

Aluminium and heavy metals in potable waters of the north Ceredigion area, mid-Wales

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Abstract

Routine monitoring of the public water supply in Aberystwyth revealed high levels of aluminium during November 1989. These levels were twelve times the EEC recommended level and three times the maximum permitted level. While the reservoirs supplying the region and the streams draining their upland peaty catchment areas generally contain moderate levels of Al, Al salts added as coagulating agents are a major source. There is also considerable variation of the Al in potable waters through the month of November 1989 for an Aberystwyth supply. Private supplies, from groundwaters, in the region generally contain low Al.

While most drinking waters in the region contain low Pb, values close to the EEC limit have been recorded for some samples from older houses with Pb pipes, while a sample from a well supply in an old lead mining area contained three times the EEC limit. Despite the wide use of Cu piping for water supplies in the area, most values for this element in mains-water are low, with occasional higher values. However, many private supplies from spring sources are extremely Cu-rich and again levels of this element in a private supply showed a marked temporal variation during November 1989. Zinc levels in potable waters of the area are very variable. That most of the Zn in potable waters is derived from the dissolution of Cu pipes is evidenced by a strong correlation between Cu and Zn in these waters. A few Cd values of over $2 \mu\text{g L}^{-1}$ have also been recorded.

Introduction

In recent years there has been growing concern over the possible link between dietary aluminium and Alzheimer's disease in humans. Allied to this, there is considerable debate on the possible implications of elevated Al levels in drinking water. While several workers have indicated that water as a dietary source of Al is of little concern (Epstein, 1988; 1990), other workers suggest that it may pose a problem (Craun, 1990). Studies of the geographical distribution of Alzheimer's disease in Norway have revealed a suggested relationship between Al in drinking water and the disease (Flaten, 1988, 1990; Vogt, 1988). While the Norwegian studies attribute the higher Al levels in drinking water to acid rain, a major source of the element in many European supplies is the $\text{Al}_2(\text{SO}_4)_3$ used as a coagulant in water treatment (Simpson *et al.*, 1988).

In this paper we will demonstrate that Al levels in surface runoff can vary over a limited geographical area as a function of substrate and stream profile and, further, that the use of $\text{Al}_2(\text{SO}_4)_3$ in water treatment can contribute significant amounts of Al to the water supply. In addition, the area studied has a long history of metalliferous mining and abandoned Pb, Zn and Cu mines and spoil heaps litter the area. During this study, an attempt was made to identify any contribution of metals to drinking water from these sources together with any metal contamination resulting from the dissolution of metal pipes and fittings.

Area of Study

The area studied during this work is shown in Figure 1. North Ceredigion lies on the west coast of the British Isles and consists of a dissected coastal region where the land rises to around 200 m with upland to the East. The highest point in the area is the Plynlimon range which rises to 752 m. This area was subjected to glaciation during the Pleistocene as a result of which there was over deepening of the Rheidol river valley. This area of mid-Wales is underlain by lower Palaeozoic clastic sediments which are carbonate poor and much of the upland is covered by peat bogs. Both of these are important factors influencing the chemistry of surface water in this region. Another factor is the long history of Pb, Zn and Cu mining in this area, as many of the old mines and spoil contribute significant contamination to the surface waters (Fuge *et al.*, 1991).

Water for public consumption is collected in a number of small upland reservoirs; Llyn Llygad Rheidol and Llyn Craigypistyll in the north and Llyn Egnant and Llyn Teifi (collectively known as the Teifi pools) in the south (Figure 1). The water, in these reservoirs, typically has a brown colouration due to the high levels of organic/humic material and it is the removal of this colouration which leads to some of the problems in this area. In addition to the upland supplies, water for the town of Aberystwyth is supplemented by a borehole into the river gravels of the over deepened Rheidol valley at Lovesgrove (see Figure 1).

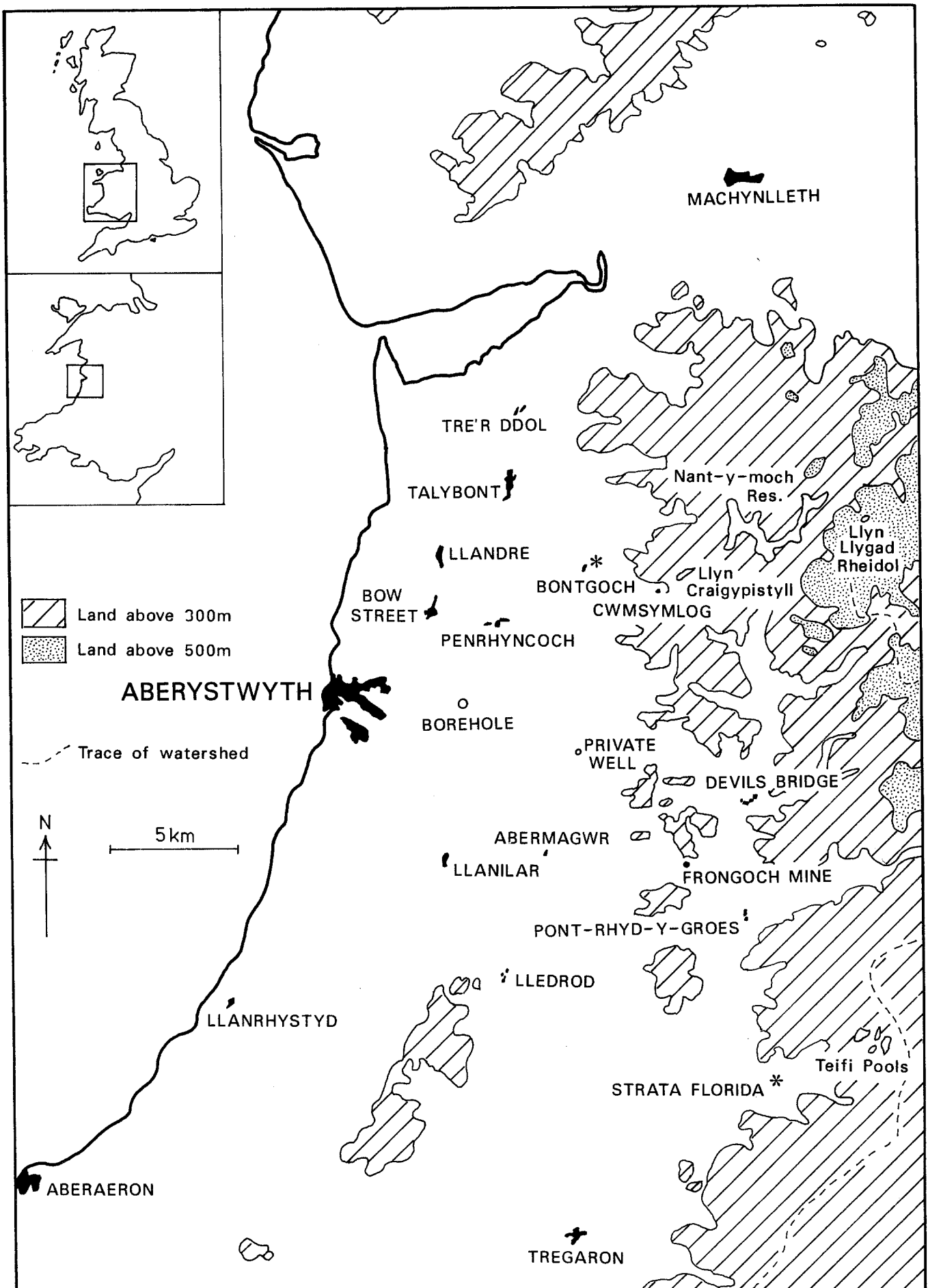


Figure 1 Location map of the north Ceredigion area with some of the villages shown. The positions of the upland reservoirs and borehole used for public supply and the water treatment plants are shown (*).

Table 1 Chemistry of surface waters in the mid-Wales area. (All values for metals in $\mu\text{g L}^{-1}$).

Reservoir waters		Al	Cu	Zn	Pb	Cd	Ba	pH
Craigpistyll								
Overspill	(Nov. 1989)	175	1.5	8	0.7	nd	2.5	4.5
	(Jan. 1990)	185	1.7	18	1.7	nd	2.5	4.4
Midway point, south side	(Nov. 1989)	154	1.2	16	1.2	nd	2.2	5.0
	(Jan. 1990)	162	1.0	17	1.2	nd	2.4	4.4
Most distal point of lake	(Nov. 1989)	117	2.2	23	0.7	nd	1.9	4.7
	(Jan. 1990)	113	1.0	22	0.4	nd	1.4	4.6
Main inflows to Craigpistyll								
Nant Glas	(Nov. 1989)	109	0.7	25	0.4	nd	1.4	5.1
	(Jan. 1990)	110	1.1	26	0.8	nd	2.1	5.2
Nant Ddu	(Nov. 1989)	102	1.6	7.2	2.8	nd	2.3	5.0
	(Jan. 1990)	103	1.0	14	0.6	nd	2.0	4.2
Nant Melyn	(Nov. 1989)	87	1.1	7.4	1.7	nd	2.5	4.7
	(Jan. 1990)	89	0.6	5.9	1.9	nd	2.3	5.0
Stream from boggy area	(Nov. 1989)	345	0.7	15	0.9	nd	2.0	4.2
	(Jan. 1990)	305	0.8	10	1.6	nd	2.9	4.8
Llyn Llygad Rheidol								
Overspill	(Jan. 1990)	208	nd	13	nd	nd	1.0	5.8
South side	(Jan. 1990)	190	nd	15	nd	nd	0.8	5.4
West side	(Jan. 1990)	206	nd	13	nd	nd	0.8	5.7
Main inflows to Llyn Llygad Rheidol								
SE side	(Jan. 1990)	146	nd	13	nd	nd	0.6	5.8
East side	(Jan. 1990)	361	nd	13	nd	nd	1.3	5.0
Teifi Pools								
Llyn Teifi								
Overspill	(Nov. 1989)	131	1.2	7.8	0.7	nd	3.3	5.5
	(Jan. 1990)	111	1.0	8.7	nd	nd	3.2	–
W side 200 m from dam wall	(Nov. 1989)	130	1.0	3.4	0.7	nd	2.6	6.2
	(Jan. 1990)	114	1.0	10	nd	nd	2.8	–
Llyn Egnant								
Overspill	(Nov. 1989)	132	0.7	8.2	2.9	nd	2.8	5.4
	(Jan. 1990)	102	0.7	6.7	0.8	nd	4.4	–
W side 200 m from dam wall	(Nov. 1989)	108	0.9	6.9	2.2	nd	2.5	6.2
	(Jan. 1990)	116	0.7	7.3	1.3	nd	2.1	–
Nant-y-Moch								
Outflow	(Nov. 1989)	260	1.6	27	7.3	nd	2.9	5.4
	(Jan. 1990)	305	2.3	27	6.4	nd	3.5	5.0
S side of dam	(Jan. 1990)	283	1.9	27	7.5	nd	3.0	4.5
Inflows to Nant-y-Moch								
Stream 1	(Nov. 1989)	127	2.2	10	nd	nd	1.9	6.4
	(Jan. 1990)	166	2.3	13	0.6	nd	2.7	6.2
Stream 2	(Nov. 1989)	134	0.9	4.2	nd	nd	1.6	6.6
	(Jan. 1990)	158	1.0	10	0.7	nd	2.3	6.3
Stream 3	(Nov. 1989)	291	2.0	13	5.6	nd	3.7	5.1
	(Jan. 1990)	284	0.9	17	4.0	nd	2.8	5.7
Stream draining old metal mine	(Nov. 1989)	325	31	210	248	1.0	4.1	5.0
	(Jan. 1990)	397	31	208	238	0.8	4.0	4.6

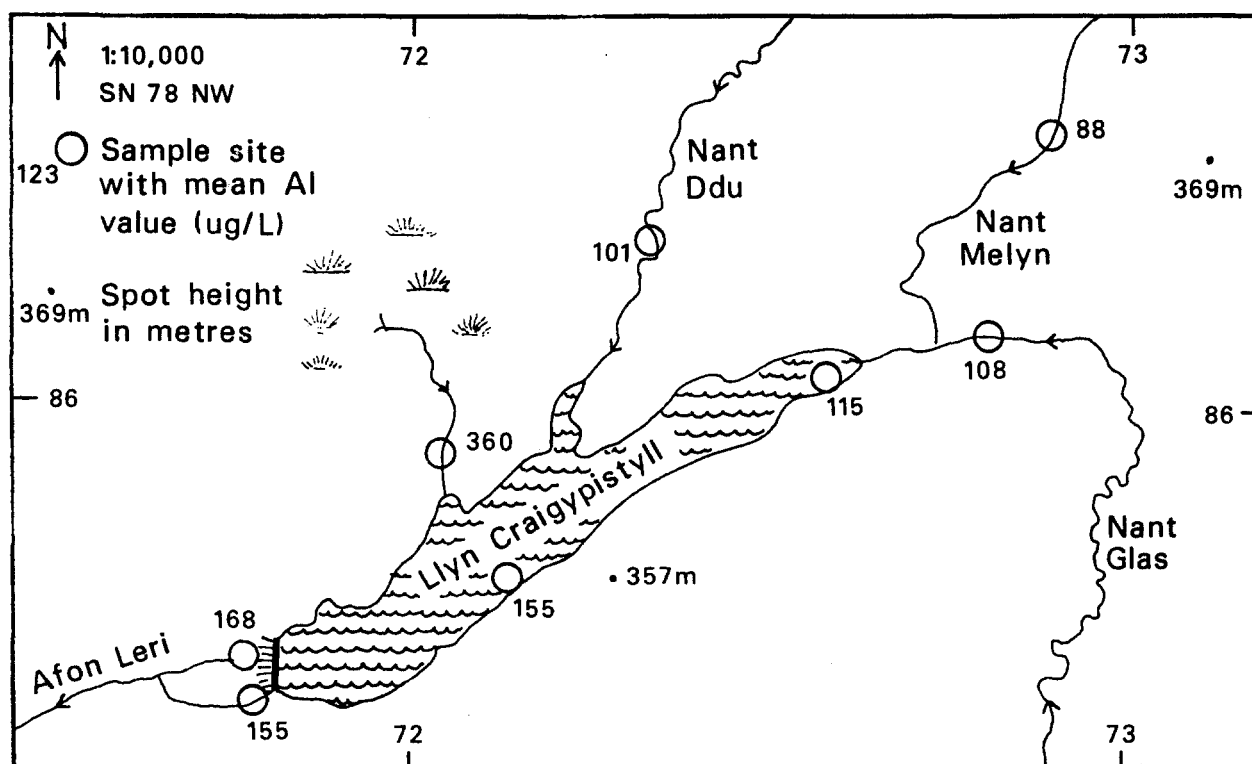


Figure 2 Map of the reservoir at Craigpistyll. Sample sites are shown with typical Al concentrations in $\mu\text{g L}^{-1}$.

Sample Collection

During this study, samples of household supplies, which consisted of both mains water and private sources, and surface waters from streams and reservoirs were collected.

Domestic supplies

Most of the samples collected were from the public mains provided by Welsh Water, with the private supplies mainly from springs plus a smaller number of private wells. Samples were collected over a wide geographical area in order to obtain a regional picture; areas from which samples were taken outside the town of Aberystwyth are indicated on Figure 1. Two of the sites were sampled on a daily basis throughout the month of November 1989. One of these sites was a domestic supply in the town of Aberystwyth whilst the other was a private well supply. This well is sunk into the Rheidol river gravels some 5 km from the Lovesgrove borehole (see Figure 1). The regional samples were collected on 2/11/89, 15/11/89, 30/11/89 and 15/1/90. Water was collected from the rising main after the tap had been running for at least five minutes. The water was collected in either acid-washed polypropylene bottles or in new polycarbonate containers. In all cases the containers were washed with running water at least three times before the samples were taken. The samples were not filtered.

Surface runoff

In order to obtain a measure of the background levels of Al and heavy metals in this region a series of samples was collected of the surface water. The samples consisted of streams feeding the reservoirs and the reservoir waters; although in the case of the Teifi pools there is only limited

surface drainage running into the reservoirs. Samples were also taken from the Nant-y-moch reservoir (Figure 1) which forms part of the Rheidol hydro-electricity scheme and is not used for water supply. Nevertheless, the reservoir at Nant-y-moch illustrates one of the problems with water supply in this region since it has flooded several old metal mines.

All surface water samples were collected in acid-washed polypropylene bottles. The bottles were rinsed at least three times with the water before samples were taken. The samples were not filtered or acidified in the field since this has been shown to be unnecessary (Pearce, 1991).

Analytical Techniques

The samples were analysed by inductively coupled plasma mass spectrometry (ICP-MS) using a VG Instruments PQ2+. The ICP-MS data were obtained in 'semi-quantitative' mode using In as an internal standard. This technique uses an instrument response curve to calculate the concentration of an analyte from the response of an internal standard. Aldrich ($1,000 \mu\text{g mL}^{-1}$) A.A. standard solutions were used to establish this response curve. The samples were acidified and a known concentration of In added prior to analysis. For most of the elements of interest in natural waters this method has been shown to be accurate to $\pm 15\%$, except where the concentrations approach the limit of detection where the accuracy is $\pm 30\%$ (Pearce, 1991). Analytical precision is better than $\pm 5\%$.

Table 2 Chemistry of potable waters in north Ceredigion. (All values in $\mu\text{g L}^{-1}$).

	Al	Cu	Zn	Pb	Cd	Ba
Private supplies						
Monitored supply						
Nov. 1989 (27 samples)	2.0–11.6	126–478	32–124	nd	nd	9.3–13
All other wells and springs (17 samples)						
	2.9–3.7	17–558	nd–175*	nd–2.2	nd–2.5	nd–44
Mains supplies						
<i>Aberystwyth town</i>						
Monitored supply						
Nov. 1989 (29 samples)	114–377	2.0–120	nd–38	nd–2.3	nd–5.2	nd–4.3
Jan. 1990 (6 samples)	123–151	2.0–14	nd–18	nd–2.2	nd	nd–2.0
All other town supplies						
Nov. 15/89 (12 samples)	231–390	nd–30	1.8–21	nd–29	nd–1.5	1.4–4.8
Nov. 30/89 (11 samples)	124–235	nd–37	12–33	nd–24	nd–5.2	nd–4.0
<i>Penparcau and Llanbadarn areas</i>						
Nov. 1/89 (1 sample)	409	53	14	3.2	nd	2.3
Nov. 15/89 (3 samples)	348–384	2.0–22	11–20	nd–14	nd–0.8	nd–3.1
Nov. 30/89 (3 samples)	200–292	1.7–64	nd–37	nd–13	nd–2.0	1.9–3.0
<i>Waun Fawr</i>						
Nov. 15/89 (4 samples)	421–596	nd–3.9	4.2–8	nd	nd–1.5	1.5–3.0
Nov. 30/89 (4 samples)	259–423	nd–5.3	6.3–59	nd	nd–2.7	1.4–2.3
Jan. 19/90 (3 samples)	152–209	2.4–3.0	11–13	1.2–1.7	nd–1.0	2.5–2.8
<i>Bow Street and Talybont area</i>						
Nov. 1/89 (2 samples)	350–368	5.9–11	15–20	nd	nd	2.3–2.8
Nov. 15/89 (6 samples)	373–606	nd–13	4.3–20	nd	nd	1.6–3.6
Nov. 30/89 (8 samples)	242–302	nd–6.8	11–18	nd–1.2	nd–3.0	1.5–2.5
Jan. 19/90 (3 samples)	168–189	nd–4.1	13–15	1.5–1.7	1.0–1.2	2.4–3.2
<i>Tregaron area</i>						
Nov. 1/89 (1 sample)	605	3.9	2.5	nd	nd	2.1
Nov. 15/89 (3 samples)	453–604	nd–2.5	nd–13	nd	nd–0.6	1.7–2.6
Nov. 30/89 (4 samples)	285–430	nd–2.4	8.3–17	nd	nd–3.0	1.4–3.0
Jan. 19/90 (3 samples)	275–316	nd–3.6	5.0–11	nd–1.1	nd	2.0–2.8

* Omitting one high value due to storage in galvanised tank (Table 3).

pH values for private supplies in range 6.0–6.3, mains water in range 6.4–7.2.

Results and Discussion

Natural aluminium levels

Previous work has shown this region of mid-Wales to be subject to acidic rainfall. Donald and Keil (1988) reported a mean rainfall pH throughout the uplands of mid- and north Wales of 4.3, and attributed this value to industrial emissions falling on the area. These authors, unfortunately, give no information on the geographical distribution of their data nor on the spread of values obtained for rainfall pH. Donald and Keil (*op. cit.*) also report pH determinations for 150 streams in this area, 13% of which gave a mean pH of less than 5.5. Our data (see Table 1) are generally in agreement with their findings.

The concentration of Al in the upland catchments for the public supply were monitored during November of 1989 and January 1990. Levels were found to vary over a

limited geographical area, as illustrated for inflows of the Craigpistyll reservoir (Figure 2 and Table 1), and are in part dependent on the type of stream. For fast flowing streams with pebble beds, the Al level was typically between 80 and 150 $\mu\text{g L}^{-1}$, whereas in streams draining flat boggy areas values of up to 360 $\mu\text{g L}^{-1}$ were consistently obtained. There was no significant difference between the pH values obtained for these contrasting streams so the results are not a function of the increase in Al solubility at lower pH (*c.f.* Birchall and Chappell, 1988). We suggest that the higher Al level found in streams draining boggy ground is the result of leaching from clay minerals, perhaps by a process of ion exchange, since the soils will be characterised by low concentrations of basic cations (*c.f.* Driscoll and Schecher, 1990). It is probable that these acid waters have long residence times in the bogs whereas the fast flowing streams, with essentially the same

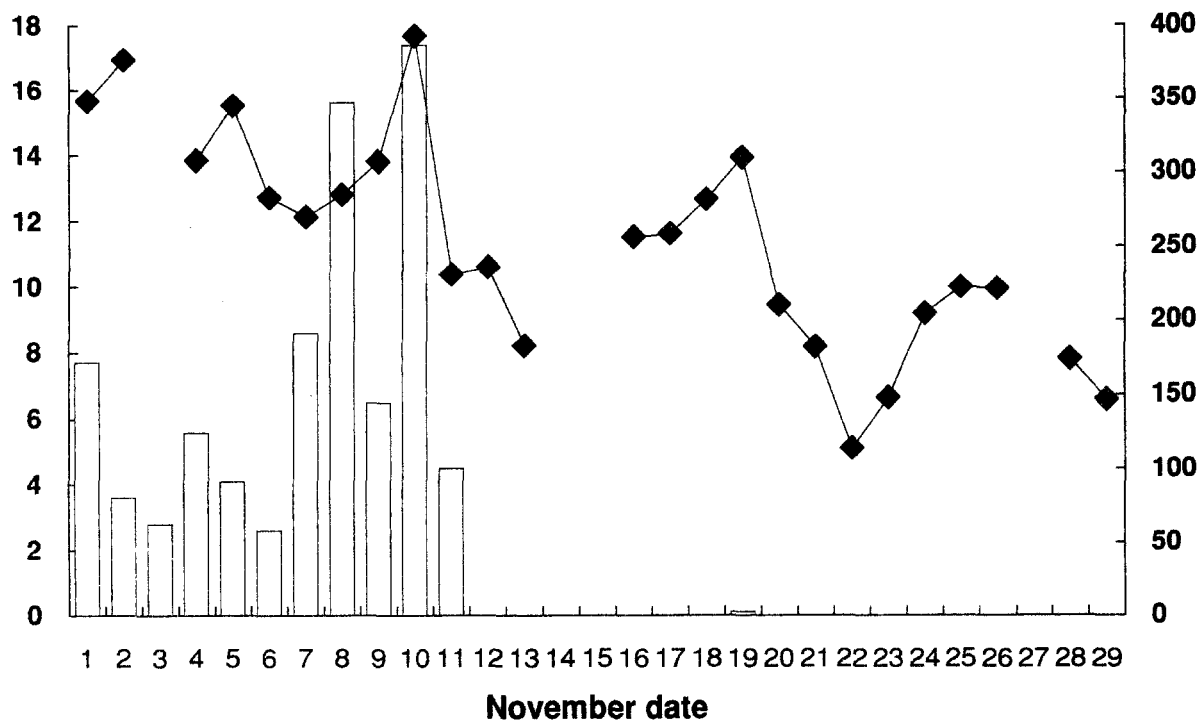


Figure 3 Al concentration for an Aberystwyth mains supply (diamonds) during November 1989 shown in relation to the daily rainfall data (vertical bars) for the area. Vertical axes are: left hand side rainfall in mm; right hand side Al in $\mu\text{g L}^{-1}$.

pH, have less time to dissolve or exchange Al.

The levels of aluminium and other elements present in the water flowing from the four surface supplies, used for public drinking water, are presented in Table 1. All of these supplies have natural levels of Al in excess of the EEC recommended level of $50 \mu\text{g L}^{-1}$ (EEC Directive 80/777/EEC, 1980 and Department of Environment Circular 20/82, 1982), and in the case of Llyn Llygad Rheidol the natural level of Al is in excess of the EEC maximum admissible concentration (MAC) of $200 \mu\text{g L}^{-1}$.

It was not possible to obtain samples from the Lovesgrove borehole (see Figure 1) but data were obtained for a private well, into the same river gravels, approximately 5 km to the SE. Samples were collected from this well on a daily basis throughout the month of November and a summary is presented as part of Table 2. The well water has a very low concentration of Al, typically less than $10 \mu\text{g L}^{-1}$. Low Al values ($<40 \mu\text{g L}^{-1}$) were also found for all of the private well and spring supplies tested during this study.

Water treatment

The water from the surface supplies is characterised by a strong brown colouration, due to the peaty nature of the upland region, and a pH of around 5.0. In order to remove the colouration and material in suspension it is necessary to use a coagulant and then to filter the water. The water is also pH adjusted to give a neutral to slightly alkaline value. Two water treatment plants, Bontgoch and Strata Florida (see Figure 1), use a pressure filtration system in which the head of water is used to force the water through an 'in-line' filter. This system can lead to problems, for example when there is a sudden demand for water the coagulant can break

through the filter into the mains supply. The two treatment plants used aluminium sulphate as the coagulant until March 1990. The water company do not monitor the water leaving the treatment plants and our data strongly suggests that significant levels of Al were entering the water supply because of inefficient filtration or break through (see below).

Aluminium levels in tap waters

Aluminium, together with Pb, Zn, Cu, Cd and Ba, was determined in the suite of samples from the Aberystwyth area during the months of November 1989 and January 1990. Two sources of supply, one from the public mains and one from a private well, were sampled on a daily basis throughout November 1989. Analyses from a selection of both public and private supplies are presented in Table 2. The analyses for the daily samples from the mains supply are presented in Figure 3. Also shown are the daily rainfall figures for November 1989. These data show that for much of the month of November the public supply was in excess of the MAC with only 6 of the 25 samples giving values below $200 \mu\text{g L}^{-1}$.

There is a correlation between the rainfall and the level of Al detected in the mains water during the early part of the month (Figure 3). Periods of heavy rainfall produce an increase in the organic material transported by the surface waters. It is suggested that the high Al levels, observed during November 1989, are the result of the increased use of coagulant to remove this increased level of organic matter. No such systematic variation in the Al level was observed for the untreated private supply during the same period. The aluminium levels were found to exceed the MAC for all of the public supplies throughout

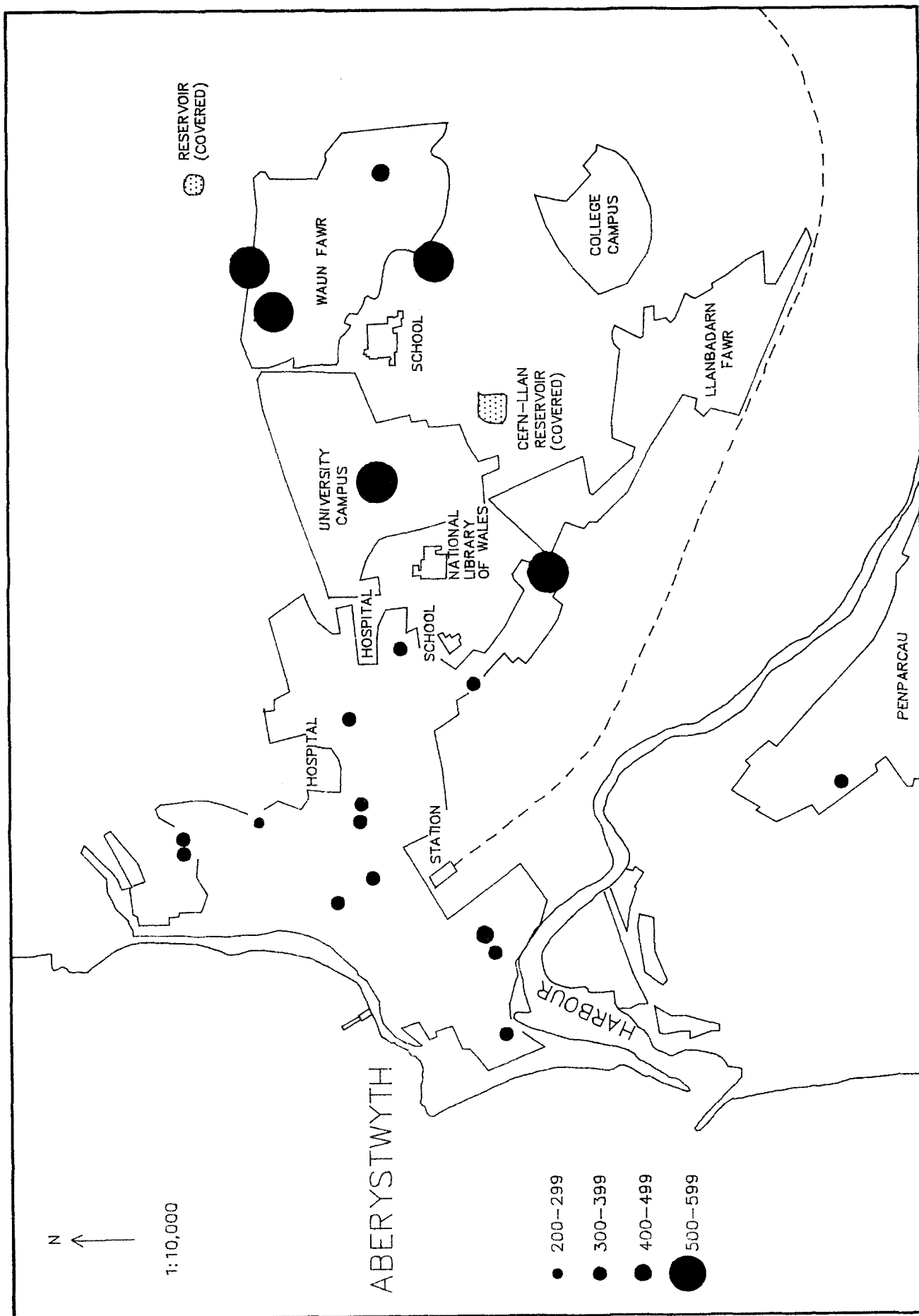


Figure 4 Map of Aberystwyth town area showing Al concentrations in mains supplies for the 15/11/89.

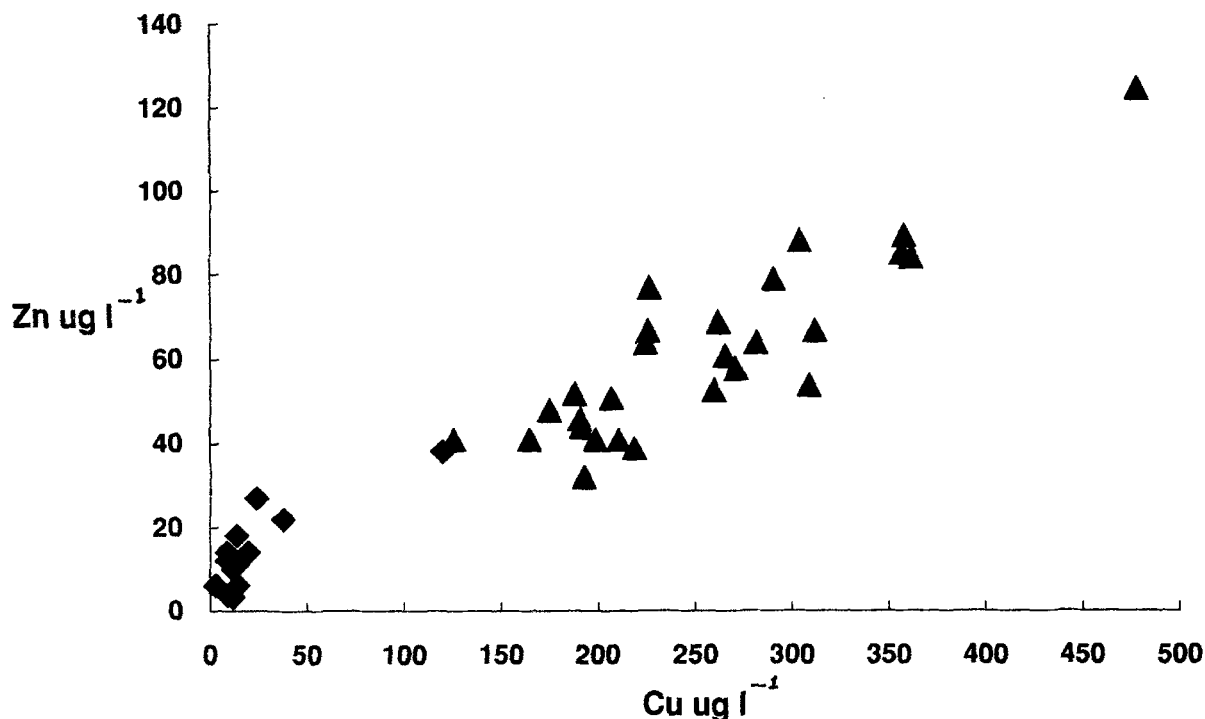


Figure 5 Cu vs. Zn for the two water supplies monitored throughout November 1989. Diamonds = mains water, triangles = well supply.

the early part of November and in some cases levels found were in excess of $600 \mu\text{g L}^{-1}$.

The levels of Al in the tap water in the town of Aberystwyth produced a distinct pattern with higher values in the area of Waun Fawr and consistently lower values in the main part of the town (Figure 4). When the water supply system was studied in detail it was found that the water from the Bontgoch treatment plant is fed to a holding reservoir near the village of Bow Street, north of Aberystwyth (Figure 1). From here the water is piped directly to the Waun Fawr area and on to another reservoir, Cefn-llan, above the town of Aberystwyth (Figure 4). At Cefn-llan the water from the Bontgoch treatment plant is mixed with water from the Lovesgrove borehole before going on to feed the main part of Aberystwyth. The consistently lower Al values found in the Town can therefore be explained by a dilution of the Al contaminated water, from the treatment plant, with virtually Al-free borehole water.

Heavy Metals

Surface water: As stated earlier there is a potential problem with the supply of drinking water in the area of study because of the long history of metal mining. The mid-Wales orefield was worked extensively for Pb, Zn and to a lesser extent Cu. Many old mine workings and spoil heaps occur throughout the area (Fuge *et al.*, 1991). During our sampling programme we did not identify a problem with the surface water supplies used for drinking water. Typical values for the surface waters are less than $20 \mu\text{g L}^{-1}$ for Cu and Zn and less than $2 \mu\text{g L}^{-1}$ for Pb. In contrast samples taken from the Nant-y-Moch reservoir, used for hydro-electricity, gave lead values of around $7 \mu\text{g L}^{-1}$. This reservoir is known to flood at least two old

Pb mines. Cadmium, which is associated with Zn mineralisation, was detected in some surface waters draining old workings at around $1 \mu\text{g L}^{-1}$. Barium sulphate also occurs in the mineralised zones but the highest recorded values of $4 \mu\text{g L}^{-1}$ compared to a background of $2-3 \mu\text{g L}^{-1}$ indicates that little has been dissolved. However, more Ba occurs in the private spring water supplies (up to $44 \mu\text{g L}^{-1}$) due probably to the longer residence times of these waters allowing dissolution of Ba from the sedimentary rocks.

Tap water: Although there is no problem with heavy metals in the surface water supplies, a number of samples of tap water did contain heavy metals.

Lead: The problem of plumbo-solvency in soft water areas is well documented (Royal Commission on Environmental Pollution, 1983). During this study a number of samples were collected from Victorian terraced houses, which still have lead pipes, in the town of Aberystwyth. These samples gave lead values of up to $29 \mu\text{g L}^{-1}$. One sample, from a farm outside Aberystwyth, with a lead supply pipe approximately 150 m long gave lead values of $40 \mu\text{g L}^{-1}$; approaching the EEC limit of $50 \mu\text{g L}^{-1}$.

One of the private well supplies analysed, from Cwmsymlog (an old lead mining village, Figure 1) gave a Pb value of $165 \mu\text{g L}^{-1}$.

Copper and zinc: Copper and zinc were detected in most of the samples analysed and, as the surface water values are low, we attribute this to the dissolution of copper pipes which also contain appreciable zinc. A plot of Cu versus Zn for the two supplies monitored during this study (Figure 5) shows a good correlation between these elements for both the mains and well water supplies. This would seem to support our contention that both elements are derived from the Cu pipes. The highest value for Cu in

Table 3 Chemistry of some metal – rich water supplies. (All values in $\mu\text{g L}^{-1}$).

	Al	Cu	Zn	Pb	Cd	Ba
Spring supply, standing water	3.8	4,900	2,960	24	nd	8.7
Mains supply, standing water	88	111	27	1.4	0.6	1.9
Spring supply, with galvanised tank	23	50	1,055	nd	nd	15
Mains supply, Pb pipes, Aberystwyth	124	17	14	29	1.8	2.6
Mains supply, farm, near Aberystwyth	286	7.6	13	40	nd	2.3
Well supply, in old Pb mining area	25	17	68	165	2.8	7.6
Spring supply, near abandoned zinc mine	nd	16	815	1.5	1.0	3.2

a mains supply was $120 \mu\text{g L}^{-1}$ but most samples seldom contain over $30 \mu\text{g L}^{-1}$. Zinc values are correspondingly low. However, the levels of Cu and Zn in private supplies were found to be very high, up to $590 \mu\text{g L}^{-1}$ and $175 \mu\text{g L}^{-1}$, respectively. Indeed, one sample of water collected in the morning prior to running the supply contained $4,900 \mu\text{g L}^{-1}$ Cu and $2,960 \mu\text{g L}^{-1}$ Zn the corresponding sample from the mains supply contained $111 \mu\text{g L}^{-1}$ Cu and $27 \mu\text{g L}^{-1}$ Zn. The high Cu and Zn values in private supplies is due to the fact that the pH of these supplies is not adjusted in contrast to the public supply. The slightly acid, soft waters of the private supplies are thus able to dissolve the Cu pipework.

While the Cu and Zn values for the private supply monitored in this study are consistently much higher than those of the mains supply, there is considerable variation through time. Copper ranges from 126 to $478 \mu\text{g L}^{-1}$, and Zn values vary between 41 and $124 \mu\text{g L}^{-1}$ during November 1989. There is no apparent reason for this variation but it may be significant that the lowest values occur at the end of November 1989, a period of dry weather following a wetter period earlier in the month. One extremely high value for Zn in a private supply recorded during this study, $1,055 \mu\text{g L}^{-1}$, was probably due to the water being stored in a galvanised tank. One other particularly high Zn level was recorded for the public supply in the area of the small settlement of Abermagwr (Figure 1). This supply, furnished by the local water authority, is derived from a spring situated below the abandoned Frongoch mine (Figure 1), one of the most productive Zn mines in mid-Wales, and it is probable that the groundwater is contaminated from the mine area (Table 3).

Cadmium: Low levels of Cd were detected in a number of samples. These were not restricted to spring supplies and could not, therefore, be attributed to Cd contamination from the groundwater. Given the evidence for dissolution of pipework and the geochemical similarity between Cd and Zn, a number of possible sources for this contamination were investigated. Samples of Cu pipe, Pb pipe, solder and brass fittings were analysed using laser ablation ICP-MS,

a technique which allows solid samples to be analysed directly. Cadmium was identified in a brass fitting and on subsequent analysis following dissolution, the brass was found to contain 5 mg kg^{-1} Cd. As the levels of Cd in potable water should be no more than $5 \mu\text{g L}^{-1}$, it is of some concern that this level is being slightly exceeded in some mains supplies.

Conclusions and Recommendations

1 The background level of aluminium in surface drainage of the mid-Wales area is high but the use of aluminium sulphate as a coagulant in water treatment plants, when combined with pressure filtration, can lead to a significant increase in the level of aluminium in drinking water. The natural level is close to the EEC MAC of $200 \mu\text{g L}^{-1}$ but the additional Al from the treatment plants increases the level up to around $600 \mu\text{g L}^{-1}$.

2 Drinking water in this region is contaminated with lead, copper and zinc due to the dissolution of pipe materials by acid water. This problem is greatest for private supplies with no pH adjustment but still occurs in public supplies despite the pH adjustment used by the water company.

3 Measurable levels of cadmium have been found in some drinking water which is the result of dissolution of brass fittings. Values obtained are up to $5 \mu\text{g L}^{-1}$, the EEC MAC for this toxic heavy metal.

4 This work shows that the use of $\text{Al}_2(\text{SO}_4)_3$ coagulant in combination with a pressure filtration system can result in serious Al contamination of the water supply. We suggest that an alternative coagulant be used to avoid this problem in the future.

5 In this work we have demonstrated the application of ICP-MS as a powerful tool in the analysis of waters. The technique offers analytical speed combined with exceptional detection limits making the analytical aspect of this type of study routine.

Acknowledgements

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