



Your reference

Our reference

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Dear Dr Grainger

LOWERMOOR INCIDENT

We have discussed the Lowermoor incident, and its implications for the health of consumers locally, on several occasions recently. Dr Lawrence's report on the incident contains a toxicological assessment which is to the point and, I believe, accurate. We agreed, however, that it would be of value to have another more detailed assessment from the standpoint of one who has clinical experience and who was not involved in the immediate aftermath of the incident or in Dr Lawrence's enquiry.

In preparing my report, I have been able to use the specialised toxicology information source based here, and I have discussed the findings with Dr Matthew (who also spoke to you and others locally) and other colleagues. In the attached document, I have tried to relate information from the published scientific literature to the range of exposures which people may have experienced after the incident. In this light, I have also considered the various symptoms which have been reported in association with the incident. I have accepted those reports, and the information provided by SWWA on the water quality following the incident, at their face value. I have not of course undertaken clinical or laboratory examination of any of those who may have suffered ill-effects, and have not been in a position to verify any of these clinical reports or water quality data independently. You will wish to show this letter, and the attached document, to interested parties locally. If it becomes clear that my understanding of the events surrounding the incident needs to be corrected or added to, or if there are further points which I should address, please let me know. I would be pleased to come to Cornwall if you or others there feel that it would be helpful to meet for further discussion.

Yours sincerely-

M WARING MA, MB, FRCS
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LOWERMOR INCIDENT AND EFFECTS ON HEALTH

Sources of information used in this report

1. Information on the concentrations of chemicals in the water was provided to me by Mr Fawell, the toxicological adviser to Dr Lawrence's enquiry, with the permission of South West Water Authority. Additional information was contained in letters from a local resident, Mr Cross, to the Department of the Environment, the Department of Health, and others. Data on current concentrations of aluminium were provided to me from SWWA through the Department of the Environment. Dr Lawrence's enquiry contained an account of the circumstances giving rise to the abnormal concentrations.

2. Information on reported symptoms was gathered, from conversations with Dr Grainger and Mr Fawell, from Dr Lawrence's report and Mr Cross's letters, from the initial analysis by Camelford Scientific Advisory Panel of over 200 responses to its questionnaire, and from reports in national newspapers.

3. I have accepted all the information at face value. I have not undertaken clinical or laboratory examination of any of those who may have suffered ill-effects, and have not been in a position to verify any of the clinical reports or water quality data independently.

Introduction

4. The presence of abnormal concentrations of aluminium sulphate in the water supply lowered the pH of the water, and resulted in the release of copper, lead and perhaps zinc from plumbing systems. SWWA has reported no other chemical abnormality in the water supply. With the exception of aluminium concentrations, which have remained slightly higher than the Maximum Admissible Concentration in the relevant European Community (EC) Directive, the SWWA data indicate that within a few days of the incident the water put into supply was within the limits set by the Directive. In areas of the distribution, or Individual properties, where so little water was used that the polluted water was still present at a later date, then the effects of the incident would have been delayed. For any individual consumer, however, it appears that exposure to the polluted water would have lasted for at most a few days.

pH

5. The lowest pH recorded in the SWWA results is 3.7, from a hot-water tap. There are several other readings of 4 and slightly greater, from various sampling points. Lower readings (from pH 3 upwards) were

mentioned by Mr Cross, as well as one uncorroborated reading of between 2 and 3. The lower end of the acceptable pH range stipulated by Department of the Environment is 5.5. The World Health Organisation (WHO) Guidelines suggest a guideline value of pH 6.5 as the lower limit.

6. Limits on pH in drinking-water are set because of the secondary effects of a low pH on releasing metals from pipework: these metals (copper, lead, zinc) are considered individually below. Short-term consumption of water with a pH even as low as 2 to 4 would not in itself affect health. Many things that we eat and drink - in particular, fruits and soft drinks - are in this range.

Aluminium

7. The highest aluminium level reported by SSWA was 109 mg/l, recorded at the inlet to a service reservoir on the day following the incident; water from the outlet contained 7.9 mg/l. On the same day, 50 mg/l was detected at Slaughterbridge. On the following two days, the highest detected concentrations were reported as 34.5 mg/l and almost 12 mg/l. Thereafter, the highest concentrations were up to 3 mg/l, on occasions, during the next two weeks. Latterly, they have fallen to below 1 mg/l, but in some areas were not back to below the Directive limit of 0.2 mg/l by mid-August.

8. Both the EC Directive limit, and the WHO Guideline Value, is 0.2 mg aluminium per litre. This number was chosen because higher concentrations would be likely to lead to discoloured water (especially in the presence of iron). No effect on health was considered likely, from this or even substantially higher exposures. Aluminium is very poorly absorbed from the gut, and is excreted efficiently and rapidly, principally by the kidneys. There is long experience of the use of aluminium salts as food additives, and in medicinal preparations such as antacids, and there has been no evidence of harm except from prolonged ingestion of very high doses (several thousand milligrams daily, for months).

9. Water containing aluminium at the highest recorded concentration of 109 mg/l would be discoloured, and have a noticeable taste. Anyone who drank the water despite these aspects could conceivably have been nauseated. If however, the water was not vomited, then the aluminium contained in it would not have had any adverse effect. To put it into context, the 109 mg of aluminium in 1 litre of water would have represented about five to ten times the average daily intake from food, but it would be perfectly possible to ingest this amount from food on any given day. It would be equivalent to the aluminium contained in two

slices of certain American cheeses, or in ten servings of a cake made with aluminium-containing baking-powder, or in two-thirds of an aluminium hydroxide tablet taken to treat indigestion, or from swallowing the toothpaste used at one brushing.

10. There has been recent interest in the possibility of a link between aluminium and Alzheimer's disease, a form of dementia in the middle-aged and elderly. It is a very tentative hypothesis to which there are some objections, and is framed in terms of the aluminium intake over many years. The additional amount of aluminium which people are likely to have consumed from the water as a result of the Lowermoor incident is negligible in this context.

11. Long-term ingestion of several thousands of milligrams of aluminium daily is known sometimes to affect bones and (in patients with severe renal failure) the brain, but such exposures were not approached in the present incident.

12. In summary, the aluminium concentrations would have had no effect other than rendering the water distasteful.

Sulphate

13. The concentrations of sulphate recorded by SWWA did not exceed the Directive limit of 250 mg/l or the WHO guideline value of 400 mg/l. The earliest of these results dates from 3 days after the incident. A sample analysed for the Camelford Scientific Advisory Panel by the County Analyst is reported by Mr Cross as containing more than 1000 mg/l. For comparison, concentrations slightly more than 1000 mg sulphate per litre are found in some continental bottled, natural mineral waters. Regular consumption of water containing 4400 mg/l has been reported from an African village.

14. Aluminium sulphate itself is said to have a "sweet astringent taste", and a saturated solution to be "mildly caustic". Less concentrated solutions of 5-10 percent have been used as local applications to treat ulcers. Aluminium potassium sulphate in concentrations of 1-4 percent has been used as a mouthwash and gargle. These concentrations are far greater than those noted in the water supply following the Lowermoor incident.

15. In a population not accustomed to water containing high sulphate levels, 1000 mg/l would be expected to produce a noticeable taste, and to have a laxative effect. Sulphates such as Epsom salts and 'Glauber's salt are used as laxatives, in doses corresponding to a sulphate intake

of 700 to 12000 mg in a day. The laxative action is due to the retention of more water than usual in the gut because of the poor absorption of the salt, and is not due to an irritant effect. Since sulphate is poorly absorbed, these high intakes do not lead to effects on other organs.

16. In summary, the only effect expected from the sulphate concentrations would be a mild laxative effect.

Copper

17. The highest concentration of copper recorded by SWWA appears to have been 20 mg/l, from a hot-water supply. It is standard advice that water for drinking or cooking should only be taken from a "cold" tap drawing direct from the mains supply, but it is not uncommon in practice for the "hot" supply to be used also. The highest concentration of copper other than in the hot supply was one reading of 8.8 mg/l, but otherwise all such readings were no higher than 1.8 mg/l, and nearly all below 1 mg/l.

18. The EC Directive limit is 3 mg/l, set to prevent an unpleasant taste in the water; the WHO Guideline Value is lower at 1 mg/l, based on the risk of staining of laundry and plumbing fixtures.

19. Copper is an essential nutrient, but the diet is adequate to provide the 2-3 mg required daily. The effects of ingestion of excessive amounts of copper are well described, and there have been several reports of the effects of water or soft drinks contaminated with copper. In several such reports, the copper level was about 30 - 40 mg/l, and the symptoms were abnormal taste, nausea, vomiting and diarrhoea, some times with abdominal pain, headache and dizziness. No mention of soreness or ulceration of the mouth appears in these reports. One unusual report attributes intermittent nausea and stomach cramps in a family to peak concentrations of 5.6 to 7.8 mg/litre experienced over several years. In every case, recovery from the effects seems to have been rapid and complete, and no residual disability was recorded.

20. Skin sensitivity to copper and its compounds appears to be extremely rare even from relatively high exposures in the industrial setting. There is one report of a skin rash in a mother and child, attributed to copper concentrations of 4 to 7.6 mg/l in the water supply. The rash disappeared following the use of other water. No other consumer of the water over the previous ten years had come to demonstrable harm.

21. There are also several reports in the scientific literature of accidental poisoning, or deliberate self-poisoning, with very large amounts of copper sulphate from 1000 mg to over fifty times that amount. 1000 mg of copper sulphate contains 400 mg of copper. The clinical picture in these cases is of a metallic taste, nausea, vomiting, diarrhoea and abdominal pain, associated in the most severe cases and highest doses with bleeding from erosions of the gut lining, shock, jaundice from intravascular haemolysis and from direct liver damage, and kidney failure from shock and from tubular damage secondary to haemolysis. Free haemoglobin, and red blood cells, are seen in the urine in severe cases. Deaths are associated with the ingestion of upward of 25000 mg of copper sulphate. The case reports, associated as they are with copper intakes vastly greater than those arising from the Lowermoor incident, are only relevant to the question of delayed or persistent after-effects. No such after-effects are recorded in those patients who survived the early phase of massive copper sulphate poisoning.

22. The question of 'chronic copper poisoning' has been raised, perhaps because such a condition is described in ruminants, particularly sheep. It is a misleading suggestion, because:

a) the processes within the human body for storing or eliminating copper are different from those in ruminants;

b) no condition of chronic copper poisoning has been established in humans; and

c) only a brief exposure to untoward copper concentrations resulted from the Lowermoor incident.

23. In summary, the highest recorded copper concentrations would be expected to cause nausea, vomiting, diarrhoea, abdominal pains, headache and dizziness. A skin rash would be a very rare effect. The symptoms would abate completely and rapidly on changing to water with a normally low copper concentration.

Lead

24. Out of a large number of analyses in the first five days after the incident, only a few exceeded the EC limit of 50 microgrammes per litre. The highest reported by SWWA was 460 $\mu\text{g/l}$ in a hot-water sample. The highest concentration from the cold supply was 220 $\mu\text{g/l}$. Such brief exposure to these concentrations is of no consequence.

Zinc

25. The concentration of **7.83** mg/l in one SWWA sample, from a hot-water tap, exceeded the EC limit, and WHO Guideline Value, of 5 mg/litre. No other samples breached the limit. A concentration of **7.83** mg/l would be expected to impart a taste to the water, but to have no effect on health. Zinc is an essential element, the daily requirement being in the range 4 to 15 mg. There is a report of irritability, muscular stiffness and pain, loss of appetite and nausea in two adults whose drinking-water contained zinc at 40 mg/litre. However, daily oral doses of up to 660 mg zinc sulphate (containing 270 mg zinc) have been given for long periods to promote wound healing, apparently without adverse effects.

Symptoms associated with the incident

26. A wide range of symptoms and ailments have been mentioned in newspaper reports of the incident, and elsewhere. Many are similar to the nonspecific, common, minor conditions which occur commonly in clinical practice, for which it is often difficult or impossible to find a cause in individual patients, and which resolve without treatment. What follows is a discussion of the reported symptoms in the light of the recorded chemical composition of the water supply at the time of the incident.

27. Tap water, particularly from the hot water system, containing a variable mixture of these substances, must have been very unpalatable in some households. This by itself would be enough to induce nausea and vomiting in some of those who had swallowed a quantity of it. The sulphate content would have had a laxative effect in some people. It is not possible to derive, from the published reports, a threshold to the irritant effect of copper but it seems possible that this may have added to the gastrointestinal symptoms experienced.

28. The complaints of sore throats, blistering and mouth ulcers are not readily explicable on the basis of the water quality. Aluminium potassium sulphate solutions have been used as mouthwashes, and aluminium compounds are frequently taken by mouth in large quantities. Zinc sulphate by mouth does not cause these effects, nor are they described in cases of acute copper or copper sulphate poisoning. The pH of the water was comparable to that found in many soft drinks. Sore throats and mouth ulcers are common and could well have occurred coincidentally. Although ulceration commonly occurs without apparent cause, the mouth can be irritated by a variety of substances, sometimes with short-lived, superficial ulceration. Such effects are not

described- in the published reports in relation to any of these substances. Severe, widespread or prolonged ulceration would not be expected.

29. Skin rashes in sensitive individuals bathing in the water could have resulted from the change in water quality. Specific sensitivity to copper compounds has been described, but appears to be rare.

30. Muscle pains, joint pains and recrudescence of arthritis have not been described as consequences of any of the agents, with the possible exception of zinc at higher concentrations than are relevant (see para 25 above). Muscle cramps are another common symptom, often occurring for no particular reason. They can be a consequence of dehydration, but it is probable that anyone with this degree of dehydration would have sought medical advice.

31. Various urinary symptoms have been mentioned. Dehydration from vomiting and diarrhoea or avoiding drinking could have resulted in dark concentrated urine passed in smaller amounts than usual. Haemoglobinuria, haematuria and renal failure are consequences of severe copper sulphate poisoning, but the doses necessary are very much greater than the exposures from this incident. Anyone who believes that they have passed blood in the urine and has attributed it to the Lowermoor incident would be best advised to seek medical advice urgently for this to be checked and so that, if haematuria has occurred, the true cause can be ascertained by appropriate investigations.

Groups who may have been at special risk

32. It is unlikely that the unborn child would have been affected. The brief maternal exposures to slightly elevated amounts of lead and zinc should have no consequence. Aluminium is poorly absorbed from the gut, and far greater maternal exposures result from the use of antacids containing aluminium in the treatment of heartburn in pregnancy. Sulphate is likewise poorly absorbed. Tablets containing copper sulphate as one component are sometimes prescribed throughout the antenatal period to prevent anaemia, the daily dose containing 2.5 to 5 mg copper sulphate. Studies in animals have shown no effect on the foetus, even from very large amounts of copper compounds taken throughout the period of gestation.

33. Bottle-fed babies and young children could have been more susceptible to the abnormal water, because their intake is greater in relation to body weight. Feed made up with the water may have been unpalatable, and in some instances it may not have been possible to make

up the feed (curdling milk featured in some consumers' complaints).

34. The only patient in the area on home dialysis was elsewhere at the time of the incident.

35." Given that Wilson's disease, an abnormality of copper metabolism, occurs in only 5 people out of one million, it is likely that no sufferer from this condition was in the area. A patient on treatment for Wilson's disease would not be at risk from the small additional intake of copper, since the treatment ensures adequate excretion of copper. In a patient with undiagnosed Wilson's disease, it is conceivable that the onset of symptoms could have been accelerated, leading to earlier diagnosis and treatment.

Long-term effects

36. There is no reason to expect long term or delayed harm following on the evident effect of these substances on the gastrointestinal tract. Long term effects on other organs would not be expected for several reasons as follows:

(a) the amount of the substances absorbed and retained at the time of the incident would have been very small

(b) the period of exposure was relatively short; where long term effects of chemicals on health are described in the absence of acute effects, protracted dosage, usually over many years, is required to produce a significant risk of harm

(c) no long term effects are reported in the scientific literature for the most of these substances, even in relation to long continued exposure at moderate levels. The main exception is lead but, as already indicated, no ill-effects will be expected from the total quantities of lead at issue in the incident.