

WATER HARDNESS AND MORTALITY IN THE NETHERLANDS

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ABSTRACT

In 1975 central water softening was discouraged by the Public Health Council because of the statistical negative association found in 23 communities between the hardness of drinking water and death rate from Ischemic Heart Disease (I.H.D.) over the period 1958-1970. Further studies were carried out during the last decade by a specially assigned interdisciplinary Working Group of the Health Aspects of Central Water Softening.

Recent studies showed that the release of metals (Pb and Cu) from household waterdistribution pipes was positively correlated with water calcium. Furthermore a significant negative correlation was found between hardness and pH for these types of water.

The hypothesis that the Ca and Mg deficiency in areas with soft drinking water increases the risk of I.H.D. death rate was supported by the finding that food looses more Ca and Mg when it is cooked in soft water as compared to cooking in hard water.

In contrast with earlier statistical investigations no significant relations were found over the period 1970-1977 between I.H.D. mortality and hardness of drinking water in 30 municipalities.

The disappearance of the statistical relation could not be attributed to changes in water hardness. However, investigation of a group of 17 municipalities of which mortality and water quality data are known for three periods, 1958-1962, 1965-1970 and 1971-1977, showed that the inverse statistical relation between I.H.D. mortality and water hardness still existed but with decreasing significance of correlation coefficients. The provisional conclusion of the Working Group is that other factors than water hardness overrule to a large extent the potential effect on I.H.D. mortality. Central water softening down to 2-3 meq/l Ca probably will have no observable effect on mortality. Other studies are still continuing. In 1981 a final report will be presented to the Minister of Health and Environmental Protection.

HISTORY

In 1971 The Netherlands Water Works Association (VEWIN) proposed central softening of the drinking water in The Netherlands, down to about 2 meq Ca/l (40 mg Ca/l). However, this proposal was criticized by public health experts, because in The Netherlands two studies had shown a negative relationship between water hardness and mortality from cardiac diseases, particularly in women (ref.1, ref.2). The Minister of Health and Environmental Protection asked the Public Health Council (PHC) to consider this matter. In 1975 a commission of the PHC proposed to delay central water softening pending further research.

The research should try to answer the following questions:

1. Is the relationship between cardiovascular mortality still observed when more recent and more accurate water quality data are taken into account ?
2. Does such a relationship reflect a gradient in hardness or in metal content in drinking water, which again could be related to aggressivity of soft water?

A Working Group on Health Aspects of Water Softening was founded with representatives of various governmental and non-governmental institutes from the fields of water technology and of public health (see Annex). Since 1975 several studies have been carried out. Data on the relation between mortality (1958-1977) and water quality (1952-1977) can be presented. Additional studies are going on. The studies were supported by grants from the Ministry of Public Health and Environmental Protection and the Dutch Prevention Fund, and from the EEC (contract 273-77-1-ENV-N).

RESEARCH OBJECTIVES

Aspects of the relationship between mortality and water hardness, which the Working Group decided to investigate were inter alia:

1. the quality of drinking water in 1977 and 1979 particularly with respect to hardness (Ca, Mg) and aggressivity (pH, metals), comparing the 1977 and 1979 data with those from 1952 as far as available.
2. the trend of mortality from ischaemic heart disease (ICD 410-414, 428) and of cerebrovascular mortality (ICD 430-438) in males and females > 30 yr of age, over the periods 1958-1962, 1963-1970 and 1971-1977.
3. the relation between mortality from ischaemic heart disease and/or cerebrovascular disease and water quality data (at pumping station and at tap) from 1952 and 1977.

WATER QUALITY DATA 1952-1977-1979

Consistency of drinking water quality

The Laboratory of the National Institute for Public Health (R.I.V.) examines water quality at pumping stations on a routine basis. The water quality data from 1952 and from 1977 for 17 communities showed a high Spearman ranking order coefficient of inter-correlation, except for pH:

pH	: r = 0.41
K ₂ O	: r = 0.93
rCa	: r = 0.86
rMg	: r = 0.83
rCl	: r = 0.78
rSO ₄	: r = 0.68
rHCO ₃	: r = 0.84

The rather good consistency in ranking order of the parameters of water hardness, in addition to the fact that the average concentrations also did not differ considerably, allow to correlate water hardness with mortality over the whole period 1958-1977.

There was no consistency in the pH. However, the pH was calculated on the basis of CO₂- and HCO₃-concentrations. This may have been the reason for the low coefficient of correlation. Therefore, in 1979 the National Institute for Water Supply (NIWS) carried out accurate measurement of pH in 28 water supply areas; in addition a new calculation of the Langelier index of water aggressivity was carried out. This study showed a negative correlation between pH and Ca-content: $r = -0.70$ ($n=28$). Although in general natural soft waters are expected to be more aggressive than natural hard waters, various measures taken by the Dutch water production companies to condition (de-acidification) the water in the last decennia have led to an increase of the pH of soft waters. It was not possible to establish fixed data for most water works with respect to the time of introduction of these conditioning measures, because many measures to improve water quality were taken over a period of several years.

Metals in water

In Amsterdam a pilot study was carried out to establish the random sampling size of tapwaters in order to derive a valid estimate of metal intake through tapwater. At 200 taps proportional sampling (ref. 4) of water used for consumption was carried out. A sample size of 50 taps from an at random number of 200 taps proved to yield a valid estimate of the contribution of drinking water to the intake of metals (Cd, Pb, Cu, Zn, Fe).

The concentrations of Mn, Si, Li, Sr, Ba, B, Al, Cr, V, Mo, Co, Ni, As and Sb were determined in composite samples. The concentrations of these elements were

not expected to change during distribution; they should therefore be determined in water at the pumping station.

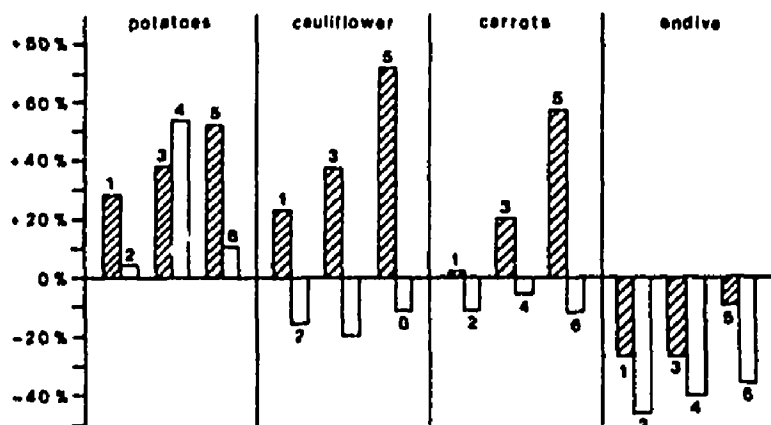
A study was carried out in 20 communities, with 40,000 inhabitants, and with a reasonable consistency of water hardness over the last 25 years. In tapwater the lead and copper levels were positively related to Ca-levels: $r_{Ca-Pb} = +0.43$, $r_{Ca-Cu} = +0.38$ ($n=20$). The pH in these 20 water supply areas was negatively related to Ca-level ($r=-0.66$, $n=20$). These findings already suggest that a negative correlation between hardness and mortality will not be due to increased metal levels (ref. 6).

The effect of water hardness on the mineral (Ca, Mg and Pb) content of some food stuffs was investigated in a limited study by the National Institute for Water Supply (ref. 5). Tapwater from 6 communities, varying in hardness from Ca = 114 mg/l and Mg = 19 mg/l to Ca = 17 mg/l and Mg = 2.2 mg/l, was used to cook potatoes and vegetables. The results (Figure A, B, C) indicated that the Ca-level in the food stuffs generally increased when cooked in hard water, whereas a decrease or only a slight increase was found when cooked in soft water; the Mg-content decreased both when cooked in hard and in soft water. The Pb-content generally increased in hard water and decreased in soft water; however, the hard waters contained higher Pb-levels than the soft waters.

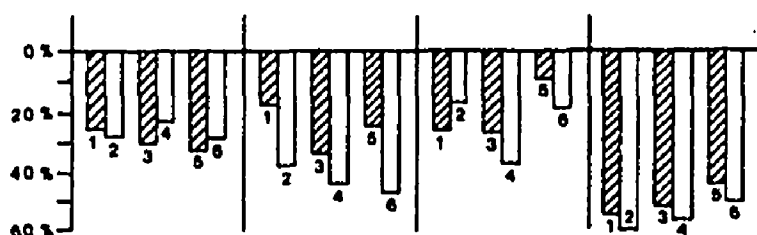
The results of these tests may support the hypothesis that an inverse relation between hardness and ischaemic heart disease mortality is due to a deficiency of Ca and/or Mg in soft water. Such a deficiency will further be increased by the extractions of Ca and Mg from food by soft water. This particularly may have consequences when the nutritional intake of Ca and/or Mg is low.

The studies of water quality allow the following conclusions:

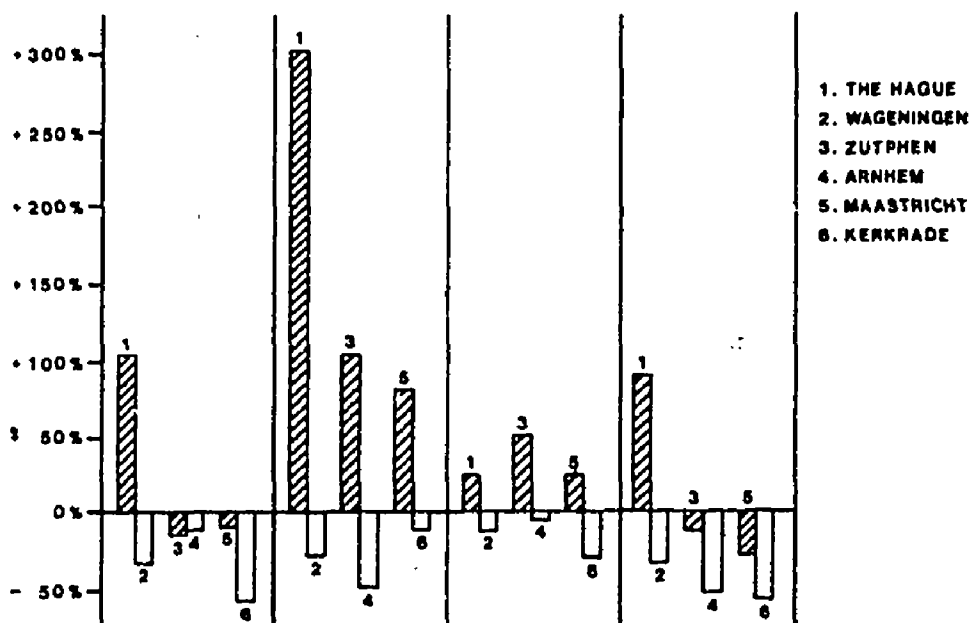
- over the last 25 years there was a good consistency in hardness of drinking water
- in 1979 there was a negative correlation between pH and hardness
- in 1977/1978 lead and copper levels in tapwaters were positively related to calcium levels
- cooking vegetables in soft waters decreases the Ca- and Mg-content of these foods probably more than in case hard water was used for cooking.



A. PERCENTAGE OF THE CHANGE OF THE CALCIUM CONCENTRATION IN SOME FOODSTUFFS DURING COOKING WITH HARD AND SOFT DRINKING WATER



B. PERCENTAGE OF DECREASE OF THE MAGNESIUM CONTENTS IN SOME FOODSTUFFS DURING COOKING WITH HARD AND SOFT DRINKING WATER



C. PERCENTAGE OF THE CHANGE OF THE LEAD CONCENTRATION IN SOME FOODSTUFFS DURING COOKING WITH HARD AND SOFT DRINKING WATER

FIGURE A,B,C. CONCENTRATION CHANGES OF ^{40}Ca , Mg AND Pb IN POTATOES, AND VEGETABLES BY COOKING THEM IN HARD (GREY BARS) AND SOFT (OPEN BARS) DRINKING WATER TYPES

MORTALITY IN 1958 - 1977 IN 17 COMMUNITIES

Correlation studies between mortality and water quality have been carried out over 1958/1962 (ref. 1), 1963-1970 (ref. 2) and again over 1971-1977. However, the Working Group doubted whether for 6 communities studied over 1958/1962 and 1963/1970 the water quality data used for 1952 were well enough representative, because of admixture of water with different quality from other water works. The Group, therefore, selected other communities with a number of inhabitants $> 40,000$, served by one water works and with no indication of change in water quality over about 20 years. The Group selected 30 communities for the final study; 17 communities of these had been studied as well over 1958/1962 and 1963/1970.

The mortality from ischaemic heart disease and cerebrovascular disease in males and females > 30 yr of age was compared over the periods 1958-1962, 1963-1970 and 1971-1977, age-standardized on the population - 1968 (table 1 and table 2); 17 communities.

TABLE 1

Ranking order correlation of ischaemic heart disease mortality in 1958-1962, 1963-1970 and 1971-1977

<u>Males > 30 yr of age</u>	1963/1970	1971/1977
1958/1962	0.42 ^x	0.39 ^o
1963/1970		0.74 ^{xx}
 <u>Females > 30 yr of age</u>		
1958/1962	0.78 ^{xx}	0.66 ^{xx}
1963/1970		0.83 ^{xx}
legenda:		
o	P	< 0.10
x	P	< 0.05
xx	P	< 0.01

Over the period 1958/1977 in 17 communities the consistency of mortality from ischaemic heart disease in females and from cerebrovascular disease in males was reasonably good. In a correlation study with water quality data over the period 1958-1977 particular attention should be paid to these two groups of mortality.

TABLE 2

Ranking order correlation of cerebrovascular mortality in 1958-1962, 1963-1970 and 1971-1977

Males > 30 yr of age	1963/1970	1971/1977
1958/1962	0.80 ^{xx}	0.57 ^{xx}
1963/1970		0.79 ^{xx}
Females > 30 yr of age	1963/1970	1971/1977
1958/1962	0.35 ^o	- 0.00
1963/1970		0.66 ^{xx}

legenda: o < P 0.10
 x < P 0.05
 xx < P 0.01

RANKING ORDER CORRELATION BETWEEN MORTALITY AND WATER HARDNESS

The age-standardized mortalities from ischaemic heart disease and from cerebrovascular disease in males and females > 30 yr of age, were correlated with Ca- and Mg-content of water-1952 and -1977 in 17 communities (table 3).

TABLE 3

Ranking order correlation between cardiovascular mortality over 1958-1977 and water hardness in 1952 and 1977 in 17 communities

	water 1952		water 1977	
	Ca	Mg	Ca	Mg
Males > 30 yr of age				
mortality				
1958/1962	-0.05	-0.08	-0.31	+0.12
1963/1970	-0.48 ^x	-0.41 ^x	-0.45 ^x	-0.46 ^x
1971/1977	-0.36 ^o	-0.45 ^x	-0.36 ^x	-0.33 ^o
Females > 30 yr of age				
1958/1962	-0.38 ^o	-0.17	-0.28	-0.16
1963/1970	-0.67 ^{xx}	-0.42 ^x	-0.56 ^{xx}	-0.54 ^x
1971/1977	-0.48 ^x	-0.30	-0.36 ^o	-0.37 ^o

legenda: o P (one sided) < 0.10
 x P < 0.05
 xx P < 0.01

For cerebrovascular mortality no significant correlations existed.

From this study on mortality in 17 communities over 1952-1977 it could be concluded that:

- the negative correlation established over 1958/1962 for IHD-females with hardness- 1952 ($r = 0.49$, $P < 0.05$, $n=23$), based upon standardisation on the Segi-population, was not fully confirmed for 17 communities, after standardisation on population-1968: $r=-0.38$; $0.05 < P < 0.10$; $n=17$);
- the ranking order correlations for mortality 1971/77 generally was lower than for 1963/1970, both in relation to water-1952 and water-1977;
- the ranking order correlation with the Ca-content of water was higher than with the Mg-content; there was no correlation with the $\frac{Ca}{Mg}$ quotient;
- the ranking order correlation only existed for ischaemic heart disease and not for cerebrovascular disease;
- the ranking order correlations were higher for females than for males, but also for males a negative correlation was repeatedly observed.

The Working Group finally studied the relation between ischaemic heart disease mortality and cerebrovascular mortality in 30 carefully selected communities, with >40.000 inhabitants and with no apparent change in hardness over last 20-30 yr, and the hardness of water in 1977 (table 4).

TABLE 4

Ranking order correlation between ischaemic heart disease (IHD) and cerebrovascular mortality (CNS) in males and females >30 yr of age with Ca- and Mg-content of water in 1977 in 30 communities

Males 30 yr of age		Ca	Mg
IHD		-0.01	-0.19
CNS		-0.14	-0.02
Females 30 yr of age			
IHD		-0.11	-0.10
CNS		-0.12	-0.07

There did not exist any relationship between water hardness and mortality from ischaemic heart and from cerebrovascular disease in 30 carefully selected communities, although the 17 communities in which a relation between cardiovascular mortality had been observed, were included. In fact, for the other 13 communities there existed a positive correlation.

In 16 communities for which the metal (Pb, Cu, Zn) content of tapwater was known, no correlation between mortality and metal content could be established.

In 23 communities no correlation was observed between mortality and the Li- or the SiO_2 -content of drinking water.

The Working Group concluded from these studies that at the present moment a negative relationship between mortality from ischaemic heart disease and hardness of drinking water cannot be fully rejected, but apparently many other factors which contribute to this mortality may completely overshadow such a relationship.

DISCUSSION AND CONCLUSION

The studies carried out in The Netherlands since 1975 have made it clear that The Netherlands is not a suitable country to elucidate the "water story" for the following reasons:

- the number of communities with >40.000 inhabitants served by one water works, and with an expected consistency in water quality is small (n=30);
- the range in water hardness is limited (Ca 16-117 mg/l; Mg 1-15 mg/l) in comparison to e.g. the U.K. (Ca 4 mg/l to 160 mg/l). In the 30 communities studies in The Netherlands 46 % had a Ca-level < 60 mg/l, 33 % < 40 mg/l and 3 % < 20 mg/l in 1977;
- there is a considerable mobility within the country; this would severely hamper a longitudinal study;
- some communities have an age-distribution which very much deviates from the country average, because of e.g. institutions for old invalids, and aged subjects; such a deviation cannot be adequately overcome by age-standardisation;
- in The Netherlands community based data on factors which may contribute to cardiovascular mortality do not exist; therefore, it is not possible to adjust the mortality data for e.g. socio-economic conditions as done by Pocock et al. (ref. 7).

One of the questions which could not be answered in 1971 was whether hardness or aggressivity of drinking water was the decisive factor for the negative correlation between ischaemic heart disease mortality and water hardness. The studies have brought forward evidence that - at least in The Netherlands at the present time - aggressivity (pH, metal content) does not play a role. If there would appear to be a causative relationship between water quality and ischaemic heart disease mortality, then this should probably be related to the hardness of water, particularly the Ca-content.

Studies in the UK strongly suggest that particularly soft water with Ca content below 40 to 60 mg/l may contribute to cardiovascular mortality. The EEC also recommended (ref.3) that Ca-levels should not be lower than 60 mg/l. The total number of 30 communities was too small to divide these into subcategories of water hardness; therefore, the British suggestion could neither be con-

firmed, nor be rejected.

In 1971 public health experts strongly opposed the proposal for central water softening. However, in view of the data gathered since 1975, the preliminary conclusion of the Working Group is that, although a contribution from water softness to mortality from ischaemic heart disease cannot be rejected, a partial softening of drinking water down to say 60 mg/l probably will have no measurable effect on ischaemic heart disease mortality in The Netherlands at the present moment.

We still present this conclusion as preliminary. Small scale additional studies are still going on (Table 5).

Most studies will be completed in 1980 or 1981. The Working Group will submit their final conclusion, based upon all studies, in 1981 to the Minister of Health and Environmental Protection.

TABLE 5

Small scale studies on the relation between water hardness and parameters of health(hazards), carried out by the Working Group on Health Aspects of Water Hardness:

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- relation between blood levels of Pb, Cu, Zn and Li in aged males and cardiovascular parameters
 - analysis of metal levels in autopsy tissues
 - analysis of metals in hair of school children
 - perinatal mortality from anencephalia and water hardness
 - cardiovascular parameters in workers.
 - animal experiments on resorption of metals from different types of drinking water.
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ANNEX

Composition of the Working Group in Health Aspects of Central Water Softening

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