

A CHEMICAL GASTRO-ENTERITIS FROM WATER SUPPLIES*

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THESE studies were commenced in an attempt to find a bacterial cause for a type of recurrent gastro-enteritis affecting a small town and the surrounding rural area.

Patients associated this illness with the intermittent brown discoloration of the water supplies after heavy rain. From analyses of this discoloured water taken at the time of an epidemic it was reported that the water was normal and suitable for drinking, containing no chemical, physical or metallic irritants. Further investigations, done at a later date in another laboratory, using more modern methods, showed that these water supplies were capable at times of attacking the lead, copper, and iron pipes through which they were conveyed. When no bacteriological cause could be found for this illness, attempts were made to trace any association with lead. As a result of this, suggestions are now made of a possible mechanism by which changes in the water character and intermittent aggressive tendencies toward piping could give rise to an illness of this sort.

It is usual to associate lead with obstinate constipation. References to lead causing diarrhoea however are of great antiquity. Both Galen and Aetius mentioned that water conveyed in lead pipes sometimes caused dysentery (Adams 1846). In an early description of lead poisoning at Leadhills, Wilson (1754) comments "Sometimes diarrhoea makes a cure but if it continues too long it is very hurtful". Baker (1767) in his classical description of the cause of Devonshire colic mentions that among painters "some are cured by a spontaneous looseness of the belly". Tanquerel des Planches (1839) discusses at some length the gaseous distension found so frequently in lead poisoning, and Pliny has a comment on the special sensitivity of dogs to the toxic effects of lead fumes. In modern

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times, those who are engaged in the care of lead workers are quite prepared to accept that diarrhoea can occur in some cases of lead poisoning.

Material and methods

These investigations were carried out as part of, or in addition to, the routine general practice care of a practice of 2,000 patients comprising approximately half of the population of a small town and the surrounding rural area. They consisted of examination of water samples for lead content, bacteriological and virological culture of stool samples from patients with diarrhoea, and blood lead, urine coproporphyrin estimations and punctate basophil counts in an attempt to reveal any increased lead absorption.

The clinical condition

The gastro-intestinal upset which is prevalent occurs in single cases, groups or epidemic form. Its features are abdominal pain, nausea, vomiting, and diarrhoea, often with flatulent distension of the abdomen. There is no pyrexia and no rise in white blood count or erythrocyte sedimentation rate. The illness may affect one or more persons in a household and can occur repeatedly in the same person, recurrences in some cases being separated by only a few days. Onset and termination of vomiting and diarrhoea are abrupt. Many patients return empty stool sample jars after two or three days because the diarrhoea has been followed by a period of constipation. In some families it seems that those who vomit most have less diarrhoea and *vice versa*. At the time of one epidemic a number of patients said that their vomit was "as green as grass". Cases have occurred simultaneously and inexplicably at isolated places at opposite ends of the practice. Lists of foodstuffs eaten, compiled both by family doctor and by the staff of the public health department, have been completely unhelpful as were attempts to trace contacts. Bottle-fed babies were sometimes affected at the same time as adults and some affected patients said even their dogs had diarrhoea. The burgh surveyor of the town, who also received complaints associating this illness with discoloration of the water supply, once said that it seemed as if the water was acting like "a dose of salts", but the original water analyses gave no hint as to how this effect could be caused.

The population are in the habit of accepting this illness as temporary and self limiting and the doctor is only informed of a small proportion of the people who are affected. In one instance where this point was explored it was found that only two out of 20 patients affected sought medical advice. The distribution of symptoms in the cases where the family doctor was consulted during a period of 11 months is given in figure 1.

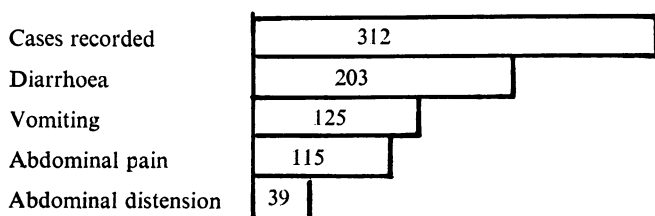


Figure 1
Symptoms during 11 months

Water analyses

There is a large number of small private water supplies to farms and cottages as well as those provided by town and county councils. Samples have been taken from 49 houses and 25 different water supplies in the practice area. More detailed information has already been given (Wilson 1966) concerning these analyses. The range of lead content was from 1 mg/litre to nil and a considerable number exceeded the present World Health Organization international standard limit for the lead content of drinking water of 0.05 mg/litre.

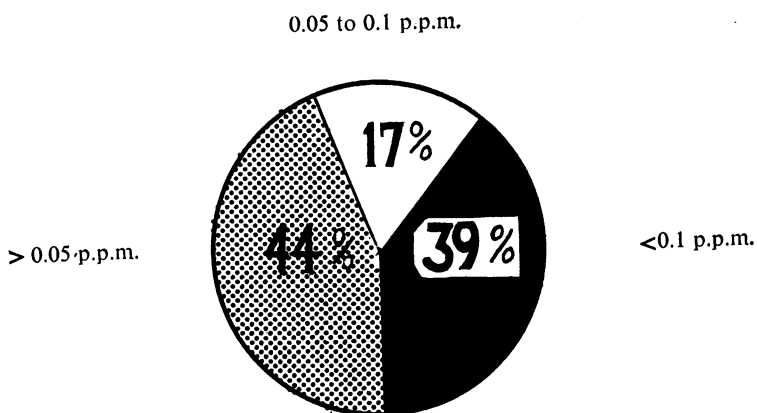


Figure 2
307 water analyses for lead

The lead content fluctuates with the rainfall. Samples were taken in a house which had no mains water tap, all water passing through a lead lined storage tank, though some of the internal pipes were of copper. These samples showed that the lead solvent activity was virtually absent at a time when there was no rain. After heavy rain there was a marked rise in the lead content. On a subsequent occasion the copper content was also estimated after rain.

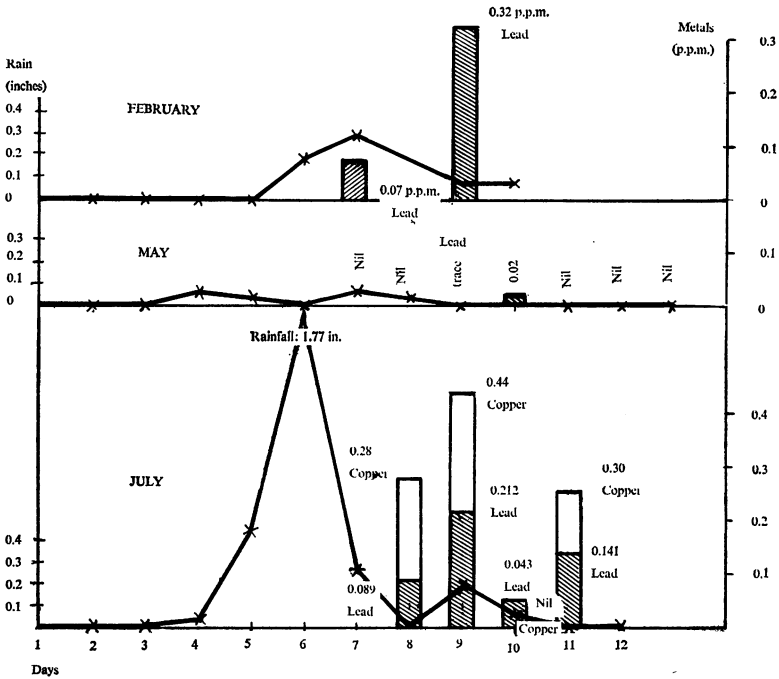


Figure 3
Variation in metal concentration after rain

Other metals besides lead and copper may be found in domestic water supplies. Table I shows especially the effects of aggressive water delivered through iron pipes.

TABLE I
INNERLEITHEN BURGH WATER SUPPLY

pH	..	..	..	..	6.8
Hardness total	..	..	..	..	26 p.p.m. Ca CO ₃
Iron total	..	..	..	..	Fe 4.4 p.p.m.
Iron in solution	..	..	..	..	Fe 0.05 p.p.m.
Manganese	..	..	..	..	Mn 0.05 p.p.m.
Zinc	..	..	..	..	Zn 0.06 p.p.m.
Lead	..	..	..	..	Pb 0.05 p.p.m.
Copper	..	..	..	..	Cu 0.05 p.p.m.

Bacteriology and virology

During a period of 4½ years (October 1958 to May 1963) the only organism found frequently was *shigella sonnei*. This was almost entirely limited to two small epidemics. In 1959, 12 cases were

diagnosed in five weeks and in 1962, 42 cases in 13 weeks.

Originally, an attempt was made to obtain a single stool sample for bacteriological culture from every patient who complained of diarrhoea. No intestinal pathogens were found in a very high proportion of these. The routine was therefore modified and samples were latterly obtained only if diarrhoea was severe or persistent. Apart from the samples taken during the two dysentery epidemics, out of 347 stool cultures 323 were negative. The 24 positive cultures included seven different organisms. This is a 93 per cent negative culture rate if the epidemics are excluded or 80 per cent over the whole period.

When bacteriological culture was proving unsuccessful in identifying a specific pathogen to account for this illness virus culture was added to the investigation. Of 198 virus cultures 96 per cent were negative. The positive virus cultures were: Polio virus 3-4 (two non-paralytic poliomyelitis and two diarrhoea following oral polio immunization), Coxsackie A9-1, Coxsackie B2-1, E.C.H.O. 7-1, adenovirus 5-1.

Blood lead estimations

These were done on 20 ml. blood samples by dithizone methods. For comparison with 44 cases of gastro-enteritis of unknown cause, results have also been given in figure 4 for 18 patients with other conditions where the diagnosis was known (ranging from a facial paralysis to a foot-drop from a prolapsed intervertebral disc).

One patient had two separate attacks of gastro-enteritis and a number of blood lead estimations were done.

M.A. female, aged 58. Complaints: abdominal pain, nausea, distension, diarrhoea. She had no vomiting or pyrexia. Hb 17.2 Gm./100 ml. W.B.C. 4,200 per cu. mm., ESR 2 mm. in 1 hour (West). Stool—no intestinal pathogens isolated. Blood lead estimation on the second day of illness 54 $\mu\text{g./100 ml.}$, and on the eighth day 83 $\mu\text{g./100 ml.}$ with punctate basophil count of 0.6 per cent. Repeat samples three and four months later: 42 $\mu\text{g./100 ml.}$ and 39 $\mu\text{g./100 ml.}$

A year later there was a similar apyrexial attack, but in this episode a Coxsackie virus A9 was isolated from the stool. Two blood samples had a lead content of 41 $\mu\text{g./100 ml.}$ A barium enema done during the four-week interval while virus culture was proceeding showed no abnormality.

Dogs

Bacteriological cultures of stool samples from four dogs with diarrhoea were negative. Blood lead levels on three dogs with diarrhoea were 100, 75 and 115 $\mu\text{g./100 ml.}$ In a fourth dog the blood lead rose from a previous level of 50 $\mu\text{g./100 ml.}$ to 100 $\mu\text{g./100 ml.}$ during an attack of diarrhoea and fell to 56 $\mu\text{g./100 ml.}$ afterwards. The normal blood lead level of animals is 0-25 $\mu\text{g./100 ml.}$ (Gardner 1961).

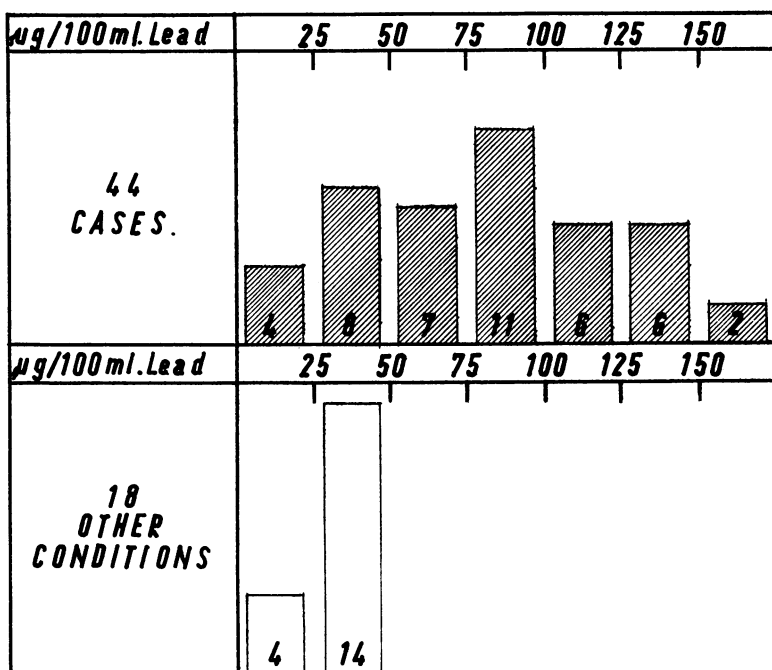


Figure 4
Abdominal pain, vomiting and/or diarrhoea of unknown cause and blood lead level

Screening of patients in the practice for increased lead absorption

The detailed results of screening 450 patients for punctate basophilia and 746 patients for increased urine coproporphyrin have already been published (Wilson 1966). Of the 69 patients from whom punctate basophilia was reported 88 per cent had one or more of the following complaints: abdominal pain, vomiting, flatulent distension and diarrhoea. The corresponding figure for patients with increased urine coproporphyrin—after excluding certain groups including those with known hepatic disorder—was 75 per cent with one or more of these complaints.

Discussion

There are many possible causes for the symptoms of gastrointestinal upset which have been described, ranging from dietary indiscretion to malignant disease of stomach and colon. The cause of some can be diagnosed from the history, while others need radiological and surgical investigation. There remains in this practice, however, a large group of patients with very similar symptomatology. The type of history is very suggestive of gastro-

intestinal irritation, rather than of an infective process and this is supported by normal white blood counts and erythrocyte sedimentation rates. The negative results of stool culture, both for bacteria and viruses, show the failure of a conventional bacteriological approach to demonstrate a cause.

There is evidence of an association between outbreaks of this type of gastro-intestinal disturbance and the occurrence of heavy rainfall but this was not constant (eight out of 12 episodes studied). With a condition where as few as two patients may consult the doctor out of 20 affected, such simple correlation is of little value. Some patients with gastro-enteritis, but not all, have shown definite evidence of increased lead absorption. The most conclusive of the three diagnostic methods used—blood lead estimation—has given similar results from different laboratories for dogs and humans. This seems in the nature of a transient increase. The fluctuating lead content of the water is inevitably suspect as the source of this lead though there are other sources of lead absorption. It directs further attention towards the water supplies.

The brown discoloration in the water after heavy rain includes a fine sediment of organic matter. This is a common occurrence in some country districts and is by no means confined to this practice area. Such organic matter has three relevant properties: (1) It is one of the important factors in increasing the aggressive attack of water on the pipes which carry it. (2) It contains weak acids which form salts. (3) It absorbs heavy metals. In one water sample 87 per cent of the lead was contained in the sediment. A sample of the sediment alone was reported as containing lead in excess of 10 p.p.m.

There is a seasonal fluctuation in the organic matter in water associated with the rotting of vegetation. It is greater in winter than in summer. A graph prepared by the laboratory of the Permutit Company from London water over a seven-year period shows the organic matter in December and January consistently much above June and July. Lead salts of humic and fulvic acids have been prepared from organic matter extracted from London water supplies and experiments with these have confirmed that being the salts of weak acids they are readily broken down by dilute hydrochloric acid into lead chloride. Similar salts have also been prepared with copper (Kressman 1964). Sir Thomas Oliver in 1911 suggested that ingested lead would be converted in the stomach into the chloride by the action of the gastric hydrochloric acid.

It seems probable therefore that any metals present in the sediment will be released in the stomach in the form of metallic chlorides. The chlorides of metals in sufficient quantities have properties ranging

from astringent to corrosive. Occasional upsets caused by iron preparations are familiar in clinical practice. Copper in sufficient quantity causes acute gastro-enteritis of which an outstanding feature is the bright green vomit. Zinc chloride is used in dermatology as an astringent and reference has already been made to lead causing diarrhoea.

The clinical features described seem much more in the nature of a local gastro-intestinal irritation than the effects of a chronic poisoning. If a combined astringent effect was involved from lead, iron and copper derived from different sections of water piping, then wide variations in the amount of lead absorbed would be expected, and there might also be a considerable loss of the irritant material in the vomit and the diarrhoea. This seems the most probable cause of the illness.

Outbreaks of gastro-enteritis of this sort are frequently reported by the Press in other areas apart from this practice, without any satisfactory bacterial or other cause being found. Studies of the water supplies for evidence of transient changes in aggressive action on piping may be important. These should be considered where the water supplies are soft with a pH below 7.8, and there have been climatic changes likely to cause disturbance in the water catchment area. Such disturbance took place for example in the water supplies of Worcester at the time of a large epidemic of gastro-enteritis recently. After flooding in the water catchment area the water pH fell from a normal of 7.1 or 7.2 down to 6.7. No toxic metals were detected by a test accurate to 0.1 mg./litre (O'Donnell 1966). From a recent study of the water supplies of 43 county boroughs in the British Isles it has been suggested that 96 per cent of their population is consuming water which is at times sufficiently acid to dissolve lead (Reed and Tolley 1967).

Summary

A recurrent gastro-enteritis affecting a small town and the surrounding rural area was attributed by some patients to intermittent brown discoloration of the water supplies. It affected adults, children, bottle-fed babies and dogs. There was no pyrexia or rise in white blood count or E.S.R. No bacterial or viral cause was found on examination of stool samples. The water was discovered to have intermittent aggressive activity against lead, copper and iron pipes. Some patients with gastro-enteritis had transient evidence of increased lead absorption and four dogs also had raised blood lead levels. This illness seems more in the nature of an acute gastro-intestinal irritation than a chronic poisoning. It is suggested that a probable cause is the release in the stomach of a mixture of metallic chlorides. This effect would be produced by the action of the gastric

hydrochloric acid on the sediment of organic matter in the water and on the metals which it contains.

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