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Sewage Hardness and Mortality from Cancer and Cardiovascular Disease

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Schroeder's "water story" (Schroeder 1960; Schroeder and Brattleboro 1960) relating water hardness to reduced cardiovascular disease (CVD) rates has been a controversy for more than two decades (Folsom 1982; Neri et al. 1979; Sharett 1979). Whether the negative association is causal remains uncertain. Excessive deaths in soft water areas from causes other than CVD also have been found in some reports including those on the correlation with cancer (Schroeder 1960; Neri et al. 1979).

We have conducted a study involving a comprehensive analysis of pollutants in 24-hour-flow composite sewage and sludge samples taken from 25 Standard Metropolitan Statistical Areas (SMSA) in the U.S. (DeWalle et al. 1982; Sung et al. 1986). Sewage treatment methods were considered in selecting study areas. Measures of hardness and its major determinants, calcium and magnesium, were included. The hardness of sewage can well reflect the average hardness of municipal drinking water. This report attempts to test the association of sewage hardness with mortality from cancer in addition to mortality from CVD among these areas. However, two study areas are not included in this report because populations were not available (Table 1).

MATERIALS AND METHODS

The sewage data were examined in 1979–80. However, the 1970 mortality data (National Center for Health Statistics 1970) and population data (US Dept. Commerce 1970) were used for this study assuming that the chronicled variations of sewage hardness were constant among studied areas.

Cancer sites that were evaluated in the study were buccal cavity and pharynx, esophagus, stomach, large intestine,

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Table 1. The Standard Metropolitan Statistical Areas for the survey of pollutants in sewage.

Akron, OH	Muskegon-Muskegon Heights, MI
Allentown-Bethlehem-Easton, PA., NJ	Newark, NJ
Appleton-Oshkosh, WI	Peoria, IL
Atlanta, GA	Providence, RI
Chattanooga, TN-GA	Rochester, NY
Fayetteville, NC	Rockford, IL
Fort Meyers, FL*	San Francisco-Oakland, CA
Fort Wayne, IN	Seattle-Everett, WA
Gary-Hammond-East Chicago, IN	Springfield-Holyoke, MA
Greensboro-Winston Salem-High Point, NC	
Greenville, SC	Washington, DC
Kenosha, WI	Wilmington, DE-NJ-MD
Lawrence-Harverhill, MA*	
Modesto, CA	

*Not included in this report because populations were not available.

intestine, rectum, liver, bile ducts and gall bladder, trachea, bronchus and lung, breast, cervix uteri, corpus uteri, prostate, urinary bladder, other and unspecified urinary organs including kidney, brain and other nervous system and leukemia. The list of cancer sites was adapted in this study from Hogan's study on the association between chlorinated drinking water and cancer (Hogan et al. 1979) and the eighth revision of the International Classification of Diseases (US Dept. HEW 1968). In addition, mortality rates from hypertensive disease, ischemic heart disease, cerebrovascular disease and arteriosclerosis were examined. Only rates for Caucasians were evaluated because some areas had very few non-whites. Direct age standardized cause-specific death rates were calculated using U.S. white population in 1970.

The simple correlation coefficient was used as a preliminary screening procedure. Multiple regression was then used to assess the contribution of each sewage hardness variable of significance in a stepwise entrance into the regression equation. The possible confounding variables which were considered as covariates were percent foreign born population, percent nonwhite population, percent population who have completed 4 years high school or more (US Dept. Commerce 1970), the sex-specific reciprocal of the SMSA white population multiplied by 1,000,000 (i.e., 1,000,000/ population) and estimated smoking rates among persons over age 17 for the state in which the SMSA was located (US Dept. Agriculture 1973). The smoking estimation was calculated as: (Receipts of state taxes on tobacco)/(Rate of tax per standard package of 20)/(Population over age 17 in the state).

Two stepwise regressions were performed for the sewage characteristics and covariates. In the first regression, all 7 covariates were entered. In the second regression, only those covariates having a t-value equal to, or greater than 1 which appeared in the first regression were entered. Each sewage characteristic was entered last and a partial correlation coefficient was computed. The covariate, 1,000,000/population was always entered first to prevent the occurrence of a spurious association (Friedlander 1980).

RESULTS AND DISCUSSION

The matrix of simple correlations with hardness characteristics consists of 90 associations for cancer mortality rates and 24 associations for deaths from CVD, by sex. It is likely that we would find 6 significant simple correlations at 0.05 level just by chance. We actually found 21 significant simple correlations as shown in Table 2, which also displays the respective partial correlation coefficients. Among the 21 simple correlations, 15 were negative and 6 positive. The positive associations were found for deaths from arteriosclerosis and were common to both sexes. However, the partial correlations for females were not significant.

As anticipated, some CVD death rates were higher in the soft water areas. However, the association with death from ischemic heart disease was significant only in males and remained significant only in males after holding covariates constant.

Table 2 also indicates that negative associations existed between sewage hardness characteristics and death rates for some cancers, including leukemia, prostate cancer in males and total cancer in both sexes. The negative associations for total cancer in females were particularly significiant according to partial correlation coefficients, -0.633, -0.617 and -0.599 with hardness, calcium and magnesium, respectively.

Table 3 illustrates the regressions for total cancer mortality rates by sex. Hardness and covariates could explain 62.7% of variation in the cancer mortality rate for males and 70.1% for females. Comparing the significance of these variables, the percent of the population employed in the manufacturing industry, smoking as well as hardness characteristics were important predictions for both males and females.

This study demonstrated a relationship between sewage hardness and ischemic heart disease for males which was consistent with other "water story" study findings for drinking water hardness. This suggests that the analysis of

TABLE 2 Significant correlation coefficients between the hardness components of sewage and the mortality from cancer and cardiovascular disease, in 23 SMSA.

Cancer Site or Disease	Chemical Parameter	Male Correlation		Female Correlation	
		Simple	Partial (Covariates)	Simple	Partial (Covariates)
Leukemia	Mg	-0.453*	-0.606** (1,2,5,7)		
	Hardness	-0.434*	-0.595** (1,2,5,7)	-0.418*	-0.384 (1,5)
Prostate	Ca	-0.618**	-0.497* (1,2,3,5,6,7)		
	Mg	-0.595**	-0.563* (1,2,3 5,6,7)		
	Hardness	-0.624**	-0.545* (1,2,3,5,6,7)		
Total Cancer Death	Ca	-0.394	-0.418 (1,2,5,6,7)	-0.133	-0.617** (1 through 7)
	Mg	-0.481*	-0.599** (1,2,5,6,7)	-0.186	-0.599** (1 through 7)
	Hardness	-0.441*	-0.513* (1,2,5,6,7)	-0.159	-0.633** (1 through 7)
Ischemic Heart Disease	Ca	-0.434*	-0.567* (1,2,4,6)		
	Mg	-0.488*	-0.527* (1,2,4,6)		
	Hardness	-0.468*	-0.567* (1,2,4,6)		
Cerebrovascular Disease	Ca			-0.420*	-0.402 (1,2,3,5,6,7)
	Mg	0.420*	-0 309 (1,2,3,4,6)		
	Hardness	-0.413*	-0.316 (1,2,3,4,6)	-0.418*	-0.420 (1,2,3,5,6,7)
Arteriosclerosis	Ca	0.607**	0.462 (1,2,4,5,6,7)	0.442*	0.407 (1,2,3,5,6)
	Mg	0.629**	0.512* (1,2,4,5,6,7)	0.482*	0.377 (1,2,3,5,6)
	Hardness	0.632**	0.502* (1,2,4,5,6,7)	0.470*	0.408 (1,2,3,5,6)

*P<0.05; **P<0.01; ***P<0.001

Covariates:
1. 1,000,000/population, i.e., the sex-specific reciprocal of the SMSA white population multiplied by 1,000,000;
2. % of manufacturing in industry;
3. median family income;
4. % of foreign born population;
5. smoking;
6. % of non-white population;
7. % of population completing four years of high school or more.

Table 3 The multiple regression coefficient for total cancer mortality on major hardness characteristics in sewage and covariates.

	Calcium		Magnesium		Hardness	
Variable	Male	Female	Male	Female	Male	Female
Intercept	11.0	-115*	-8.55	-112*	-0.39	-119*
1,000,000/ population	-1.11	1.13	-1.29	0.939	-1.17	1.08
% MIND	1.30*	1.65**	1.31**	1.46**	1.36**	1.60**
FINCOM	-	0.009*	-	0.008*	-	0.009*
% FBOR	-	-9.27*	-	-9.04	-	-9.45*
Smoking	0.309*	0.336**	0.384**	0.361**	0.345*	0.357**
% NWHI	1.38*	1.14*	1.05	1.00*	1.22*	1.05*
% HSCH	1.45*	1.24	1.65*	1.27	1.59*	1.30
HARDC	-0.369*	-0.472**	-1.16**	-0.993**	-0.107*	-0.114**
R^2%	58.2*	69.0*	67.5*	68.0**	62.7*	70.1*

*P<0.05, ** P<0.01

1,000,000/population: the sex-specific reciprocal of the SMSA white population multiplied by 1,000,000;
%MIND: % of manufacturing in industry;
FINCOM: median family income;
%FBOR: % of foreign born populations;
%NWHI: % of non-white population;
%HSCH: % of population completing high school or more·
HARDC: Hardness characteristics.

sewage is a valid, if indirect, measure of important environmental variables.

The more interesting findings are the negative partial correlations between sewage hardness characteristics and leukemia for males, at 0.01 level, and prostate cancer, at 0.05 level. These associations have not been reported in the literature. As has been mentioned, sewage hardness largely reflects drinking water hardness. The negative association between drinking water hardness and cardiovascular disease has been questioned (Folsom 1982; Neri et al. 1974; Sharett 1979). Similarly, the association between sewage hardness and leukemia and prostate cancer deaths found here deserves further analysis. It is known, however, that more cadmium and other metals can be leached from the water supply system by soft water than hard water (Sung 1975). Previous studies also have questioned the association of cadmium exposure in CVD (Beevers et al. 1980) and prostate cancer (Soraham and Waterhouse 1985).

The other striking finding is the partial correlations relating hardness and total cancer death. However, other variables are also good predictors in the regression. The percent of the population employed in the manufacturing industry in an area as well as smoking was as important as hardness characteristics for males in the prediction. The percent of population that was non-white and education were also important variables.

The water hardness association might be a mere coincidental to an ecological association. Industrialization and urbanization apparently were important. Non-white population tends to concentrate in urban or industrial areas and has a higher mortality rate. An area that is more populous or industrialized has more of an opportunity to use surface water because of the quantity and the convenience of obtaining it. Using surface water could be an alternative indicator of urbanization or industrialization. Surface water sources generally tend to have softer water (Snoeyink and Jenkins 1980.) They have more chance to be exposed to pollution. Hard water, on the other hand, because its source is mainly from ground water, tends to be used rurally.

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