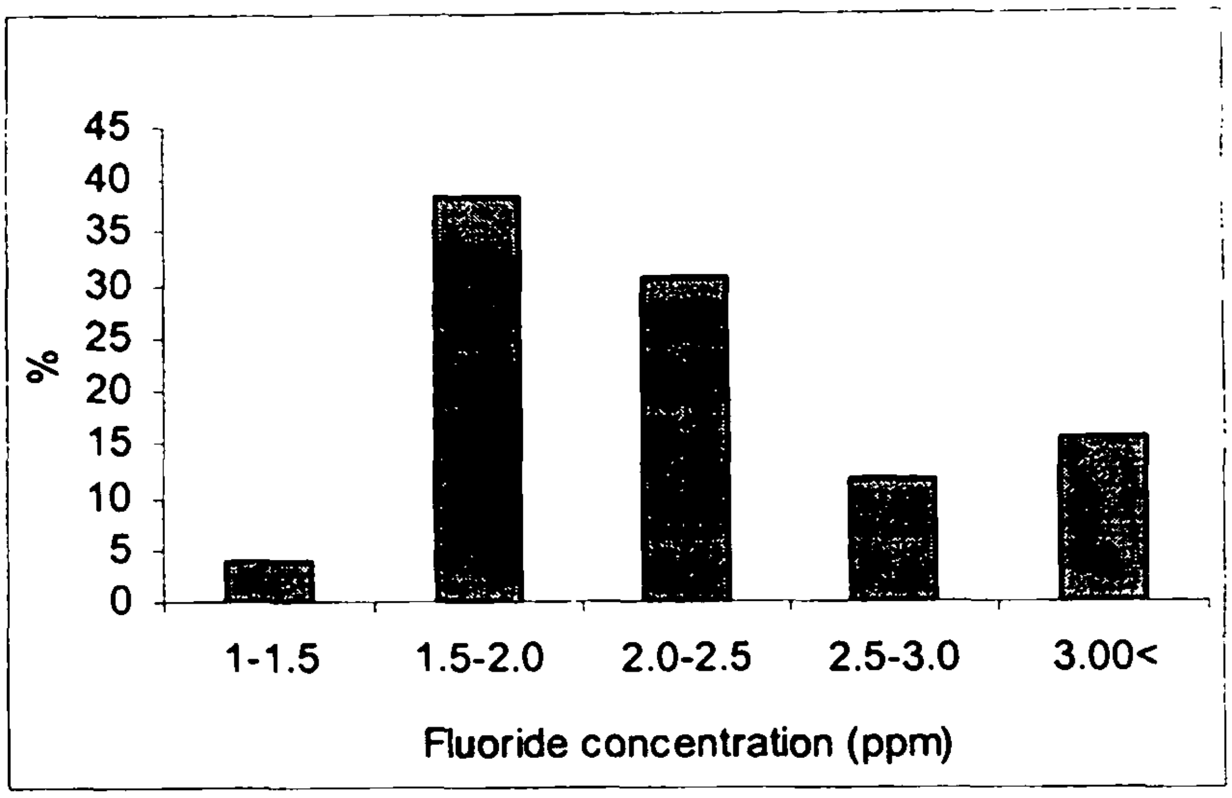


Figure 1 Frequency Distribution of Fluoride in the Groundwater of the Padaviya Area

Although the WHO standard for drinking water is 1 ppm fluoride, this assumes, *inter alia*, that the fluoride uptake per day is 1 mg. This may be a reasonable standard for temperate countries but in our opinion this is not a reasonable standard for tropical countries where people drink more water. A farmer working in the hot sun may drink about 5L of water a day which translates to an intake of around 5-10 mg of fluoride.

5.3 Other discoveries

A startling discovery made during these field studies was that people exclusively use aluminium utensils and that holes were observed in these utensils after continuous use (Figure 2). This was an observation made during visits to the homes of some of the people affected. This was an interesting finding in view of the world-wide scientific research carried out on the effects of aluminum as a causative factor for the Alzheimer's disease.

During the present survey at Maha-Divulwewa, Padaviya, the field observations showed that the water used by these people mostly come from dug wells and in certain cases from deep tube wells. Subsequent analysis of water samples collected from this area as shown above revealed that the water quality is quite satisfactory. The fluoride content was generally in the range of 1 to 2 ppm in most water sources but there were a large number of instances where the fluoride is present in higher concentrations sometimes as high as 4.00 ppm. Hence studies were undertaken to establish any relationship between *fluoride, aluminum utensils and chronic renal failure.*

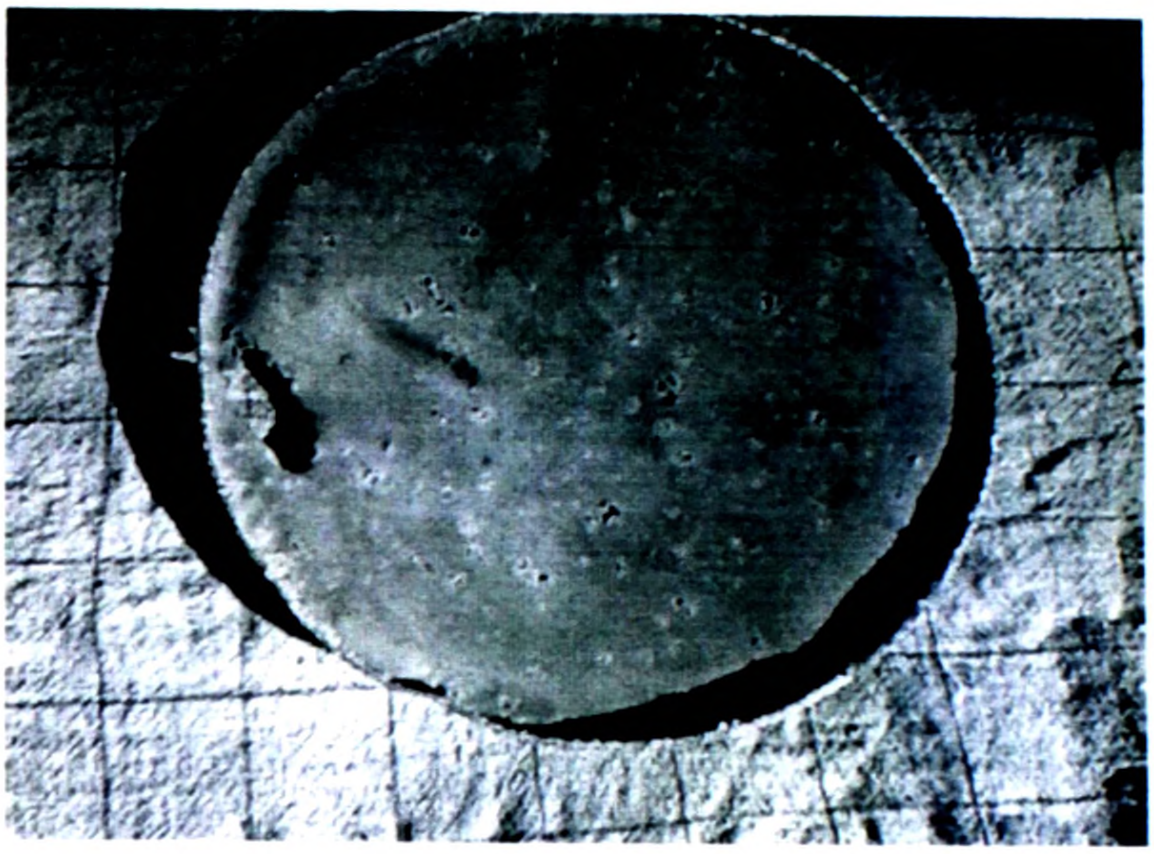


Figure 2 Development of holes in Cooking Utensils

6.0 DISTRIBUTION OF FLUORIDE AND ITS RELATIONSHIP TO CRF

As indicated above, one common feature evident from this study was the observation of a direct correlation between high fluoride content and occurrence of CRF. Almost all CRF cases reported are from high fluoride areas. The fluoride distribution map of the Anuradhapura district is given in figure 3.

Dug wells represents the commonest source of drinking water and the general distribution pattern given in table 2 shows that most wells have fluoride in the 1.0-2.0 region and over 90% of the wells had fluoride in excess of 1.00 ppm. Recently, WHO has lowered the fluoride standards for drinking water in tropical countries to 0.5 ppm on account the heavy uptake of water by people who work in the fields and even others due to warm weather. The occurrence of CRF in the Mahaweli areas was rather unexpected. However, a visit to the homes of affected people revealed that they are far away from canals fed by the Mahaweli and they use dug wells for drinking water. The underlying rock is particularly rich in fluoride and the drinking water had fluoride in the 2-3 ppm range. It is noteworthy to report that those who depend on water supply schemes from the main tanks of Anuradhapura which are fed by Mahaweli waters low in fluoride had a far less tendency to develop CRF. The same is true in Padaviya where the occurrences of CRF in the town where the wells are close to the Padaviya tank with low fluoride are less prone to CRF. However, the areas in Padaviya further away from the tank have extremely high fluoride in their well waters. The conclusion from these investigations leads to undisputable evidence that there is a direct link between high fluoride uptake and CRF.

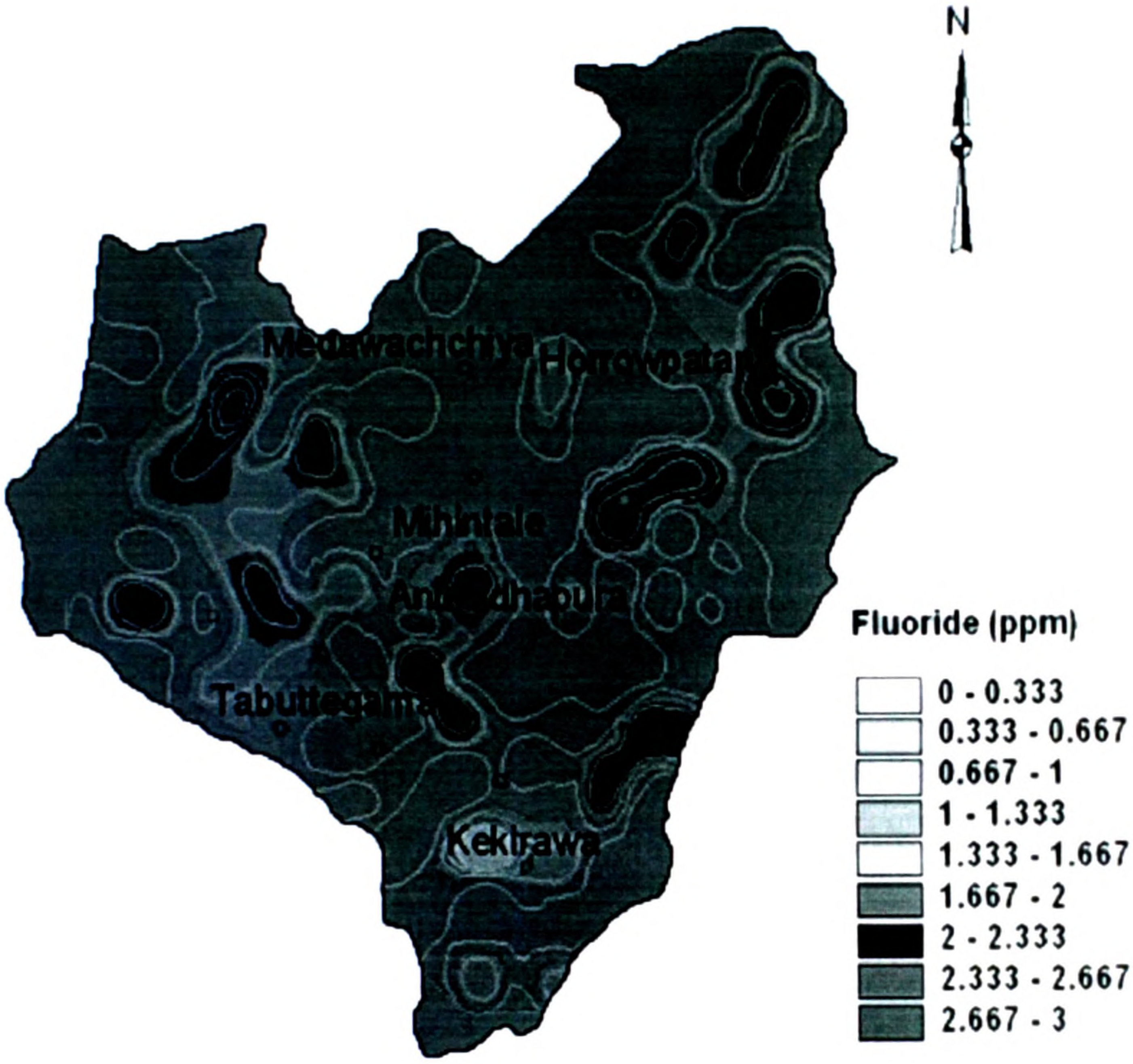


Figure 3 Fluoride Distribution in Groundwater of the Anuradhapura District

7.0 MEDICAL INVESTIGATIONS- ANALYSIS OF BLOOD AND KIDNEY SAMPLES

The investigators worked closely with the medical teams from the Peradeniya Medical Faculty (Dr. Nimmi Athuraliya and her team) and those from the Nephrology unit of the Kandy General hospital (Dr.Tilak Abeysekera and his team). During field visits to the affected areas entire villages were screened for proteinurea and the positive cases were then brought over to a school for kidney scans and other tests. Once it is fully established that the patients are suffering from CRF their homes were visited to collect water samples and to observe their life styles. While nephropathy is generally attributed to high blood pressure and hypertension, there is no evidence for these conditions amongst people screened. The results of such surveys in three villages where the investigators participated are given below.

Table 4 Distribution of patients suffering from CRF in selected villages

Village	Total population screened	Total number with proteinuria (%)	Males positive with proteinuria	Females positive with proteinuria	Farmers affected	Non-farmers affected
Mahadivulwewa	813	28	15	13	15	13
Yakawewa	1111	38	24	14	20	18
Puhudivulwewa	964	22	15	7	11	11
Thammena-Elawaka	435	63	33	30	35	28

It is seen from the table that the prevalence of CRF shows no gender bias although initially it was thought to be more prevalent among men. The majority of the villagers in these areas are farmers but the occurrence of CRF also shows no distinction between the farmers and non-farmers indicating that it is most likely not an occupational hazard caused by insecticide spraying.

During this investigation, aluminum levels in the blood of several affected persons who regularly attend the Medawachchiya clinic were determined using atomic absorption technique. These were compared with control samples of blood from people not affected by CRF. These preliminary results are given in table 5.

Table 5 Blood aluminium and lead concentrations

Patient's name	Age	Aluminium concentration/ppb	Lead concentration/ppb
Ansira	20	2777	
P.Nawarathna	30	1056	
SA Bandara	37	746	
K.Kapuri	48	951	
A,Dayarathna	50	7985	52
L.Punchibanda	50	958	46
MV Kiriappu	53	1160	46
UB Siriwardane	58	570	50
M.Kaluwa	70	3305	44

The high concentrations of aluminum observed is far in excess of the reference levels of aluminum found in the blood serum of a normal person which is 1000 ppb. Again, the blood aluminium levels may not represent the total body burden of aluminium since heavy metals get concentrated in the skeletal tissues. A sample of bone from a person who died of CRF was thus analysed for the aluminium and lead. The results confirmed our assertion that these two metals have a positive role as causative factors in CRF. These results are summarized in table 6.

Table 6 Heavy metal concentrations in the bones of an affected person against a control

Sample	Bone from a CRF affected person/ppm	Control (Bone from a non-affected person/ppm)
Al_2O_3	2265	1720
Pb	13.26	1.86
Zn	1022	466
As	53.01	15.47
Cd	2.47	1.29

Thus it is clearly seen that the heavy metal burden of the CRF affected people are far and significantly higher compared to the control. While the aluminium and

8.0 LEACHING OF LEAD AND ALUMNIUM UNDER DIFFERENT FLUORIDE STRESS

One striking geo-environmental factor in the general geographical area is the high fluoride content in drinking water sources. Most of the wells are of the dug well type with occasional tube wells also used to obtain water for drinking and cooking. The fluoride content is highly variable but most fall within the range of 1-4 ppm although in some isolated cases this reaches values as high as 7 ppm. Along with this, the shift to inferior quality aluminum pots for cooking is practiced by the population without exception. These cooking pots and pans are made from the re melting of scrap aluminum and used aluminum containing alloys (Figure 4) and hence likely to be contaminated with other heavy metals such as lead known to be a potent poison to kidneys.

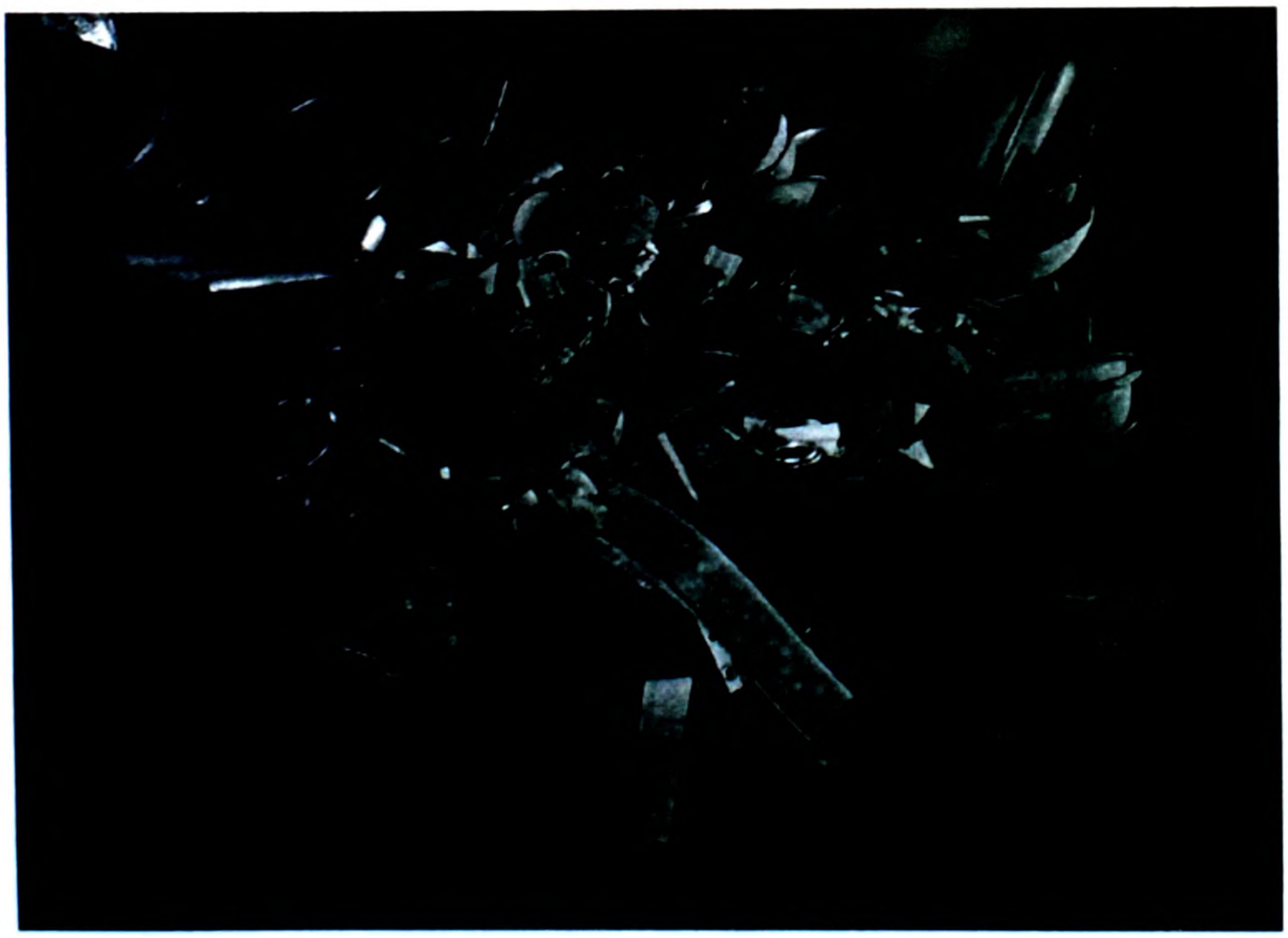


Figure 4 Items used in re melting and fabricating Aluminum cooking utensils

Such impurities present in the utensils could accelerate dissolution of the metal specially when subjected to the acidic conditions obtained during cooking. Furthermore these utensils are not anodized and hence likely to corrode more easily compared to pure aluminum. Aluminum and fluoride in combination exerts a profound influence on human health than when they are present alone. Cocktails of AlF_3 given at such low concentrations as 0.5 ppm were found to cause Alzheimer like symptoms in rats and their premature deaths have been attributed to kidney failure.

The harmful effects of fluoride on the kidney are well documented. There is association of 50-180 μM serum concentrations of fluoride with dose related clinical renal impairment. Fluoride at micromolar concentrations inhibits phosphate and this affects the endothelium of the affected arterioles and in glomeruli. The kidney appears to be the main target of fluoride toxicity affecting renal tissue and renal dysfunction. Some studies suggest that they are more pronounced in the proximal tubule than the glomeruli region.

The leaching of aluminum in fluoridated water is reported to result in Alzheimer like symptoms and chronic renal failure in rats. This has created a flurry of public activity where the merits and the demerits of fluoridating municipal water supplied have been debated. The effect of fluoride on the amount of aluminum dissolved by boiling fruit acids has been reported. The present study was prompted by the high incidence of acute renal failure in areas where these pots and pans are extensively used and the water has relatively high fluoride concentrations. The water in these areas typically exceeds the WHO standards for potable water quality. Chemical analysis of these kitchen utensils yielded relatively high lead concentrations in addition to other heavy metals such as nickel and copper. The objective of this study was to determine the role of fluoride in the leaching of aluminum from cooking utensils under the typical cooking conditions and to assess the intake of fluoride to the body through all possible ways.

Table 7 gives the results of the analysis of the impure aluminum material taken from a cooking pot and carried out at the Water analysis laboratory, Virginia state Health department, Charlotte Hill, Virginia, USA (sample 1). The method employed for analysis of sample 1 was inductively coupled plasma spectrometry.

Sample 2 was analyzed at the Suranaree Institute of Technology, Nakhon Rathashima, Thailand using graphite furnace atomic absorption spectrophotomtery. The wide disparity of the heavy metal concentrations is evident from the analytical data. This arises from the different raw materials used in the fabrication of impure aluminum pots and most of them are alloys with varying heavy metal concentrations.

In addition, lead is frequently employed to seal the holes of pots which are damaged due to continuous use. Lead based solder is employed for this purpose which results in an additional burden of lead into the body.

Table 7 Concentrations of Various Elements in Inferior Quality Aluminum Cooking Utensil from Padaviiya area

Element	Sample 1 (Concentration μg/g)	Sample 2 (Concentration μg/g)
Sb	48.1	0.10
As	72.5	500
Ba	<12.5	-
Be	<12.5	-
Cd	<2.50	-
Cr	70.1	13
Cu	11,695	19,900
Pb	8202	14,500
Hg	<0.10	-
Ni	587	1300
Se	<1.25	-
Ag	<1.25	
Tl	131	-
Zn	15,230	34,100

These inferior quality aluminum cooking utensils are fabricated by remelting of scrapped aluminum from various industries, particularly the engine heads of motor cars. Thus, it is not surprising to find a whole array of heavy metals in high concentrations. It is a cottage industry in some parts of Sri Lanka and mixed scrapped metal when employed for this purpose could give different compositions for different batches of products. However, we believe that the analysis shown above is typical and representative of the actual cooking utensils used in Sri Lanka. It is remarkable to see priority pollutants in such high concentrations particularly lead with a percentage of around 0.8% in the above analysis. A similar analysis carried out on a different pot yielded even a higher concentration of lead at 1.45%.

9.0 SIMULATION OF ALUMINUM LEACHING IN COOKING ENVIRONMENTS

Use of acidic substances such as Lime, Vinegar and Tamarind in cooking is very common in the rural areas of Sri Lanka. Tamarind is readily available in the Anuradhapura district and is heavily used in preparation of almost all types of curries. All these increase the acidity in the cooking medium and therefore facilitate leaching of metals from cooking utensils. Fluoride rich water, acidic medium and boiling can thus act as agents facilitating the leaching of aluminum and lead. Laboratory experiments were carried out to simulate these conditions and the concentrations of aluminum and lead thus released were analyzed.

Pieces of these kitchen utensils weighing between 1-2 g were treated with 100 ml of a fluoride solution with concentrations ranging from 1-5 ppm in neutral media. Similarly, media laced with tartaric acid and extracts of the spice tamarind were also used where the fluoride concentration was kept at a constant concentration of 2 ppm.. The concentrations of tartaric acid employed were in the range of 10-100 ppm while with tamarind, 5 g of a commercially available sample was extracted with water and the solution was made up to 1 L. Different concentrations of the tamarind extract were obtained by taking 20,30,40,60 80 and 100 ml of the extract and making the solution up to 100 ml with de-ionized water. In all cases controls were run with de-ionized water alone. Aluminum and lead were determined using atomic absorption spectra photometry using a graphite furnace.

When a piece of a used aluminium pot was treated with fluoride solutions of different concentrations, the variation of the total aluminum leached with fluoride concentration is given in figure 5.

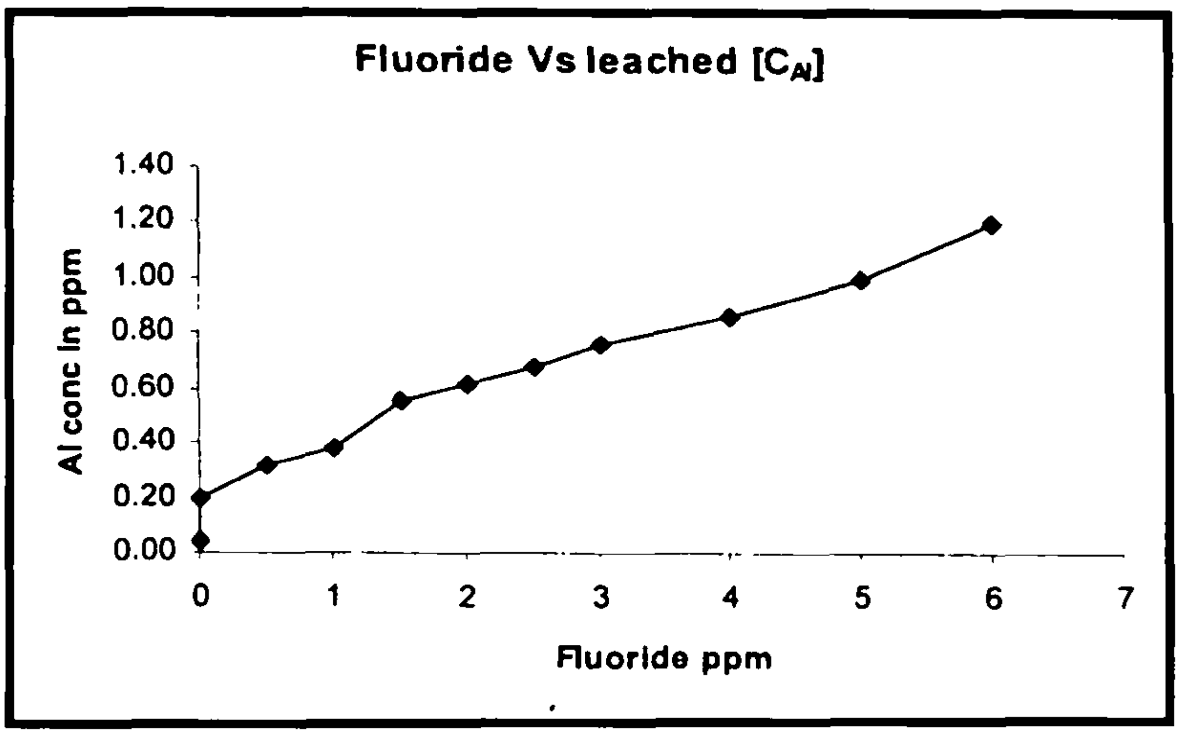


Figure 5 Leaching of aluminium from a used cooking pot under different fluoride concentrations

The results show that aluminum leaching is enhanced by fluoride and the Al concentration leached at 6 ppm fluordie was around 1.20 ppm. Alumnium dissolution is far higher from the impure aluminium pots compared to a piece of pure alumnium where the corresponding concentration is only 0.3 ppm. Corrosion of impure metals compared to impure ones is a fundamental principle of electrochemical corrosion. When a tartaric acid medium was employed giving acidic conditions (pH = 2.12), the aluminium leached was far higher compared to a distilled water medium and the results are given in figure 6. Tartaric acid is the main acidic component in tamarind and hence its choice in this study.

Thus tartaric acid medium which gives a pH of about 2.12 shows leaching of 55 ppm aluminium at a fluoride concentration of 6 ppm. This represents a phenomenal increase in the aluminium leached increasing the degree of leaching by nearly 50 fold. When tamarind was used which gives a pH of 3.12 the corresponding value of aluminium leached at 6 ppm fluoride was ~30 ppm (figure 7).

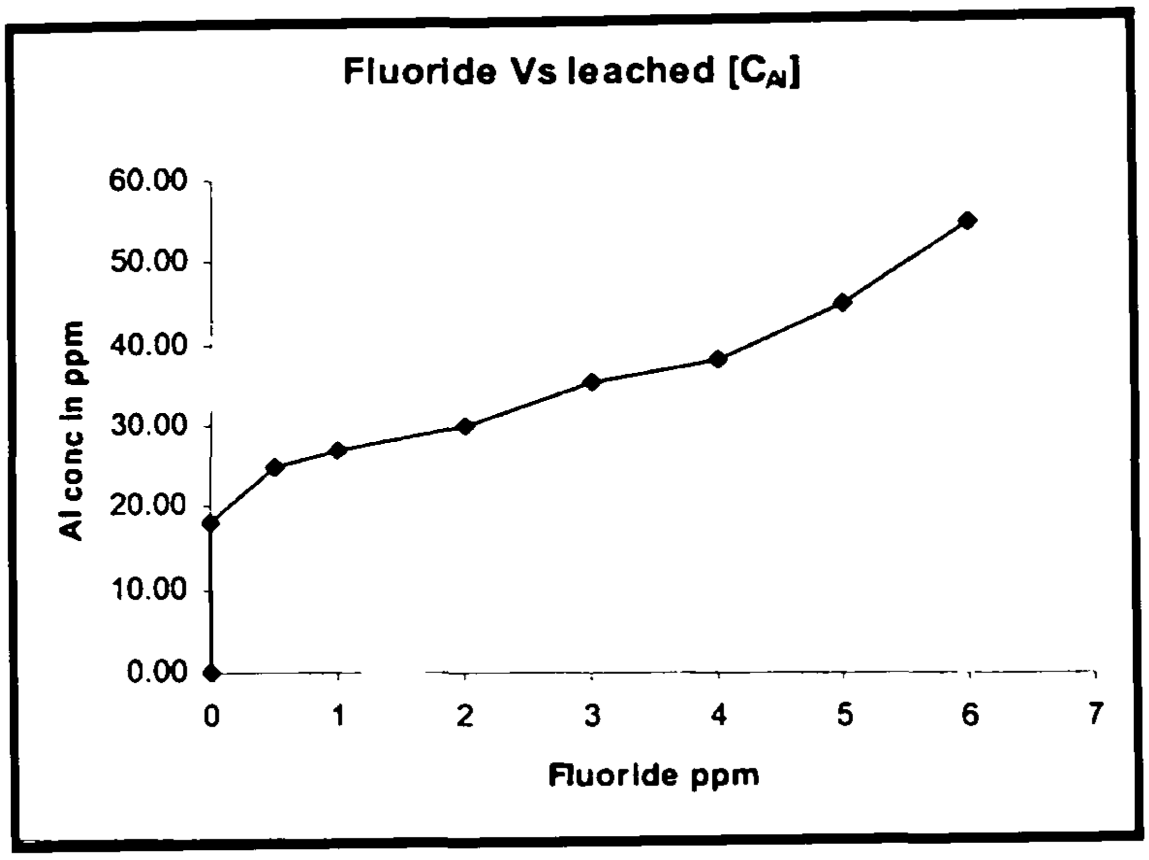


Figure 6 Effect of tartaric acid on the leaching of aluminium from cooking pots under different fluoride concentrations

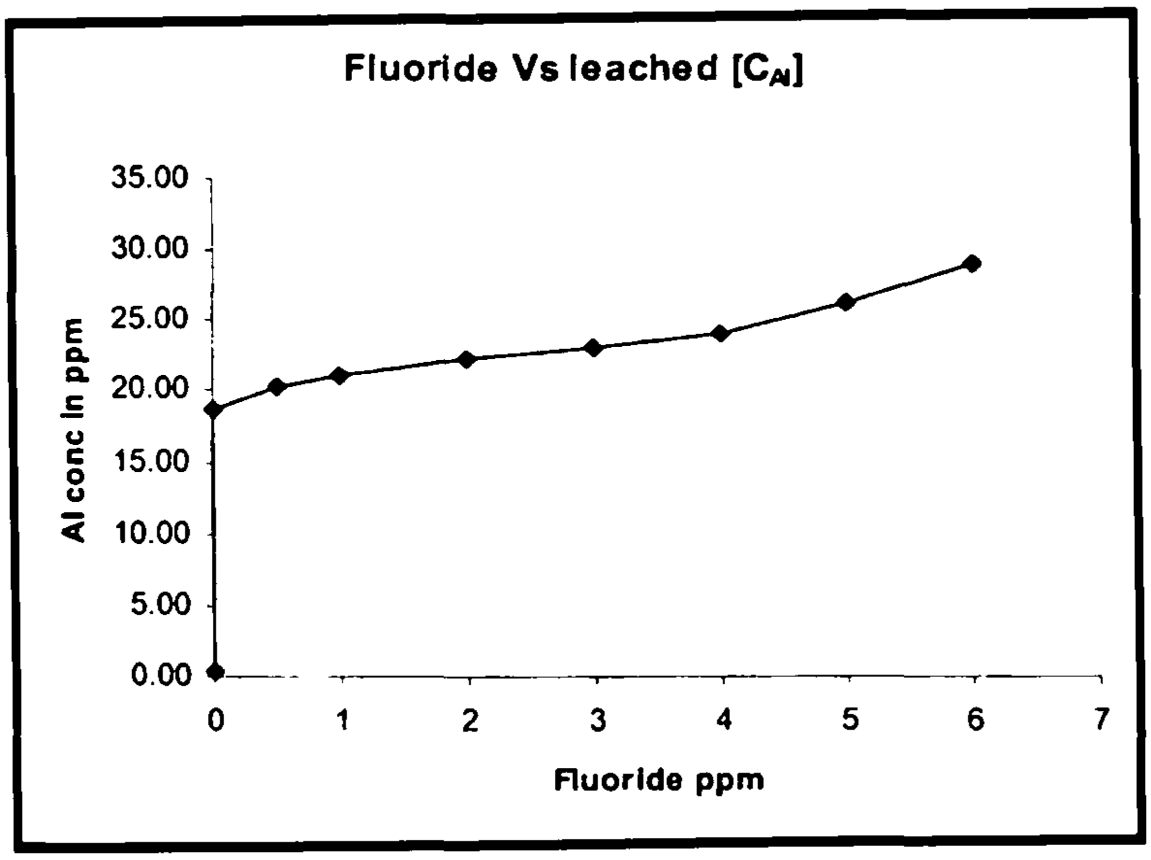


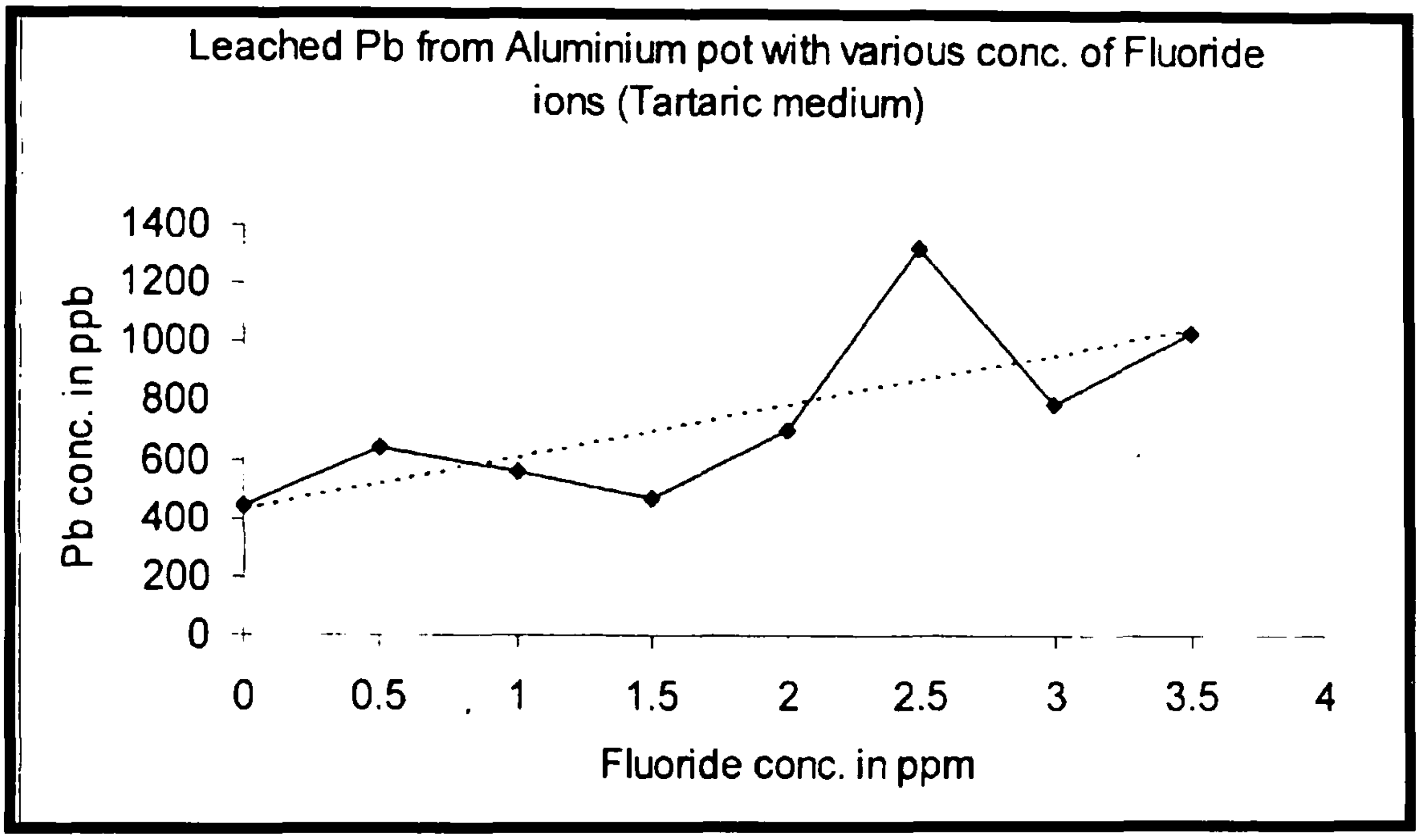
Figure 7 Effect of tamarind on the leaching of aluminium from cooking pots under different fluoride concentrations (pH= 3.12)

The corresponding value in the presence of a tomato medium at a pH of 3.99 was only 5.20 ppm. The addition of tamarind which gives a pH of 3.04 in solution leaches only 13.8 ppm of aluminium.

Dissolution of lead in the presence of fluoride

Lead is present in high concentrations in the alumnium utensils typically used in these areas. The concentrations of two such samples analysed abroad gave values of 0.82% and 1.45%. The composition of these pots is highly variable (table 6) and lead contamination through the lead based solder used to seal the holes in the aluminium pots is a common occurrence. Lead is a well known poison that affects the kidney and the presence of excessive lead concentrations in the bone samples is added proof of the positive role played by lead as a major causative factor for CRF.

An experiment was conducted to elucidate the leaching of lead under different fluoride concentrations. In this experiment pieces of the aluminium pot were exposed to varying fluoride concentrations. The variation of the amount of lead leached as determined from atomic absorption spectrophotometry against the fluoride concentration is given in figure 8.



Dissolution of lead in the presence of tartaric acid

The solution had a pH of 2.5 and this mimics the acidic conditions employed in cooking where tamarind is used. This gives a similar pH value.

10.0 CONCLUSIONS

The occurrence of CRF in the north-central province is attributed to geo-environmental factors of the region and not due to a prevalence of other health conditions such as hypertension and diabetes. The geographical occurrence of CRF has a direct relationship to the presence of high fluoride in drinking water. This investigation conclusively establishes the fact that leaching of aluminum is enhanced in the presence of excessive fluoride and in the presence of acidic conditions. This type of leaching is increased by a factor of 4 for inferior quality aluminum pots and pans used for cooking in the affected areas of the north-central province. The presence of lead in these pots in isolated patches has been established through electron microscopy. Leaching of lead is also shown especially under the typical acidic conditions used in cooking.

11.0 RECOMMENDATIONS

1. Since there is a direct correlation between CRF and the presence of high fluoride in drinking water, regular monitoring of all drinking water sources for fluoride is an urgent necessity.
2. In cases where the fluoride levels exceed 0.5 ppm which is the presently accepted level by the WHO for tropical countries the use of fluoride filters should be encouraged.
3. Use of poor quality cooking pots and pans should be avoided. Sri Lanka Standards bureau should be requested to develop SLS certification about the quality of such utensils.
4. Cooking with acidic spices such as tamarind, lime juice and tomato in aluminum pots should be avoided.
5. Further research is necessary to completely understand this unusual occurrence of CRF in the north-central province including the analysis of more body samples along with controls. The occurrence of CRF in other districts with high fluoride content in water.

12.0 DISSEMINATION OF KNOWLEDGE

While the precise reasons for CRF cannot be conclusively established from the results of this investigation there is no doubt that fluoride and inferior quality aluminium pots is a major causative factor. Thus it was thought that this information should be disseminated to the general public of the affected areas. This was achieved through the following.

1. Articles in Newspapers: Articles in the Sinhala newspapers (Lakbima, 19th November 2003 2004, Divayina 26th June 2005, Vidusara Centre page feature article in November 2005, Television (Nugasevana, July 2005).
2. Dissemination through voluntary organisations such as Dharmavijaya foundation through a Newspaper conference.
3. Research dissemination- Proceedings of the Annual Scince Congress of the University of Peradeniya, 2004.
4. Paper read at the 11th Asian Chemical Congress, Seoul, South Korea August 24-26, 2005.
5. Poster presentation made at the Annual Science Congress 2005, Thailand, held at the Suranaree University of technology, Nakhon Rathashima, Thailand September 2005.
6. M. Phil Thesis, K.R.P.K .Herath 2006. University of Peradeniya (Under preparation)