Is lead in tap water still a public health problem? An observational study in Glasgow

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Abstract

***Objective*—To assess the relation between tap water lead and maternal blood lead concentrations and assess the exposure of infants to lead in tap water in a water supply area subjected to maximal water treatment to reduce plumbosolvency.**

***Design*—Postal questionnaire survey and collection of kettle water from a representative sample of mothers; blood and further water samples were collected in a random sample of households and households with raised water lead concentrations.**

***Setting*—Loch Katrine water supply area, Glasgow.**

***Subjects*—1812 mothers with a live infant born between October 1991 and September 1992. Blood lead concentrations were measured in 342 mothers.**

***Main outcome measures*—Mean geometric blood lead concentrations and the prevalence of raised tap water lead concentrations.**

***Results*—17% of households had water lead concentrations of 10 μg/l (48.3 nmol/l) or more in 1993 compared with 49% of households in 1981. Tap water lead remained the main correlate of raised maternal blood lead concentrations and accounted for 62% and 76% of cases of maternal blood lead concentrations above 5 and 10 μg/dl (0.24 and 0.48 μmol/l) respectively. The geometric mean maternal blood lead concentration was 3.65 μg/dl (0.18 μmol/l) in a random sample of mothers and 3.16 μg/dl (0.15 μmol/l) in mothers whose tap water lead concentrations were consistently below 2 μg/l (9.7 nmol/l). No mother in the study had a blood lead concentration above 25 μg/dl (1.21 μmol/l). An estimated 13% of infants were exposed via bottle feeds to tap water lead concentrations exceeding the World Health Organisation's guideline of 10 μg/l (48.3 nmol/l).**

***Conclusions*—Tap water lead and maternal blood lead concentrations in the Loch Katrine water supply area have fallen substantially since the early 1980s. Maternal blood lead concentrations are well within limits currently considered safe for human health. Tap water lead is still a public health problem in relation to the lead exposure of bottle fed infants.**

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Introduction

Concern about the neurological toxicity of lead in young children[1-6] has renewed interest in safety limits for lead in tap water.[7-9] The current European standard for lead in drinking water is 50 μg/l (241.5 nmol/l), which may be reduced to the World Health Organisation's new guideline of 10 μg/l (48.3 nmol/l).[9] We assessed the current lead exposure of infants (directly via tap water used in bottle feeds and indirectly via maternal blood) in a water supply area in which about half of households still have lead pipework[10] and in which maximal treatment measures (namely, pH adjustment from 1978, orthophosphate treatment from 1989) have been introduced to reduce plumbosolvency.[11-16]

Subjects and methods

The study set out to measure tap water lead and blood lead concentrations in a random sample of 150 mothers (sufficient to estimate the geometric mean blood lead concentration with a standard error of 0.4 μg/dl (0.019 μmol/l)) and to compare blood lead concentrations in groups of 80 mothers whose tap water lead concentrations were in the ranges <2, 2-9, 10-24, and 25-49 μg/l (<9.7, 9.7-43.5, 48.3-115.9, and 120.8-236.7 nmol/l (see table 1)), which gave 90% power to detect a ratio of mean blood lead concentrations of 1.4:1 at the 5% level of significance.

A total of 9243 women resident in the Loch Katrine water supply area gave birth to a live child between October 1991 and September 1992. To obtain sufficient numbers of households with raised tap water lead concentrations the study targeted all 1391 mothers living in areas in which water quality monitoring had shown a high prevalence of high water lead concentrations[17] and a 30% random sample of mothers in the remainder of the water supply area.

All mothers were sent a postal questionnaire in 1993 and invited to return a 30 ml water sample from the household kettle. Home visits were carried out by a research nurse, who obtained a 4 ml sample of maternal venous blood after stasis, a repeat kettle water sample, and a daytime water sample, comprising a 1 litre sample taken from the drinking water tap with no prior flushing.

Blood lead determinations were carried out at Glasgow Royal Infirmary by means of graphite furnace atomic absorption spectrometry after blood deproteinisation[18 19] in a laboratory participating in the United Kingdom National External Quality Assurance Scheme.

Water lead measurements were carried out at the National Measuring Accreditation Service accredited Strathclyde Water Chemistry Laboratory by atomic absorption spectrometry with electrothermal atomisation.[20] External quality assurance procedures included participation in the Water Research Centre Aquacheck scheme.

As response rates varied with neighbourhood type (eight categories of postcode sector based on census based housing and household characteristics) population prevalence data were estimated by applying observed prevalences within neighbourhood types to the distribution of neighbourhood types in the target population.[21]

The study was approved by the Greater Glasgow Health Board's community and primary care research ethics committee.

Results

A total of 1812 postal kettle samples were received (response rate 49%). Some 17% of all households and 43% (104/242) of households reporting the presence of lead pipework had kettle water lead concentrations of 10 μg/l (48.3 nmol/l) or more. A total of 83.5% of infants were wholly or partly bottle fed. Some 84.5% of households with bottle fed infants had tap water lead concentrations below 10 μg/l; 9.7% were in the range 10-24 μg/l, 4.1% in the range 25-49 μg/l, and 1.7% in the range 50 μg/l or more.

Table 1—*Geometric mean blood lead concentrations by exposure to water lead as measured in daytime water samples*

Water lead			Mean blood lead (range)		No (%) of blood samples with lead concentration:	
µg/l	nmol/l†	No	µg/dl	µmol/l	>10 µg/dl (> 0.48 µmol/l)	>5 µg/dl (> 0.24 µmol/l)
< 2	< 9.7	140	3.64 (1.04–21.13)	0.18 (0.05–1.02)	5 (4)	29 (21)
2–9	9.7–43.5	97	4.36 (1.86–24.24)	0.21 (0.09–1.17)	5 (5)	30 (31)
10–24	48.3–115.9	64	5.25 (1.86–12.43)	0.25 (0.09–0.60)	4 (6)	36 (56)
25–49	120.8–236.7	21	5.65 (2.28–21.76)	0.27 (0.11–1.05)	2 (10)	12 (57)
⩾ 50	⩾ 241.5	20	6.63 (2.90–13.88)	0.32 (0.14–0.67)	3 (15)	14 (70)

† 1 µg/l ≈ 4.83 nmol/l. Hence divisions in µg/l cannot yield exactly consecutive SI values.
Spearman rank coefficient measuring relation between blood lead and water lead concentrations 0.387 (P<0.001).
Proportion of cases of raised blood lead concentrations which were not attributable to raised water lead concentrations was estimated on basis of blood lead data in 86 subjects for whom all three water samples showed lead concentrations < 2 µg/l (< 9.7 nmol/l).

The research nurse obtained blood specimens from 342 mothers, including a random sample of 138 households and 204 other mothers stratified according to household kettle water lead concentration. A smaller than expected number of households with raised water lead concentrations (table 1) was due partly to the low prevalence and partly to the fact that daytime water samples (the legal standard) collected at the home visit provided a lower estimate of water lead exposure than kettle water samples.

The geometric mean blood lead concentration of the random sample of mothers was 3.65 µg/dl (0.18 µmol/l). In 86 households where lead concentrations were below 2 µg/l (9.7 nmol/l) in all three water samples the geometric mean blood lead concentration was 3.16 µg/dl (0.15 µmol/l).

There was a direct relation between tap water lead and maternal blood lead concentrations (table 1). The estimated proportions of cases of maternal blood lead concentrations above 5 and 10 µg/dl (0.24 and 0.48 µmol/l) which were attributable to a tap water lead concentration above 2 µg/l were 62% and 76% respectively (table 1).

Discussion

The crude response rate to the postal survey of 49% was probably an underestimate of the true rate as 21% of respondents had changed address since the birth of their child on average 18 months previously. Probably some questionnaires were not received.

Tap water data collected in 1981 in association with a European Commission blood lead survey suggested that there had been a large fall in the proportion of households with tap water lead concentrations above 10 µg/l (48.3 nmol/l)—that is, from 49% of households in 1981 to an estimated 17% in 1993 (M R Moore and S J Robertson, personal communication, 1995).

The geometric mean blood lead concentration fell from 11.9 µg/dl (0.57 µmol/l) in 1981[22] to 3.7 µg/dl (0.18 µmol/l) in 1993 (fig 1). As blood lead estimations were carried out in the same laboratory with appropriate internal and external quality control procedures the trends are likely to be real and not confounded by measurement bias. Compared with previous studies[22] the mean maternal blood lead concentration in 1993 was substantially lower in relation to a given tap water lead exposure (fig 1). The results were consistent with a reduction since 1981 of lead exposure from non-water sources such as food, air, and street dust.[23-24] It is also possible that orthophosphate in the water supply reduced the bioavailability of lead in tap water.[25]

Tap water still accounts for about two thirds of cases of raised maternal blood lead concentrations. Non-water sources of lead exposure are the most likely explanation of the background geometric mean blood lead concentration of 3.16 µg/dl (0.15 µmol/l).

HEALTH IMPLICATIONS OF MATERNAL BLOOD LEAD

It is estimated that the effect of low dose exposure to lead is a two to three point decrement in intelligence quotient for a 10 µg/dl (0.48 µmol/l) increment in blood lead concentration in the range 10-20 µg/dl (0.48-0.97 µmol/l).[6 26] As the mean maternal blood lead concentration in this study was below 5 µg/dl (0.24 µmol/l), with only 4% (5/138) of values above 10 µg/dl and no woman having a blood lead concentration above 25 µg/dl (1.21 µmol/l)[5 27]—even in the subgroup whose tap water lead concentrations were above 50 µg/l (241.5 nmol/l; table 1)—it may be concluded that current maternal blood lead concentrations in Glasgow are well within limits considered safe for adults.[28]

We could not estimate precisely the blood lead concentrations to which an unborn child might have been exposed, nor the lead exposure of infants fed with breast milk. However, the generally low mean maternal blood lead concentration, with over 96% of mothers having a blood lead concentration below 10 µg/dl (0.48 µmol/l), suggests that exposure via these routes is likely to be low. In general lead concentrations in breast milk are about one tenth of the concentrations in blood.[29] The WHO recommends that when most children have blood lead concentrations below 10 µg/dl no further action is required.[28]

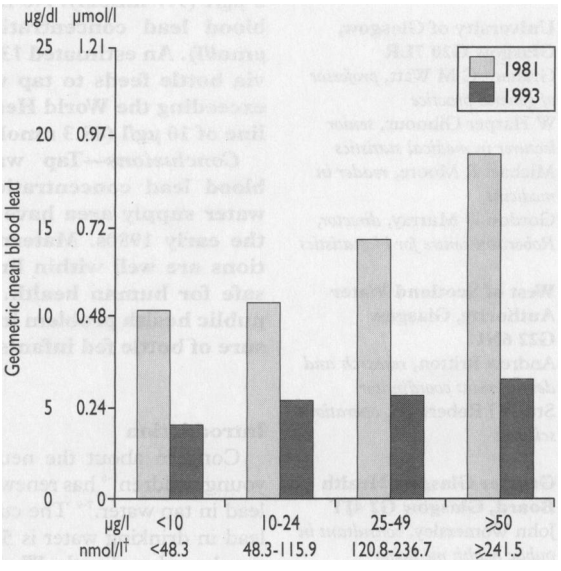

Fig 1—*Geometric mean blood lead concentrations according to tap water lead exposure in 1981 and 1993. (In 1981 detection limit for lead in water was 10 µg/l (48.3 nmol/l); 1993 blood lead results for water lead exposure below 2 and 2-9 µg/l (below 9.7 and 9.7-43.5 nmol/l) are therefore pooled to show mean blood lead value for water lead exposure below 10 µg/l). †Note that 1 µg/l ≈ 4.83 nmol/l. Hence divisions in µg/l cannot yield exactly consecutive SI values*

Key messages

- Tap water lead and maternal blood lead concentrations have fallen substantially in the past decade
- For a given tap water lead concentration maternal blood lead concentrations are much lower than they were in 1981
- Tap water lead remains the main correlate of raised maternal blood lead concentrations
- An estimated 13% of infants are exposed via bottle feeds to tap water lead concentrations of 10 μg/l (48.3 nmol/l) or more
- Maternal blood lead concentrations are generally within limits considered safe for human health

HEALTH IMPLICATIONS OF LEAD IN TAP WATER

The 1993 WHO guidelines for the quality of drinking water describe a guideline lead concentration of 10 μg/l (48.3 nmol/l) for water used to make up bottle feeds.[10] In the Loch Katrine water supply area about 13% of infants are exposed via bottle feeds to tap water lead concentrations which exceed the WHO guideline.

A precautionary measure, therefore, might be to assess tap water lead in the homes of pregnant women and when concentrations are raised to advise the use of lead free bottled water during pregnancy or until lead pipework can be replaced. Mothers in these homes should be strongly advised in favour of breast feeding.

A fuller version of this report may be obtained by writing direct to GCMW. We thank Mary Stewart for the postal survey and home visits; Margaret Slowman for maintaining the research office; Dr Robert Low and colleagues for help with recruitment; Dr David Halls, of Glasgow Royal Infirmary, for supervising blood lead measurements; and colleagues at Strathclyde Water Chemistry Laboratory, Rutherglen, for analysis of water samples (Steven Davis and staff) and collating results (Jim Dillon). We also thank the mothers who took part and granted access to their homes. The views expressed are ours alone and do not necessarily represent those of the supporting organisations.

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Conflict of interest: Two of us (AB and SJR) are employed by the West of Scotland Water Authority.

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A MEMORABLE PATIENT

The station master

My first appointment, in 1952, was as house physician at an acute general hospital.

Shortly after my arrival a man aged 66 was admitted having had a moderately severe stroke, with aphasia. His wife had struggled for a few weeks to care for him at home, but had found it too difficult. He was very demanding and refused to try to help himself. Home care facilities at that time were not as comprehensive as they are today, and in spite of her efforts he was scruffy and unkempt.

After his admission his wife spent as much time with him as the visiting hours allowed, and she willingly helped the nursing staff as much as she could. Within a few days I got to know her well. She told me that his working life had been spent on the railway, and at his retirement he was station master at a local station. For several years his station had been awarded the top prize for the best kept and best organised local station. His personal appearance had been immaculate, with a daily clean shirt and white stiff collar and, if possible, a fresh floral buttonhole. Nothing was too much trouble for him, and he would help everybody.

To see this man as I saw him as a patient, it was impossible to realise what sort of person he had been before his illness.

During my subsequent life, spent mostly working in general practice in a village community for over 30 years, I saw several similar patients, but I have never forgotten this scruffy unkempt man, slumped in a chair. He taught me a great amount about life and I hope this was reflected in my care for all my patients.—ERIC HAINSWORTH *is a retired general practitioner in Liskeard, Cornwall*