FLUSHING AT THE
CONSUMER’S TAP AS A
MEANS OF REDUCING
DRINKING WATER
LEAD LEVELS

LEAD IN POTABLE WATER
TECHNICAL NOTE No.2

ISSUED BY
WATER POLLUTION
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FLUSHING AT THE CONSUMER'S TAP AS A MEANS OF REDUCING DRINKING WATER LEAD LEVELS

PREFACE

1. This report has been prepared for the Lead in Potable Water Sub-Committee of the Standing Technical Advisory Committee on Water Quality by the Water Research Centre. The report has been approved by the Sub-Committee and endorsed by the Standing Committee and the Joint Committee on the Medical Aspects of Water Quality.

2. The report summarizes the available data on the likely effectiveness and cost of flushing at the consumer's tap as a means of reducing drinking water lead levels and it suggests advice that might be given to consumers by water undertakings which decide to implement a flushing policy as an interim solution in areas where high drinking water lead levels are found. It is considered that flushing should not be relied upon as a long term solution and this view has been endorsed by the Joint Committee on the Medical Aspects of Water Quality.

3. The Department of the Environment gratefully acknowledges the contribution which the Water Research Centre has made to this report.

T A DICK
Chairman
Lead in Potable Water Sub-Committee

O D HYDES
Secretary
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SUMMARY

1. This report has been prepared by the Water Research Centre to summarize the available data on the likely effectiveness and cost of flushing as a means of reducing drinking water lead levels.

2. For the purposes of this report, flushing is defined as the drawing off of water from the tap by consumers, preferably for some useful purpose, before the drawing of water for drinking, cooking or preparing babies' feeds.

3. The available data suggest that flushing at the consumer's tap could be an effective low cost means of reducing drinking water lead levels, but other factors have to be taken into account before a water undertaking recommended such a flushing policy in any particular area.

4. The data presented are used to suggest what advice might be given to consumers by a water undertaking where it decided to implement a flushing policy.

5. It is generally accepted that flushing may offer an interim solution in areas where high drinking water lead levels are found, but that it should not be relied upon as a long term solution. This view has been endorsed by the Joint Committee on Medical Aspects of Water Quality.
INTRODUCTION

6. In the past there has been considerable discussion of the merits of flushing at the consumer's tap as a means of reducing drinking water lead levels but there has been little factual information available on the effectiveness of this measure. Consequently the Lead in Potable Water Sub-Committee asked the Water Research Centre to bring together recently acquired data, to assess the effectiveness and cost and to provide guidance to water undertakings to enable them to assess the applicability of a flushing policy in any particular area.

7. For the purposes of this report, flushing is defined as the drawing off of water from the tap by consumers, preferably for some useful purpose, before the drawing of water for drinking, cooking or preparing babies' feeds.
8. High drinking water lead levels can arise where water has stood in contact with lead pipes.

9. Analysis of data obtained from the Regional Heart Study has shown that flushing reduces water lead levels at the consumer's tap. This can be seen in the comparisons of the lead levels in first draw, random daytime and flushed samples taken from properties with lead supply pipes in the eight towns for which data are currently available. (Figures 1A to 1I and Table 1). The water supplied to those towns for which data are presented included soft upland, hard groundwater and moderately soft river sources.

10. In each case, flushing was carried out in a manner that would comply with the suggestion in paragraph 15, with a considerable safety margin. In some cases flushing was effective in reducing lead concentrations to less than 100 μg/l. Flushing will not reduce lead levels at a tap which is not supplied directly from the rising main.

11. The effectiveness of flushing in reducing lead levels rests entirely with action taken by the consumer.
SUGGESTED RULES FOR FLUSHING

12. The effectiveness of flushing depends upon the interrelated variables of the volume of water flushed and the flow rate used. The volume of water to be flushed is a function of the capacity of the pipe (pipe volume) between the main and the kitchen tap in each particular case.

13. Laboratory experiments have been carried out in a simulated plumbing system in which the relative mix of 'fresh' and 'standing' water discharged from pipes during flushing at various flow rates was measured. These experiments enable an estimate to be made of the number of pipe volumes of water that have to be flushed to ensure that all the 'standing' water has been drawn off. Typical results are given in Figure 2.

14. Measurements of the steady state lead levels achieved in lead plumbed systems at various rates of flushing are given in Figure 3. These experiments enable the optimum flushing rate to be determined.

15. Considering the data presented in Figures 2 and 3 together, it can be seen that this experimental evidence suggests that an effective flushing policy, allowing a reasonable margin of safety, would be to flush 1.5 pipe volumes at a rate of 3 to 10 litres/minute. Flushing smaller volumes would run the risk of achieving little benefit (Figure 2), and using higher flow rates would run the risk of lead levels beginning to increase, perhaps due to disturbance of pipe deposits (Figure 3). These flow rates and volumes need to be expressed to the consumer in descriptive rather than numerical terms.

16. The flow rate of 3 to 10 litres/minute could perhaps be described as "a fairly fast rate, but not so fast that excessive splashing occurs". The interpretation and description of 1.5 pipe volumes is not so straightforward. For a 0.5 inch diameter pipe, 1.5 pipe volumes is equivalent to 0.19 litres/metre length and data from 23 large towns in the Regional Heart Study indicate that this would amount to about 1.3 litres (approximately 1 gallon or half a washing-up bowl full) in the average case and less than 11.7 litres (approximately 2.5 gallons or a washing-up bowl full) in 95% of cases. This is consistent with data gathered by the Expert Advisory Group on Costs of the Lead in Potable Water Sub-Committee of the Standing Technical Advisory Committee on Water Quality.

17. It is suggested that water undertakings advice to consumers on flushing at the tap should aim to be effective in at least 95% of cases. Possible advice would be to flush half a washing-up bowl full for 0.5 inch diameter pipes up to 20 metres and to flush a washing-up bowl full for 0.5 inch diameter pipes over 20 metres long.
18. If a flow rate of 3 litres/minute is used the flushing time would be about 1.5 minutes to be effective in the average case, and about 4 minutes to be effective in 95% of cases. If a flow rate of 10 litres/minute is used the flushing times would be about 0.5 and 1.25 minutes respectively.

19. Data from stagnation curves indicate that relatively high water lead levels can be produced when water has stood in contact with lead pipes even for relatively short periods of time. Therefore, when flushing is recommended by a water undertaking it is suggested that the consumer should be advised to flush every time water is taken for drinking, cooking or preparing babies' feeds unless about 12 litres (2.5 gallons) of water have been drawn within the previous 15 minutes. If this water has been drawn from anywhere other than the cold kitchen tap (ie any hot tap or by flushing the toilet) then it is still necessary to flush the short length of pipe between the rising main and the cold kitchen tap. This would require the drawing off of about 1 litre (2 pints) of water in most cases. The consumer should be advised to use or retain for later use any water drawn during flushing.

20. Data from the Water Research Centre Technical Report 137, "Drinking Water Consumption in Great Britain" suggests that on this basis flushing might be required up to about nine times per day, involving about 40 litres/household/day (14.6 m³/household/year) of water to be effective in the average case or about 100 litres/household/day (36.5 m³/household/year) to be effective in 95% of cases.
OPERATIONAL AND COST ASPECTS

21. If all the water drawn during flushing were used for some useful purpose for which water would otherwise have been drawn at some other time, then the increased usage and cost would be zero.

22. If instead, all of this water were flushed to waste there would be an increase in water consumption. If all the houses in an area flushed about 100 litres/day to waste, there would be about a 17% increase in domestic consumption (based on 600 litres/household/day). This is equivalent to about a 10% increase in the total water consumption (domestic plus trade based on 1000 litres/household/day). In practice the increase in average domestic consumption would be less because non lead plumbed properties would not need to flush and some lead plumbed properties would not need to flush the maximum volume.

23. It is likely that much of this increased demand would be experienced at times of peak flows, and operational constraints may restrict the implementation of a flushing policy. If flushing is to be implemented as an interim measure then it is reasonable to assume that this is most likely where the installed capacity was sufficient to treat and supply any additional water used, and to collect and treat the resulting increased sewage flows.

24. Where sufficient capacity exists the unit cost for the water supplied is likely to be in the range 0.5 to 1.5 p/m$^3$ and the unit cost for sewage treatment is likely to be in the range 0.5 to 1.5 p/m$^3$, which gives a total cost of 1 to 3 p/m$^3$. Hence, if the volume of water flushed to waste were in the range 14.6 m$^3$/year/household to 36.5 m$^3$/year/household (see paragraph 20), the annual costs would be in the range of £0.15 to £1.1 per household.

25. Table 2 gives the range of estimated costs of flushing in various sizes of supply areas, together with estimates of the possible maximum increase in demand.

26. Although flushing may increase demand for water, it is unlike leakage from the distribution system in that it can produce a beneficial effect in reducing drinking water lead levels. Thus the cost of providing any additional water for flushing must be compared with other means of reducing lead levels and therefore Table 2 also shows the possible range of capital and annual operating costs for water treatment for comparison. It can be seen that
flushing has the potential to offer a cheap interim solution in many cases. Comparison of the costs of remedial action in typical supply areas on the basis of Nett Present Values is given in Figure 4.

27. If flushing were considered where additional water supply and/or sewage disposal capacity were required there would be a financial penalty in bringing forward planned extensions or new works. If the total demand was increased by up to about 10% this might imply new schemes being brought forward by up to about 5 years.
CONCLUSIONS

28. Flushing can be an effective means of reducing drinking water lead levels where the kitchen tap is fed directly from the rising main. It will not be effective where the water is supplied through lead lined tanks.

29. The effectiveness of flushing rests entirely upon action by the consumer. In some cases it is likely to be effective in reducing lead levels to less than 100 μg/l.

30. For flushing to be effective in at least 95% of cases the available evidence suggests that about 4.3 litres (approximately 1 gallon or half a washing up bowl full) needs to be flushed for 0.5 inch diameter pipes up to 20 metres long and about 11.7 litres (approximately 2.5 gallons or a washing up bowl full) needs to be flushed for 0.5 inch diameter pipes over 20 metres long.

31. Flushing should be carried out at a rate between 3 and 10 litres/minute which can be described as "a fairly fast rate, but not so fast that excessive splashing occurs".

32. To be effective flushing would need to be carried out every time water is drawn for drinking, cooking or preparing babies' feeds unless about 12 litres (2.5 gallons) of water have been drawn within the previous 15 minutes (see paragraph 19). The consumer should be advised to use or retain for later use any water drawn during flushing.

33. If the water drawn during flushing is allowed to run to waste the likely increase in demand in most areas could be relatively small. However, any increase is likely to be imposed at times of peak demand and thus there may be operational difficulties in some areas.

34. The cost of flushing can be very small compared to that of water treatment or pipe replacement but since its effectiveness relies entirely on action by the consumer flushing is considered to be an interim solution to high water lead levels.
LEAD LEVELS

Fig. 1A TOWN A (28 properties)

Fig. 1B TOWN B (16 properties)

No. of properties

Mean

FIRST DRAW

Random Daytime

No. of properties

Mean

First Draw

Random Daytime

FLUSHED

FLUSHED

Lead level (µg/l)
LEAD LEVELS

Fig. 1E TOWN E (33 properties)

Fig. 1F TOWN F (33 properties)
LEAD LEVELS

Fig. 1 G TOWN G (29 properties)

FIRST DRAW

RANDOM DAYTIME

FLUSHED
LEAD LEVELS

Fig. 1H TOWN H (17 properties)

FIRST DRAW

RANDOM DAYTIME

FLUSHED

Fig. 1I SUMMARY OF LEAD LEVELS IN ALL TOWNS, EXCLUDING TOWN H (167 properties)

FIRST DRAW

RANDOM DAYTIME

FLUSHED
<table>
<thead>
<tr>
<th>TOWN</th>
<th>FIRST DRAW</th>
<th>RANDOM DAYTIME</th>
<th>FLUSHED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Properties</td>
<td>Mean Lead Level (µg/l)</td>
<td>Median Lead Level (µg/l)</td>
</tr>
<tr>
<td>A</td>
<td>28</td>
<td>22.0</td>
<td>3.5</td>
</tr>
<tr>
<td>B</td>
<td>16</td>
<td>9.0</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>15</td>
<td>41.8</td>
<td>40</td>
</tr>
<tr>
<td>D</td>
<td>12</td>
<td>65.5</td>
<td>7</td>
</tr>
<tr>
<td>E</td>
<td>33</td>
<td>30.2</td>
<td>19</td>
</tr>
<tr>
<td>F</td>
<td>33</td>
<td>24.0</td>
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</tr>
<tr>
<td>G</td>
<td>28</td>
<td>24.5</td>
<td>18</td>
</tr>
<tr>
<td>H</td>
<td>17</td>
<td>559.0</td>
<td>260</td>
</tr>
</tbody>
</table>

**NOTE:** All samples were taken from properties with lead.
Fig. 2 EFFECTIVENESS OF FLUSHING IN REMOVING STANDING WATER

![Graph showing the effectiveness of flushing in removing standing water. The x-axis represents the number of pipe volumes of water flushed, and the y-axis represents the portion of fresh water in discharge during flushing (%).]

Flushing rate 1 litre/minute
Flushing rate 5 litres/minute

Fig. 3 EFFECT OF FLOW RATE ON LEAD LEVELS ACHIEVED BY FLUSHING

![Graph showing the effect of flow rate on lead levels achieved by flushing. The x-axis represents the flow rate (litres/minute), and the y-axis represents the steady state lead level achieved by flushing (µg/l).]

SOFT WATER
HARD WATER
<table>
<thead>
<tr>
<th>TOTAL WATER CONSUMPTION IN AREA (Ml/d)</th>
<th>ESTIMATED NO. OF PROPERTIES</th>
<th>ESTIMATED NO. OF PROPERTIES WITH LEAD PIPES</th>
<th>FLUSHING</th>
<th>POSSIBLE WATER TREATMENT COSTS (£'000 Q2 1979)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ALL PROPERTIES</td>
<td>LEAD ONLY PROPERTIES</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TOTAL ANNUAL COST (£'000 Q2 1979)</td>
<td>MAXIMUM INCREASE IN DEMAND (Ml/d)</td>
</tr>
<tr>
<td>1</td>
<td>1,000</td>
<td>450</td>
<td>0.15 to 1.10</td>
<td>0.1</td>
</tr>
<tr>
<td>5</td>
<td>5,000</td>
<td>2,250</td>
<td>0.75 to 5.50</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>10,000</td>
<td>4,500</td>
<td>1.5 to 11.0</td>
<td>1.0</td>
</tr>
<tr>
<td>50</td>
<td>50,000</td>
<td>22,500</td>
<td>7.5 to 55.0</td>
<td>5.0</td>
</tr>
<tr>
<td>100</td>
<td>100,000</td>
<td>45,000</td>
<td>15 to 110</td>
<td>10.0</td>
</tr>
</tbody>
</table>

* Range depends on whether alkalinity increase is necessary or not.

† Range depends on what treatment process used.

‡ Assuming 45% of properties have lead pipes.
Fig. 4 NETT PRESENT VALUE (NPV) OF REMEDIAL ACTION IN TYPICAL SUPPLY AREAS

ASSUMPTIONS

Total water consumption for the area is 1000 l/household/day
46% of all properties have lead pipes
Cost of pipe replacement = £405
All water used for flushing goes to waste
No new facilities required for water or sewage treatment to accommodate flushing programme
Unit cost of flushing is 1-0 to 3-0 p/m³
NPV calculated using test discount rate of 5% pa over 30 years, with replacement of mechanical items after 15 years.