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Select Minerals and Potable Reuse of Reclaimed Wastewaters

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SELECT MINERALS AND POTABLE REUSE OF RECLAIMED WASTEWATERS

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PREFACE

This is the final report of an investigation conducted by the Environmental Engineering program of the Civil Engineering Department, Texas A&M University and supported by funding from the Texas Water Resources Institute and the Texas Engineering Experiment Station, and, in part, by the City of Dallas Water Utilities Department and Health Department and the Texas State Department of Health Resources. The project term was from July 1, 1972 to December 31, 1974.

The study was conducted mostly at the site of the Dallas Wastewater Reclamation Research Center sponsored by the Dallas Water Utilities Department in Dallas, Texas. The topic of the study, Water Quality Criteria for Reclaimed Wastewaters As an Urban Domestic Water Supply, is directed at the very heart of the reason for the existence of the Dallas Center. In developing the work, Mr. Henry J. Graeser and Dr. Irving M. Rice of Dallas' Water Utilities, Dr. E. Lowell Berry and Dr. Billie J. Moore of Dallas' Health Department, and officials of the Texas State Department of Health Resources provided continuing help and support.

One of the most intriguing questions relating to reuse of reclaimed wastewaters as a domestic supply concerns the associations repeatedly observed in the technical literature of mineral quality of drinking water with heart-circulatory deaths. An opportunity arose to investigate this relationship when it was learned that the City of Dallas had imported highly mineralized Red River water during the drought of the mid-fifties. The study was carried out and the results were so astonishing as to add an additional dimension to this project. Additional original work was carried out to completion but by this time, the organics-in-drinking-water "finding" had surfaced in the nationally-televised New Orleans episode and the associations of some of these substances with cancer would likely preclude any probabilities of developing reclaimed wastewaters for use as domestic water supplies for some time in the foreseeable future.

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ABSTRACT

The long-observed relationships of an influence of drinking water mineral content on heart-circulatory deaths are developed to indicate that sodium -- when present in sufficiently high concentrations -- may be detrimental to human health. An hypothesis is presented that suggests that drinking water sodium contributes more to the health effects picture than is ordinarily attributed to this normally minor avenue of ingestion by virtue of its influence on taste behavior.

Mechanisms of action for metals as they relate to cancer and for sulfates as they relate to urinary calculi were also observed in the literature.

CHAPTER 1

INTRODUCTION

In August 1912, the Congress authorized the Ohio River studies "to provide data that will eventually be used as a basis for framing the necessary laws for preserving interstate rivers of our country as a safe source of water supply for the large cities located on them"(1). In that same year, an obscure incident occurred that was to have a profound effect on water pollution and its relation to health, *viz*., the chlorination of a public water supply using liquid chlorine (2). The use of liquid chlorine enabled a high degree of control of the chlorination process -- not previously attainable with chloride of lime -- and, hence, a high degree of bacteriological control of public water supplies. By the time the studies authorized by Congress were reported -- *ca*. 1925 -- the value of chlorination of public water supplies was widely accepted and practiced. Rivers could now be used to convey sewage and at the same serve as sources of public water supply.

Previous overt relationships of human health with water pollution effectively ceased to exist. Water pollution control programs -- generally under the aegis of departments of health -- were slow to respond to the environmental insults of water pollution, and consequently because of prodding by environmentalists -- new environmentally responsive agencies were created to administer water and other environmentally impacting programs. Yet from the post World War II years on, there were increasingly frequent indications that society was entering a new era of human health concern for water pollution -- this time for chemical substances. Barium, cadmium, cyanide, silver, alkyl benzene sulfonates, carbon chloroform extract, fluoride, and nitrates were included for the first time in the 1962 U.S.Public Health Service Drinking Water Standards (3) -- most for health reasons. One authority stated, "During the middle 1960's a major hoax was committed on the American public, abetted by the inability or unwillingness of the Surgeon General of the Public Health Service to combat effectively a major public relations campaign by the Secretary of Interior (which resulted in) the acceptance by Congress of the myth that water pollution was no longer a health issue but rather one of 'natural resource.' It is now evident that only a short period of time occurred between the control of overt waterborne illness and the developments that now or potentially exist with respect to chemical contamination of waters" (4).

When the above prophetic words were written (1969), almost 10 years had elapsed since Schroeder's publication observing relationships between drinking water hardness and cardiovascular disease deaths (5). Yet, the idea that there was no health relationships with drinking water any longer was so pervasive that the Bureau of the Budget insisted that the U.S. Public Health Service water supply program conduct a national study to demonstrate if there was indeed any need at all for a federal program. This study was subsequently conducted and published, and the results without doubt contributed to the passage of the Safe Drinking Water Act which prescribes to the federal government a very strong role.

Another observation -- which provided even greater impetus to the Congress to pass the Safe Drinking Water Act -- was the finding of trace amounts of carcinogenic organic chemicals in the finished drinking water of three communities served by the lower Mississippi River (6), the observation of higher cancer deaths among males consuming such waters (7), and the finding that chloroform -- a known animal carcinogen (8) -- is among the products of chlorination (9).

The research effort described hereinafter was to have been essentially a review of the literature, documenting the existence of specific chemical substances found in drinking water supplies and wastewater effluents and their importance to public health, and evaluating the capability of both conventional and other treatment technologies (but not including demineralization systems) to remove these substances. An opportunity was presented to add one bit of original evidence which was to have contributed to the intriguing water hardness: cardiovascular disease relationship by reporting the heart disease mortality experience of the City of Dallas during a period of drought when a highly mineralized water was imported to augment local supplies (10). The observations were so extraordinary as to require a followup study (11). The writer was subsequently swept along by events and was unable to achieve the goals of the project in spite of being within 90% completion of the literature search.

Much of the flow of recent events concerns organic substances in drinking water and their potential for causing cancer in human beings. The extended project completion date of December 1974 would have terminated just prior to the "explosion" in organic-carcinogenic information which has developed since the Harris publication (7). An effort was made to extend the project to include this highly publicized era -- but in vain. Hence, the submission of this completion report.

The sodium story is gathered together and presented in the beginning of the next chapter, and it is followed by a summary of the remaining findings.

CHAPTER 2

SUMMARY OF RESEARCH RESULTS

SODIUM

In 1960, the late Henry A. Schroeder, M.D., published a provocative paper which observed a significant protective effect of water hardness on cardiovascular disease (CVD) mortality (5). Other water qualities that might be expected to be generally associated with increased hardness (calcium and magnesium) also related protectively, such as bicarbonate, sulfate, fluoride, dissolved solids, specific conductance and (high) pH. Since the relationship was a protective one, i.e., their increased presence was associated with a lowered CVD death rate, the study did not make front-page news as have the relationships observed more recently between certain drinking water organic-chemical contents and higher cancer mortality. Nonetheless, those individuals who are responsible for delivering safe, potable water to the public were and remain quite concerned about the hardness : CVD relationships because of the obvious inference that softened water may be acting detrimentally to increase CVD death rates.

Although Schroeder had been first to observe these relationships with drinking water quality, he had been preceded by a Jun Kobayashi who had reported on a similar topic in Japan (12). Kobayashi had observed higher death rates from cerebral hemorrhage in areas of Japan where river waters were acidic as compared to areas drained by alkaline rivers. Schroeder analyzed Kobayashi's data and found a good correlation between deaths from cerebral hemorrhage and acidity of river water and an even better correlation with death rates from heart disease. But Kobayashi's paper did not specifically implicate drinking water.

Morris, Crawford, and Heady (13) then studied data from England and Wales and in 1961 reported essentially the same results as Schroeder. Although their data clearly ruled out magnesium and sulfates as operating parameters, the concentrations present in the waters studied were not given. Later, the writer was to learn that the concentrations of magnesium in that study were too low to be clearly ruled out (14).

The next significant contribution came from Canada. Anderson, leRiche, and MacKay (15) studied patterns of ischemic heart disease and drinking water quality in Ontario and found the same results. But they delved further and found the higher death rates to be due to an excess of sudden death in the soft-water areas. Their report was the first that provided data indicating that soft-water supplies might be detrimental rather than hard-water supplies protective.

In Feb. 1970, Edward Lee Russell, M.D., published a study for the Orange County Water District of California. In looking at the various contaminants and their concentrations in the ground waters of the district, he concluded "that 37.9 per cent of the residents of the district are served a domestic water supply containing 110 mg/l or more of sodium, an amount that would place in jeopardy all residents who have confirmed or incipient congestive heart disease, hypertension, renal disease, or cirrhosis of the liver" (16).

Dr. Russell's words were viewed with deep concern by the writer who was employed by a project that was utilizing a pilot plant to treat wastewater to make it potable and hence recycleable. Although water quality as described by the specific criteria of drinking water standards could be readily achieved, considerable concern was felt about the many other substances -- both known and unknown -- which are certainly present in such product waters and their possible health effects. Sodium is an example of the former. It was being monitored frequently and the concentrations in the finished pilot plant waters ranged from 63 to 130 mg/l with the majority of analyses being about 90 mg/l -- uncomfortably close to Dr. Russell's cited 110 mg/l. The original water supply of Dallas has a sodium content of 11 to 25 mg/l indicating a pick up through use of about 70 mg/l. If Dr. Russell's estimates are correct, treatments prior to reuse might often have to include demineralization -- processes that are energy intensive and add considerably to cost.

A possible test of Dr. Russell's estimates existed in that during the drought of the middle fifties, Dallas had resorted to importation of Red River water over a three-year period. The Red River is a highly mineralized stream. The high-mineral waters had caused many problems for the City of Dallas during its use because of its corrosiveness. But no one had ever checked to see what happened to heart disease deaths in the City during the period of import. The nearby City of Ft. Worth which also utilizes impounded surface waters did not have to resort to water import, so it could be observed as a control.

A paper describing heart disease deaths for the two cities during this period was presented at the October 1972 Annual Meeting of the

American Society of Civil Engineers (ASCE) in Houston, Texas, under the title "Water Quality for Potable Reuse of Wastewater" (10). It was submitted to the Proceedings of ASCE for publication but rejected by the editor. Virgil Langworthy, editor of Water and Sewage Works, however, published it in February 1974. The paper is reproduced in the Appendix.

The paper shows that increases in heart disease deaths for all categories accompanied the period of water import. This occurred in spite of increases in hardness which were supposed to be protective against heart disease deaths. The average values for Ca, Mg, and total hardness (calculated) during the study were as follows:

Water Year	Mg mg/l	Ca mg/l	Calculated Total Hardness as $CaCO_3$, mg/l
1952 - 53	1.44	29.34	79
1953 - 54	2.95	36.67	104
1954 - 55	5.72	37.45	117
1955 - 56	8.33	54.95	171
1956 - 57	12.24	59.11	198
1957 - 58	2.82	26.69	78
1958 - 59	3.00	27.27	80

Further, the increases occurred in the approximate range of sodium concentrations predicted as hazardous to certain individuals at risk by Dr. Russell. Additionally, one must conclude from the data that health delivery systems were simply not working during this period. Quite obviously, those at risk were unaware.

In sum, the paper clearly supports the hypothesis of a water factor which affects heart disease deaths. It is evidence against a hardness : protective relationship and for a sodium : detriment relationship. Similarly, it is indirect evidence against a soft water : detrimental effect -- unless the soft water contains substantial sodium content -- because Dallas waters would be classed as hard at the peak occurrence of imported water. An anomaly is present in the paper, however, in that the death rates do not appear to come down after the period of water import as promptly as one might expect.

One of the more dominant individuals to emerge in the water factor: heart disease death intrigue is Dr. Terrence Anderson of Toronto, Canada. He was asked about the possibility of sodium being the key element and had dismissed it with the statement that sodium in water could be expected to vary with hardness; in general, that is, more mineralized waters would tend to contain more sodium as well as more calcium, magnesium, etc. While this would be a true statement for surface waters and for some ground waters, the thought emerged that there would likely be an inverse relationship for most supplies because of the ion exchanging properties of many soils and sands. This should particularly be true in areas where limestone overlies the exchanging sands. Rain would pick up carbon dioxide from the air as it falls, hence, carbonic acid. The acid would dissolve limestone and the percolating water would thus pick up hardness. Then when the water reaches the exchanging sands, sodium would exchange for the hardness-causing metals. The possibility of an inverse relationship was tested using data published by the Texas Department of Health Resources (17). In this test, the calcium and sodium content of Texas water supplies were plotted. (Magnesium was not included because of the findings of Morris, Crawford, and Heady.) Clearly and generally, the high sodium supplies of Texas are soft waters, the low sodium supplies are hard water (11) (see Appendix -- Wolf-Moore). The possibility thus surfaced that the previous observations of protective effects of hard waters could have in fact been detrimental effects of sodium in soft waters.

If sodium in drinking water could have an effect on heart disease deaths, such a test was possible using the suburban communities of Dallas County. Some of these communities draw water from high sodium-bicarbonate aquifiers. Others receive low sodium water from surface impoundments.

A paper which reported on the sodium : calcium content of drinking water supplies in Texas and on the heart disease death experience of the Dallas County suburban communities was presented at the first Water Quality Technology Conference to be sponsored by the American Water Works Association in December 1974 (see Appendix -- Wolf-Moore). Although the statistical associations with sodium are weak, one cannot escape the enormity of the differences in heart disease deaths reflected by the two types of communities on older people.

This apparent association gains more credence when viewed along with M. I. Fatula's paper (Russian). Ms. Fatula reported a rate of hypertension almost four times higher among persons using a drinking water with an "elevated" sodium chloride content as compared to persons using water with a "normal" sodium chloride content (18). The paper was translated with the hope of determining how sodium was analyzed; it was not. All inferences are in terms of chloride (see Appendix). But it is interesting that Ms. Fatula observes that the age group 25 - 29 was not affected.

The anomalies mentioned, i.e., the short continuation of increased deaths in Dallas following the termination of water import and the weak associations of drinking water sodium content with higher heart disease death rates were quite troublesome to the writer. A first reaction was to wonder if people might not in reality be drinking other substances in such amounts as to possibly mask the influence of their drinking water quality. A number of popular drinks were subsequently analyzed for sodium content and the results were rather startling. The analyses were published in the popular "Percolation and Runoff" section of the Journal of the American Water Works Association (see Appendix). They showed that diet drinks contain substantially more sodium than the regular sugar-based varieties. The individuals most likely to consume the diet-type drinks are presumably those with a weight problem who are already more prone to developing heart problems. The same observation extends also to cream substitutes for coffee.

As to amounts of beverages, the American Family Physician (19) notes the following per capita consumption for 1974:

Coffee	3.33	gal/yr
Soft drinks	31.6	"
Milk	24.8	"
Beer	21.3	"
Tea	7.6	"
Juices	6.0	"
Liquors	3.7	"
Total	128.3	"
Water	56.	"

Hence, the average American drinks twice as much in the form of beverages as drinking water. Not only can the consumption of such beverages then be expected to mask the drinking water component, but -- in the case of sodium -- the diet alone will. This is illustrated by a report from a committee convened by the U.S. Environmental Protection Agency (EPA) in 1971 to update the drinking water standards (20). Important points developed in the sodium discussion include:

1) Sodium intake for American males ranges from 1600 to 9600 mg/day.
2) Heavy salt users have a markedly (50%) less salt-taste acuity.
3) Sodium-restricted diets are simpler, safer, and more economical for patients than are the use of drugs.
4) Congestive heart failure is a sequelae of several forms of disease that damage the heart and would affect some unknown portion of the 27 million persons with cardiovascular disease.
5) From 21 to 27 million Americans would be concerned with sodium intake.
6) Sodium intake through diet cannot be easily restricted to less than 440 mg/day.
7) When the sodium content of drinking water exceeds 20 mg/l, the physician must take this into account to modify the diet or prescribe that distilled water be used.

The report shows that sodium ingestion is primarily a food problem -- but importantly it also observes that the sodium content of drinking water cannot be ignored. It infers that control of sodium content of drinking water supplies via a taste limitation is unprotective unless taste panels are comprised of individuals who are on low-sodium diets. Even then, such panels could not control it at the level suggested - 20 mg/l. The report also indicates that, in practice, the physician community is either not adequately notified by water agencies of the sodium content of water supplies or the physicians are unconcerned. In other words, control through the physician community is simply not effective either.

It is now clear that there are two sodium problems of concern. The first relates to an effect clearly recognized by the medical profession : its potent effect upon individuals with congestive heart problems and several other ailments. A second problem relates to the chronic effect of sodium ingestion and its role in the ultimate development of hypertension. This latter relationship, however, still appears to be hypothetical to the medical community (21).

The writer has meanwhile submitted an hypothesis explaining how the relatively small sodium content of drinking water could exert an effect on heart disease deaths. This was published by the Journal of the American Water Works Association as an invited editorial (see Appendix -- Viewpoint). Sodium content in drinking water impairs the salt-taste acuity of individuals who then unwittingly use more salt in their diet. This could explain the persistence of deaths beyond the period of water import observed for Dallas and also the low significance, yet massive effect on the elderly observed in the Wolf-Moore paper (the major contribution of sodium not coming from the drinking water).

The Dallas data of the Wolf-Esmond paper (10) shows that small increases in death rates occurred in all categories of heart disease deaths with the smallest in hypertensive disease where one might intuitively have expected the largest increase. It is possible that this outcome simply illustrates the fourth point attributed to the EPA 1971 committee report, viz., regardless of the predisposing factors, the actual mechanism of death could have been from some sodium-mediated event such as a congestive heart failure.

The U.S. Environmental Protection Agency has asked the National Academy of Sciences to include sodium in its study of the health effects of various materials that may be present in drinking water (22). See the write up on Sodium and Sulfates in the National Interim Primary Drinking Water Regulations in the Appendix.

METALS

Sunderman, in 1971, reviewed metal carcinogenesis in experimental animals (23). He observed that selenium and lead were the only elements shown to have induced malignant tumors following dietary administration. Also, he noted there was no epidemiological evidence in humans suggesting that oral ingestion of selenium, lead, or any other metal was associated with a carcinogenic hazard. His review reported consistently negative results in experimental animals for arsenic, cadmium, tin, titanium, and zinc -- all except tin of which are carcinogenic by respiratory or parenteral routes.

Furst, also in 1971, came on a bit stronger (24). He observed that nickel, cadmium, and some chromium compounds are true metal carcinogens, and that suggestive evidence exists for cobalt and lead. Selenium is reported as questionably involved, arsenic as strongly indicated to be a primary human carcinogen, asbestos as a carrier of nickel and chromium (hence carcinogenic because of this association because no tumors developed when the asbestos was associated with iron or copper). He reported an unexpected laboratory finding that raised the question of titanium metal inducing sarcomas in select animals.

In 1972, Berg and Burbank (25) published studies of metal prevalence in surface waters and various cancer mortalities among populations within the basins drained by those waters. The basic reasoning that prompted this type of study is as follows:

> For a number of years, Dr. Stokinger and his co-workers had been studying the mechanism of asbestos carcinogenesis in the working environment. Among the hypotheses they explored was one which suggested a role for metals as contaminants of asbestos being the causative agents (25 &26). They used the microsomal fraction of homogenates of rat lungs to which was added series of increasing concentrations of certain metals and found that metals in trace quantities could induce or inhibit the activity of benzpyrene hydroxylase. Interestingly, nickel 2+, chromium 6+, and beryllium were most inhibitory and copper 2+ and magnesium the most stimulatory.
>
> In 1969, Dr. Straub of the University of Minnesota

suggested to the Public Health Service water supply activity that the application of the drinking water standards (3) ought to consider the additivity principle for those constituents that act additively. Additivity is practiced in radiological health and in industrial hygiene. The Russian drinking water standards also utilize the additivity principal. In Russia, for example, drinking water standards for arsenic and lead are, respectively, 0.05 and 0.1 mg/l. If a water supply contained both those elements and additivity were practiced, the maximum allowable limits for each would be reduced to 0.025 and 0.05 mg/l respectively, or to concentrations for which the sum divided by the allowable limits would not exceed unity. In fact, Novakova (27) did study these two elements with respect to their effect on sulfhydryl inhibition and found that when both are present, the concentration of one of the other would have to be halved in order to have no effect. Her observations would not result in such a stringent effect as would the principal of straight-line additivity, but she also pointed out that arsenic and lead are not the only sulfhydryl-active metals that can be present in drinking water.

Sulfhydryl groups are believed to be essential for enzymic activity (28). Since metals can inhibit the activity of a detoxifying hydroxylase (e.g., for the carcinogen benzpyrene), what might be their potential for acting additively in suppressing the defense mechanisms of humans in general, which might normally prevent people from getting cancer? In such a role, increased metal intake would result in decreased enzyme activity which in turn results in longer residence of the carcinogenic agent and hence, in increased cancer risk (26).

Schroeder, as quoted by Hadjimarkos (29), studied a number of metals with respect to body challenge and concluded that for all, the amounts contributed by drinking water were quite minor--possible exceptions being barium (11.4%), cadmium (<16.0%), and strontium (17.8%). Since metals can be taken into the body through food, the air, and also by direct body contact, it would appear more desirable to view cancer mortalities from the standpoint of total body burden.

The publication of Kopp and Kroner's work (30) enabled such an overview if one is willing to accept the view that over long intervals of observation, the content of metals in water flowing out of a basin is likely to be reflective of the levels of metals existing in the general basin environment. Hence, it was on this basis that the Kopp and Kroner data on metal content of surface waters was utilized in the Berg and Burbank study.

Berg and Burbank found no correlations for iron, cobalt, or chromium. Nickel concentrations correlated with mouth and intestinal cancer death rates. Arsenic correlations were biologically unexplainable. Lead and cadmium had certain correlations, some of which were questionable also. But beryllium, which produces bone cancer in animals, correlated with bone cancer mortality in humans. Potential additivity was not examined.

It was after these events had occurred that an Italian paper was found (31) which observed a relationship between cancer mortality and the metal ion content of urban drinking waters. The metals examined were iron, magnesium, aluminum, manganese, nickel, lead, copper, zinc, chromium, cadmium, and tin. Lowest ion values were associated with the lowest cancer death rates. The paper, in Italian, has been sent out for translation but -- as of the time of writing -- has not yet been returned. Presumably, it considers additivity. An application of the additivity principal to a drinking water supply as contrasted to results obtained when applied to a wastewater effluent is shown in the Appendix (Recharge of Reclaimed Waste Water:Research Needs).

SULFATES

Sulfates occur naturally in many waters, particularly in the western United States, as a result of leachings from gypsum and other common minerals. They may also occur as the final oxidized stage of sulfides, sulfites, and thiosulfates, e.g., pyrites may leach from coal and lignite deposits and the sulfide converted to sulfates in streams (31, 32). Sulfates may also occur as the oxidized state or organic matter in the sulfur cycle, probably reflected in a New Hampshire study which demonstrated that deforestation resulted in decreased sulfate content of streams (33). Sulfates may be discharged in numerous industrial wastes, such as those from tanneries, sulfate-pulp mills, textile mills, and other plants that use sulfates or sulfuric acid. Power plants may use sulfuric acid to regenerate mixed-bed resins, to neutralize alkaline water, or to decompose carbonic ions in magnesium and carbonate scale into the more soluble sulfates. Other sources of sulfates from power plant use include use of copper sulfate to control biological growth and the use of sodium sulfite as an oxygen scavenger. Certain organosulfur compounds and disulfides have potential use as non-oxidizing fungicides in cooling towers, but they do not appear to be widely used for this purpose as yet. Sulfate in the form of sulfuric acid has the greatest application of all acids in power plants (34).

Aluminum sulfate (alum) is a widely used water treatment coagulant. Sulfate concentrations in raw waters of three of Denver's water purification plants ranging from 6 to 43 mg/l were increased to the range 14-46 mg/l following alum coagulation, filtration, and chlorination (35). The normal range of increase of sulfate by one cycle of domestic use is 15-30 mg/l (36), but Dallas' data shows an increase in that city of about 58 mg/l (37). Sulfate is refractory to conventional water treatment (38) and wastewater treatment processes.

The 1962 Drinking Water Standards of the U.S. Public Health Service (3) recommend that sulfates not exceed 250 mg/l except where a more suitable supply is not available. The limit appears to be based on protecting highly susceptible transients from laxative action. Public water supplies with sulfate contents above this limit are commonly and constantly used without apparent ill effect on residents. The 1968 National Technical Advisory Committee to the Secretary of the Interior recommended that although sulfate at 250 mg/l is permissible for public water supplies, the desirable level should be less than 50 mg/l (38). Recommended quality criteria goals for sulfate at Chicago's intakes are

30 mg/l on an annual average and not to exceed 50 mg/l more than 12 days per year (39). In 1965, the California Board of Health permitted sulfates in drinking water up to 500 mg/l in the absence of an alternative supply (40).

Reports of negligible effects of excessive sulfates in drinking water have been received from around the world. A cathartic dose of 1.0 to 2.0 grams corresponds to a liter of water containing sulfates at 1000 to 2000 mg/l. Concentrations of 1295 mg/l (USSR), 2000-3000 mg/l -- one village as high as 4400 mg/l (Somalia), have been cited as having no effect on residents acclimated to such waters (31). The most definitive work in the U.S. indicates that water containing less than 600 mg/l is usually safe (41). Three case histories of infants with diarrhea attributed to sulfates (630,720, and 1150 mg/l) in drinking water have been reported (42). On the other hand, sulfates is one of the mineral qualities whose increased presence has been associated with lowered arteriosclerotic heart disease death rates (see Sodium and 43).

An interesting study of cattle drinking high-sulfate containing waters has been reported (44). A 3x3 Latin square study with replicates of 9 heifers was conducted using water with Na_2SO_4 added at 5000 mg/l (3380 mg/l as SO_4) or NaCl at 4110 mg/l for a period of 30 days. Cattle drinking sulfate water drank less, ate less, and lost weight, the sulfate causing a relative diuresis and a 450% increase in methemoglobin concentration. Sulfate water also increased serum sulfate concentration 63.1%, increased renal filtration of sulfate 45.2%, and decreased renal reabsorption of sulfate by 27.5%. It did not alter plasma calcium or renal excretion of calcium.

A study by Berlyne and Morag in Israel (45) has effectively resulted in a new concern for the sulfate content of drinking water. Briefly, they studied inhabitants -- healthy agricultural male workers ages 20 to 30 -- of three kibbutzim , two provided with drinking water sulfate content of 909 mg/l and one with 69 mg/l. They found the workers who drink the high sulfate water to have hypocalcaemia and hyperphosphataemia which is suggestive of parathyroid hypofunction. They also found the study cohort to have a low urinary pH, massive urinary sulfate excretions, and a compensated metabolic acidosis. Berlyne and Morag suggest that the low urinary pH may be one of the reasons for the high incidence of uric nephrolithiasis among the population drinking the high sulfate waters. The same authors in a later letter (46) cite sulfate as an example in recommending that drinking water tolerances be modified in view of environmental factors. A hard-working laborer on a hot day may drink 20 liters of water during an eight-hour shift, 15 to 20 times the consumption of a temperate area office worker. At a limit of 250 mg sulfate per liter, the laborer would ingest up to 5000 mg of sulfate daily, an amount that would produce gastrointestinal disturbances and extremely acid urine, and hence be associated with the formation of uric-acid stones.

The U.S. Environmental Protection Agency has asked the National Academy of Sciences to include sulfate in its study of the health effects of various materials that may be present in drinking water (22). See also the write-up on Sodium and Sulfates in the National Interim Primary Drinking Water Regulations in the Appendix.

CHAPTER 3

CONCLUSIONS

The three topics discussed in the previous chapter, sodium, metals, and sulfates, surfaced from this review as water quality criteria of enormous potential to human health -- especially sodium. The writer's publications on sodium brought him almost instant fame -- or infamy -- depending upon the individual's point of view. He found himself in the awkward position of being categorized with the "food-faddists" or "vitamin-freaks." Nevertheless, it is clear that more definitive research is urgently needed on these three topics, even though such research is difficult to do -- especially when human health is the objective.

The quality of the information with respect to sodium and sulfates is sufficiently high for the U.S. Environmental Protection Agency to have requested a review of these topics from the National Academy of Sciences pursuant to the mandate from Congress contained in the Safe Drinking Water Act, Section 1412(e)(1): "The Administrator (of the U.S.E.P.A.) shall enter into appropriate arrangements with the National Academy of Sciences ... to conduct a study to determine (A) the maximum contaminant levels which should be recommended under subsection (b)(2) in order to protect the health of persons from any known or anticipated adverse effects, and (B) the existence of any contaminants the levels of which in drinking water cannot be determined but which may have an adverse effect on the health of persons." This study was originally scheduled for completion in December 1976, and it was hoped that it's findings concerning sodium and sulfates could be included herein. The report has been delayed, however.

Other reports, in the meantime, concerning sodium and human health continue to accumulate. Dr. Page, Chief of Medicine at Newton-Wellesley Hospital in Newton Lower Falls, Mass., has been studying various peoples in differing areas of the world with respect to their sodium intake and hypertensive experiences. He is convinced that there is a relationship and was quoted as saying "Metabolic studies have shown that both children and adults require no more than 200 mg of sodium a day ... Yet the standard American diet contains about 5000 mg of sodium, and it's often much more due to the high use of snack foods ... It's time to get both the medical profession and the lay public aroused about greatly reducing salt in our diets" (21). Another study (47) demonstrates that individuals who labor heavily have a reduced risk of dying from the "sudden death syndrome" (see also 15). Hard labor seemingly ought to be accompanied by perspiration which is a highly effective means of lowering body sodium. Others however, associate the observed effect with exercise (47, 48).

There exists a possibility that perspiration will once again emerge as an important health controlling mechanism such as once practiced by the ancient Greeks! Perhaps studies ought to be done on people who perspire readily _vs._ those who do not, or people who use saunas _vs._ those who do not -- all with respect to heart circulatory problems. There might be an easier way to protect oneself against heart problems than by running several miles a day.

Sodium has incipiently crept into our lives in many ways. One way is from infancy on by drinking cow's milk. Cow's milk analyzes from 490 mg/l for sodium (our data) to 580 mg/l (49). Human breast milk contains only 150 mg/l (49). If the mother is on a low-sodium diet, one wonders what it would be? Yet, this is the situation under which the human being evolved. It thus appears that we shall be reading much more about sodium effects on human health in the coming years.

It would be tragic to wait for all possible studies to build a solid case of evidence before any action is taken. If we were to wait and find the involvement of sodium to be positively detrimental to our health, many people will have in the meantime suffered untimely disability and death. A short cut is possible. If the NAS report supports a lowered sodium content for drinking water, then demineralization demonstration programs could be applied to high sodium water supplies in order to develop the necessary engineering and economic data. Such communities who offer themselves to such demonstration programs -- and these communities should understand that they will have to bear the cost of these programs -- could also be studied for health data -- hypertension rates, ischemic heart disease death rates, and, even ulcer attack rates. The Russians studied a population drinking demineralized water and report a trend among long-term users toward gastric hypoacidity (50).

On the other hand, if the results of all efforts show sodium to not have been a health factor, what will have been wasted other than money and effort -- neither of which are as irreversible as disability and death.

Associations of metals in drinking water with cancer appear very much to be only in the hypothetical stage. Berg and Burbank's findings concerning beryllium, however, suggest that EPA ought to take a very close look at the use of this material and where it goes in our environment. Also, the writer thinks that research should be increased in the whole area of metals and other agents as they affect immune systems. For example, a number of organic agents, viz. beta-nitrostyrenes, vinyl ketones, vinyl sulfones, zinc dithiocarbamates, and quaternary salts have also been stated to be sulfhydryl inhibiting (51).

Lastly, the sulfate content of drinking water has never been studied in the U.S. with respect to urinary calculi incidence. It appears that such an epidemiological effort should be most welcome.

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APPENDIX

Water quality for potable reuse of wastewater

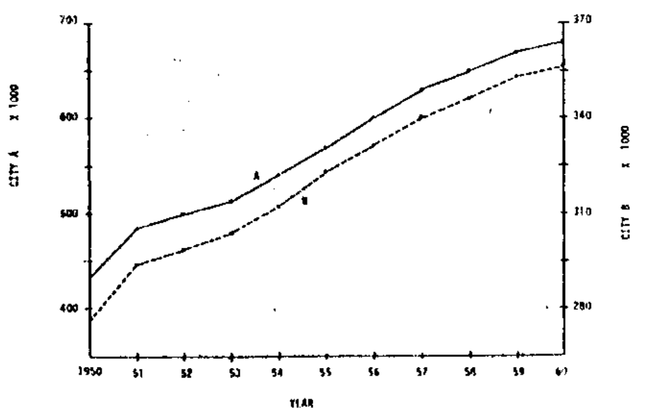

Figure 1: Population estimates

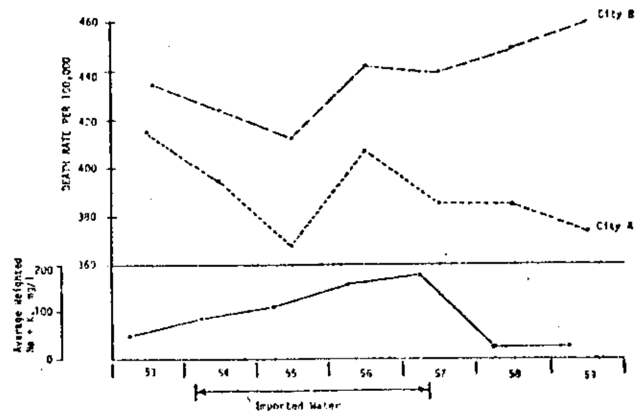

Figure 2: Total deaths

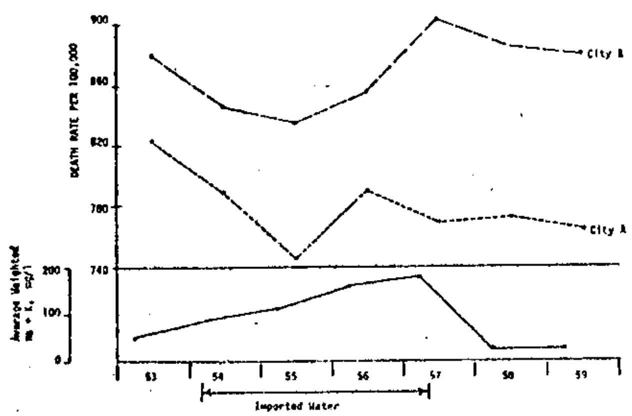

Figure 3: Major cardiovascular renal diseases

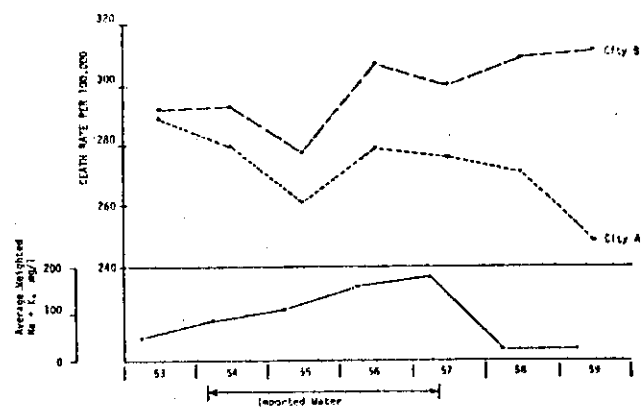

Figure 4: Diseases of the heart

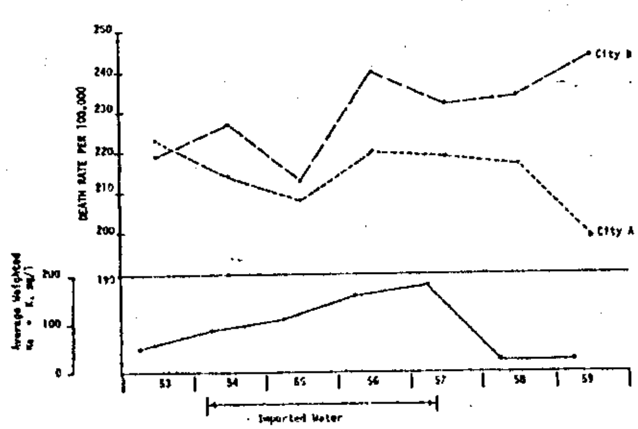

Figure 5: Arteriosclerotic heart disease, including coronary disease

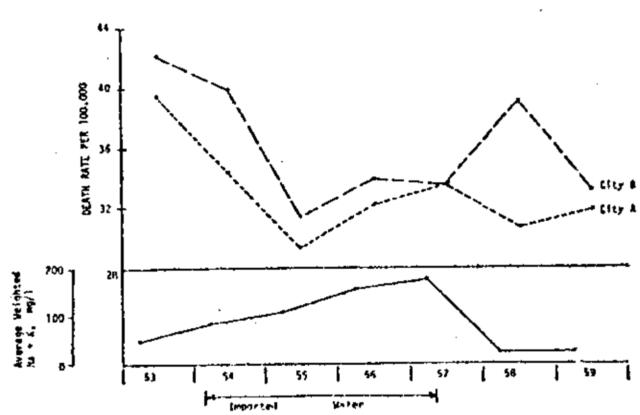

Figure 6: Hypertensive disease

It is becoming likely that highly treated wastewater will be reused for drinking purposes. Before this occurs, however, current drinking water standards demand serious qualification. A number of studies suggest strongly that high sodium concentration in drinking water relates to higher heart disease mortality rates. Hence it is recommended that low sodium concentration be considered a condition of potability.

By Harold W. Wolfe and Steven E. Esmond*

In the last few years we have witnessed a plethora of papers relating to the potable reuse of highly treated wastewaers.[1-10] The topic is obviously quite popular as compared to a decade ago when only a few were courageous enough to hold forth in a public forum on the subject. In a foreword to a series of research papers emanating from the Robert A. Taft Sanitary Engineering Center, the first volume dated May 1962, the following introductory statement appeared: "The Advanced Waste treatment Research Program of the Public Health Service has two ultimate objectives. One is to alleviate our Nation's growing water pollution problem and the other, more startling in concept, is to renovate wastewater for direct and deliberate reuse" (emphasis added).

There are not only many papers about the subject these days, but there are also public statements by high government officials:

> **The nation can expect a trillion-gallon-a-day water demand soon after the turn of the century, well above the usable surface water supply, William D. Ruckelshaus declared here last night. Multiple reuse of water will be the order of the day before long," he said. "We are going to be hearing much about recycled water, desalination and water conservation. Pollution control will become essential, not just manifestly desirable."**

> **The nation's usage of fresh water will double in the next 15 years and mean "the ability to treat sea water and recycle water will become vital for the supply of generations to come," says Secretary of the Interior Rogers C. B. Morton.****

In all likelihood, it was probably statements by high public officials that prompted the American Water Works Association on the subject.[12] Since then, the Environmental Protection Agency has published a policy statement dated July 1972, and a committee of the Water Pollution Control Federation issued still another daed Nov. 7, 1973.

Why all the action and reaction? We don't have an answer to this question, but certainly the topic is vulnerable to subjective analysis. Public health workers have expressed dismay that there should be so much interest in the domestic use of highly treated wastewaters when there are so many unanswered questions relating to the safety of our existing public water supplies.[13] It is common to evaluate the quality of highly treated wastewaters by means of the Public Health Service Drinking Water Standards even though those same standards exclude sewage as a source water by definition. The Federal employees responsible for the administering of those standards said this about the standards' short-comings: "The current Drinking Water Standards do little more than mention viruses, neglect numerous inorganic chemicals which are known to be toxic to man, and identify only one index that is supposed to cover the entire family of organic compounds.[14]

Sewage contains many hazardous materials for which no criteria exist. These materials range from substances as common as sodium to substances as exotic as the polynuclear aromatic hydrolarbons. Many polynuclear aromatic hydrocarbons are known to be carcinogenic to animals and hence probably also to man.[15] Since the Delaney Amendment specifies a zero-tolerance level for carcinogenic materials present in food additives, and since the FDA considers water to be a food, we at the Dallas Water Reclamation Research Center propose not to open that Pandora's Box at this time.[10,17] Instead we are looking at some of the "simpler" problems, such as sodium.

BACKGROUND. The Public Health Service Drinking Water Standards 1962, which are currently still valid (i.e., they have not yet at the time of writing been superceded), contain no limit for sodium. The unit processes that we have under study at the Dallas Center do not affect sodium. Hence, if the sodium concentrations present in Dallas' sewage are inimical to health, either dilution or demineralization will be an essential prerequisite to domestic reuse.

One criterion that exists for sodium is related to the American Heart Association's 500 mg/day sodium restriction diet. It has been calculated that a drinking water limit for sodium based on this diet would amount to about 20 mg/l.[18,19] Dallas' tap water ranges from 11 to 25 mg/l and handsomely meets this rather stringent figure. Dallas sewage on the othel hand ranges from 63 to 130 mg/l with the majority of analyses being about 90 mg/l.

Dr. Edward Lee Russell, an M.D. public health consultant to the Orange County Water District of California, published a paper on the subject of sodium in Feb. 1970 that should have — but apparently hasn't — created quite a stir. He calculated that 37.9 percent of the residents of the District "are served a domestic water containing 110 mg/l or more of sodium, an amount that would place in jeopardy all residents who have confirmed or inci-

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**From The Indianapolis Star, 10-8-71, and The Washington Post, 1-29-72, respectively.

pient congestive heart disease, hypertension, renal disease, or cirrhosis of the liver".[20] Using Dr. Russell's criterion of 110 mg/l, it would appear that Dallas' wastewater sodium concentrations might be acceptable some of the time.

We at the Dallas Center were aware that in the middle fifties an extensive drought plagued the southwestern states and one city in the region — in sheer desperation — resorted to import of a rather saline supply to augment its own water resources. We decided to see if there was any effect on heart disease mortality during this period of time on that city. The gross data did, indeed, reveal increases. But in order to firm the picture, we thought it advisable to include a "control city", calculate death rates for the two cities, and also determine the average sodium concentrations present in the drinking waters.

PROCEDURE. We had no difficulty in selecting a control city (indicated in the figures that follow as City B). This nearby city obtains its water supply from surface reservoirs that were of sufficient capacity to provide an ample supply during the drought. We did have trouble in obtaining population estimates, however, from which to compute death rates. Local sources for both cities apeared in error because in going from 1959 into the census year of 1960, both cities would have lost people — not a likely occurrence. Since Vital Statistics[21] provides good estimates of state populations in between census years, we decided to compute a yearly growth factor for the state and apply this factor to the increment of population change that occurred for each city between the census years 1950 and 1960. Fig 1 shows the graph of the population estimates for the two ciites derived by this means. Using these populations, death rates per 100,000 were calculated for five categories of death (one category being total deaths). Fig 2 compares the total death rates of the two cities. The control city has a markedly higher death rate throughout the period of time, averaging almost 90/100,000 more. Whether this is a consistent error, a reflection of biased data, or in fact represents something real — such as an older population in City B — we do not know.

Fortunately, City A maintains excellent water supply data. During the period in question, the bulk of the City's water supply was derived from two large purification plants located on the same stream that was augmented by the imported saline water. A small, abandoned water treatment plant plus some wells were also pressed inoi service during the drought. In the years 1952 through 1959, these additional sources contributed from 2.1 to 16.5 percent of the total volume of finished water delivered to the distribution system. In order to determine an average sodium content, the sodium content of each of the four sources was weighted by the percent of water delivered to the distribution system. The average sodium plus potassium concentration for City A ranged from a low of 24.8 mg/l to a maximum of 179.4 mg/l and is shown in the lower part of each graph, Figs 4-8. City B's supply was quite constant, its sodium concentration varying from 13.8 to 23.6 mg/l.

The mineral analyses of City A's water during this period of time combined sodium plus potassium. Analyses show that potassium is one percent of the combined sodium plus potassium figure for imported water and ten percent for native water. Hence, potassium is a realtively minor part of the Na+K values shown for City A.

The yearly death rates for both cities are shown on the upper parts of Figs 2-6. The death rates are plotted at the midpoint of each calendar year whereas the average weighted Na+K values are plotted at the midpoint of each water year (Oct. 1-Sept. 30). The categories of death are as published by Vital Statistics. Major cardiovascular renal diseases includes categories 330-334, 400-468, and 592-594. Diseases of the heart include categories 400-402 and 410-443. Arteriosclerotic heart disease including coronary disease is category 420, and hypertensive disease includes categories 440-443. The numbers refer to the categories of the 7th revision of International Lists dated 1955.

Note that Figs 2-5 all show a hump in the death rates for City A that follows the sodium concentration curve and that a similar hump for City B does not exist. Fig 5, however, which compares the curves for hypertensive disease contains a marked increase for City B in 1958 that obscures the comparison. We originally expected that of all the categories of death, hypertensive disease would be most likely to show a sodium effect. A confounding factor of considerable magnitude was introduced in this time frame however, viz., the use of drugs to lower blood pressure. These drugs have apparently had an extreme effect on lowering deaths due to hypertensive disease. If the plot of Fig 6 is carried out farther, the rates get even lower and stay lower.

DISCUSSION. From the picture presented here, Dr. Russell's prediction of increased deaths to heart disease due to increased sodium in drinking waters appears verified. Certainly the 250 mg/l limit quoted by Newsweek as a proposed limit for sodium in the impending EPA drinking water standards requires re-examination.

One cannot help but reflect upon the numerous statistical studies that have been done throughout the world which show a protective effect of hardness in drinking water supplies to heart disease deaths. A number of other factors were found also to correlate, viz., those quality factors that usually accompany hardness, such as total dissolved solids (TDS), high pH, increasing alkalinity, etc. One cannot help but wonder if these studies were in actuality manifestations of the sodium concenrations, or of sodium:calcium interrelationships.

Had we approached this study by trying to compare the death rates of City A vs City B with respect to their sodium concentrations alone, we could have concluded that sodium is beneficial. In this study, other factors could also have been shown as varying with sodium, such as sulfates chlorides, calcium, or TDS. But these lack the physiological significance of sodium. If the federal government is sincere in wanting to do some good in the area of chronic disease control, it is quite obvious where a major effort should go. The epidemiologic approach delineated limits in drinking waters for nitrates and for fluorides — both of which have been upheld by repeated study. Both also introduced new concepts to public health. Nitrates expanded the public health horizon from the concept of protecting most of the people most of the time to protecting all of the people all of the time. Fluorides introduced the concept of providing benefits to people as opposed to previous concepts of simply pro-

(Continued on page 54)

PROCEEDINGS

AWWA WATER QUALITY

TECHNOLOGY CONFERENCE

Cincinnati, Ohio

December 3 and 4, 1973

Sponsored by

THE AMERICAN WATER WORKS ASSOCIATION

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(Continued from page 49)

tecting people. A stringent limit for sodium will be equally revolutionary, because it will change our present concepts of the economics of water treatment. The California Water Plan, and the proposed Texas Water Plan will suddenly emerge as highly economic and, indeed, absolutely essential. The ramifications that would be raised by public recognition of a sodium peril are far too numerous for two men equipped with a slide rule and abacus to predict.

CONCLUSIONS. We believe that the study presented herein lends strong support to the limiting of sodium concentrations in drinking waters. Dr. Russell[20] predicted increased jeopardy to a large segment of the population when they drink water with sodium concentrations of 110 mg/l or more. This study verifies Dr. Russell's prediction. Epidemiological techniques can be used to develop a limit and it is recommended that this work be undertaken immediately.

Before highly treated wastewaters can be reused for potable purposes, many additional criteria will be needed. But unless large quantities of high quality water are available for dilution, demineralization appears a necessity.

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IS A SODIUM STANDARD NECESSARY?

by H. W. Wolf, Prof., Civ. Engrg., Texas A&M Univ. and B. J. Moore, Stat., Dallas City Health Dept.

It has long been observed that a number of diseases exhibit marked geographic distribution patterns. Among these is one of the greatest killers of the modern American -- cardiovascular disease, or disease pertaining to the heart and blood vessels(1). Each year, heart disease kills about 650,000 Americans. About twice that number suffer heart attacks and survive, encumbered by various periods of incapacity.

In 1959, Sauer and Enterline statistically examined the geographic distribution of cardiovascular disease deaths and concluded that even though the listed cause of death is often inaccurate, and even though such inaccuracies undoubtedly vary from state to state, such inaccuracies could hardly account for the large differences observed. In general, such errors for major groupings such as cardiovascular disease or coronary heart disease are possibly less than seven percent(2). Hence they concluded that "real geographic variations in death rates for cardiovascular disease and coronary heart disease of considerable magnitude exist within the United States." This conclusion can be interpreted that "something" is causing more heart disease or "something else" is protecting against heart disease in the regions.

The next major step taken in trying to explain what these "somethings" might be was by Dr. Schroeder. In 1960, he published his now-famous negative correlation between the water hardness of potable water and cardiovascular deaths. In other words, the data presented by Schroeder very definitely indicated that individuals drinking hard water had lower death rates to cardiovascular diseases than individuals drinking soft water(3). Schroeder's publication had three major impacts:

1. It resulted in similar studies throughout the world, and particularly by British investigators -- almost all reaching the same general conclusion(4-10).
2. It stimulated some investigators into determining what the physiological mechanism might be. A role for calcium in decreasing blood cholesterol, for magnesium in protecting against lipid deposits and inhibiting blood clotting, and for cadmium leached from galvanized pipes by soft water which can result in high blood pressure have all been mentioned(11-15).
3. As suggested by the cadmium relationship, it stimulated investigations into the role of environmental trace metals and their relationships to diseases(16-17).

Although Schroeder's work had a vast impact on general interest in chronic diseases and environmental aspects, he was not the first to report a relationship between water quality and cardiovascular disease deaths. Credit for this observation goes to Jun Kobayashi, a Japanese agricultural chemist, who in 1957 published his observations in a German journal but in the English language(18). Kobayashi had observed a higher incidence of deaths from cerebral hemorrhage in Japan in areas drained by the lower-alkaline, lower pH waters. However, it should be noted that Schroeder was the first to suggest that drinking water may be a factor in the differences in death rates.

In summarizing the array of literature relating cardiovascular disease to drinking water minerals(15), Winton and McCabe concluded (in 1970) that it was still not possible to recommend an optimum range of drinking water hardness, and further, "that the question of the water factor must be pursued until it is finally answered" (underline ours).

Among the factors known to have physiological significance in cardiovascular heart disease and which occurs in drinking water is sodium. In 1967, M. I. Fatula published a study in a Russian medical journal (19) reporting that in a group of 1809 persons (age 20-60) using a water supply with a "normal" amount of sodium, 3.4 percent had arterial hypertension (160/95 mm or greater). On the other hand, in a group of 1448 similar persons using water with an "elevated" sodium content, the arterial hypertension rate was 12.4 percent. The difference in morbidity was significant at $P < 0.001$. The paper, however is elusive as concerns the sodium concentrations. The best one can determine these to be is that "normal" sodium concentrations were 263 mg/l or less and that "elevated" sodium concentrations were in the range 470-1180 mg/l (both as Na).

Dr. Russell was a good deal more specific. In 1970, he calculated that 37.9 percent of the residents served by the Orange County Water District (Southern California) received a "domestic water supply containing 110 mg/l or more of sodium,an amount that would place in jeopardy all residents who have confirmed or incipient congestive heart disease, hypertension, renal disease, or cirrhosis of the liver"(20). Dr. Russell's prediction is based largely on the 500 mg/day sodium restriction diet of the American Heart Association, which calculates out to a 20 mg/l or less recommended concentration for sodium in drinking water (21).

Wolf and Esmond, in studying the production of potentially potable-quality waters from wastewaters at Dallas, Texas, observed that sodium concentrations of the wastewaters varied from 63 to 130 mg/l with the majority of analyses being about 90 mg/l(22). The original tap water ranged from 11 to 25 mg/l. They were aware that in the 1950's the City of Dallas imported water from the Red River for three consecutive drought-sticken years into its supply. The highly mineralized Red River water had created severe distribution system problems concerning corrosion-incrustation, but no one had ever reported what happened to heart disease death rates in the City.

Figures 1, 2, and 3 show these curves(22). In each figure, the period of water import is shown by a line at the bottom. At the time, Na analyses were lumped with K; hence, the lower curve shows the average yearly Na + K concentrations of the treated water. Each point is plotted at the mid-point of the water year. The upper curve shows the death rates due to the various heart disease categories recorded in Vital Statistics. Figure 1, Diseases of the Heart, includes categories 400-402 and 410-443. Figure 2, Arteriosclerotic Heart Disease Including Coronary Disease is category 420. Figure 3, Hypertensive Disease includes categories 440-443. The numbers refer to the categories of the 7th revision of International Lists dated 1955(23). Each death rate point is plotted in the middle of the calendar year. Note that for each of the disease groups, an apparent increased death rate occurred during the period of water import.

Several additional observations can be made. First, other analyses of the imported water showed potassium to be about one percent of the combined sodium plus potassium figure, and for the native water about 10 percent. Potassium intake is known to be important to individuals on diuretics, but sodium reduction through the use of low sodium foods or water does not result in accompanying losses of body potassium. Second, if a plot had been made for hardness (or Ca or Mg), it too would have increased over the same time frame thus rendering a counterdiction to the hardness: cardiovascular disease protection hypothesis. Third, the amount of increase in death rate is not large. It is no more than the normal yearly variation that occurs and consequently would not be statistically significant. However, the observation that the increase coincides with the period of water import and that it remains elevated for two or three years is not as likely to be the result of pure chance. And fourth, the important role played by the introduction of drugs for the control of hypertension in the same time frame is clearly visible in Figure 3.

Schroeder had looked at sodium in his studies, but the correlation certainly wasn't there. A Canadian scientist recently reported he had ruled out sodium on the basis that its concentration usually varies directly with hardness. Since the ion-exchange properties of many soils would tend to counterdict this concept for many waters, Wolf (24) made a "plot" of sodium: calcium concentrations published for the water supplies of Texas (25). Figure 4 shows this "plot" -- a simplified version of a scatter diagram. Each number entry shows the number of Texas water supplies that contain sodium and calcium concentrations in the approximate area of the coordinates. Clearly, high sodium waters tend to be low in calcium in Texas. In view of this evidence, we framed the hypothesis that perhaps the protective effect observed from hardness may be instead a detrimental effect of the usually-overlooked sodium.

The water supplies of Dallas County appeared to be worth taking a look at with respect to sodium since they all have a hardness of less than 89 mg/l as $CaCO_3$. Table I shows how the different communities in the county relate as to the sodium content of their water supplies -- as published by the Texas State Department of Health. If the populations are sufficient, and if Dr. Russell's predictions are correct, surely a difference in death rates to heart diseases should be apparent between comparable high-sodium and low-sodium communities.

The Texas State Department of Health supplied a print-out of all heart disease deaths in Dallas County for several years including the census year of 1970 broken down into age groups, sex, race, category of disease, and community. The categories of disease are somewhat changed from the classification system used in 1955, and for the computions discussed hereinafter, categories 410-429 of the International Classification of Diseases (WHO) were used.

Fifteen incorporated suburban communities were available for comparison, ten of which are in a low-sodium water supply group and five in a high-sodium group. The cities, the 1970 populations, the sodium concentration in their drinking water supplies, and the year in which the sample was obtained are shown in Table II. The percentage of deaths occurring by age group for 1970 was plotted for these communities, and it was observed that ages 60-74 exhibited the greatest difference between the two sodium groups (Figure 5). A second plot was then made of the pooled deaths for the years 1969-1972 (see Figure 6), and showed no difference in the 6th decade but possibly some difference in the 5th decade and in later years. (Care must be taken in interpreting these graphs since they are not corrected for population.)

Based upon this cursory overview, a Chi-square test and an analysis of variance were performed for the years 1969, 1970, and 1971 using 1970 population data for determining rates. The results of these analyses for the population group 60+ were as follows:

	X^2	F
1969	.76	1
1970	12.52	3.30*
1971	.01	1

*Significant at P = 0.10

The large difference between the census year and the two adjacent years is difficult to explain, but certainly one possibility is that the population may be in a greater state of flux than one would expect. If so, this points to the importance of having good population data the acquisition of which can be almost impossible to obtain for non-census years.

A comparison of weighted average death rates per 100,000 for the two age groups and both sexes for the two types of communities in the census year 1970 was then determined as follows:

AGE GROUP	HIGH SODIUM		LOW SODIUM	
	MALES	FEMALES	MALES	FEMALES
45-59	374	91	447	74
60-74	1730	990	1330	570

Only the rates for men in the 45-59 age group are not consistent with the hypothesis. If it is assumed that most of the men in this age group are physically active and gainfully employed and spend a large proportion of their time at work in the City of Dallas, as opposed to the 60-74 year age group which will be a more sedentary group, the hypothesis holds. Note that the difference between the communities for men in the 60-74 age group is 400 and for women is 420 indicating the likelihood of an equal impact.

These data would seem to hint that a relationship between sodium in drinking water and heart disease deaths is possible. But much additional work is indicated before it can be stated with certainty and limiting values promulgated. For example, the water supply situation is not as clear-cut as has been suggested. All five of the high-sodium communities purchase water from the low-sodium Dallas city supply. However, they rely mainly upon their own individual sources and only purchase such additional water as to satisfy the demand, and as you all know, this can vary considerably. Also, when low-sodium water is purchased, it is not uniformly mixed with local waters prior to distribution. These factors, plus the observation that sodium in drinking water normally consititutes such a small portion of total daily intake incline the senior author to feel that sodium *per se* (in food, water, or added as flavoring) is a great deal more hazardous to the sedentary individual than currently recognized.

This work was supported, in part, by a grant from the Texas Water Resources Institute, WRI Project No. B-146-TEX, and also by the cooperation of the Texas State Department of Health.

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TABLE I DALLAS COUNTY - SODIUM IN DRINKING WATER

SUPPLY	Na > 100 mg/l	Na < 100 mg/l
FWSD #15 Buckingham	680	
WCID #2 Park Cities		18
WCID #6 Balch Springs		8
WCID #7 Kleberg	494	
Addison	384	
Carrollton		22
Cedar Hill	300	
Cockerell Hill		20
Combine WSC		9
Boyd	750	
Carver Hts. & Lancaster	437	
Costom	550	
Danieldale	428	
Grand Prairie (Distribution)	301	
Ledbetter Hills	305	
Meadow Lake	720	
Pleasant Grove	600	
Coppell	249	
Dallas		25
Dallas LTV	351	
DeSoto	333	
DeSoto-Clover Haven-Carroll Water Co.	840	
Duncanville	(120)	
Farmers Branch		22
Garland		12
Grand Prairie (Well)	315	
Hutchins	500	
Irving	368	
Lancaster	415	
Mesquite		10
Richardson		14
South Hampton Water Service	446	
Sunnyvale		14
Wilmer	494	

TABLE II CHARACTERISTICS OF COMMUNITIES

High Sodium Group	1970 Population	Na concentration in Drinking Water Supply, mg/l	Year of Water Sample
Grand Prairie	50,904	301-315	1967-19
Irving	97,260	368	1972
Duncanville	14,105	120	1971
Kleberg	4,768	494	1971
Lancaster	10,522	415	1971
Low Sodium Group			
Seagoville	4,390	25	1972
Garland	81,437	12	1971
Mesquite	55,131	10	1969
Farmers Branch	27,492	22	1972
Highland Park	10,133	18	1970
Richardson	48,582	14	1971
University Park	23,498	18	1970
Balch Springs	10,464	8	1972
Carrolton	13,855	22	1972
Cockerell Hill	3,515	20	1971

FIGURE 1 DISEASES OF THE HEART

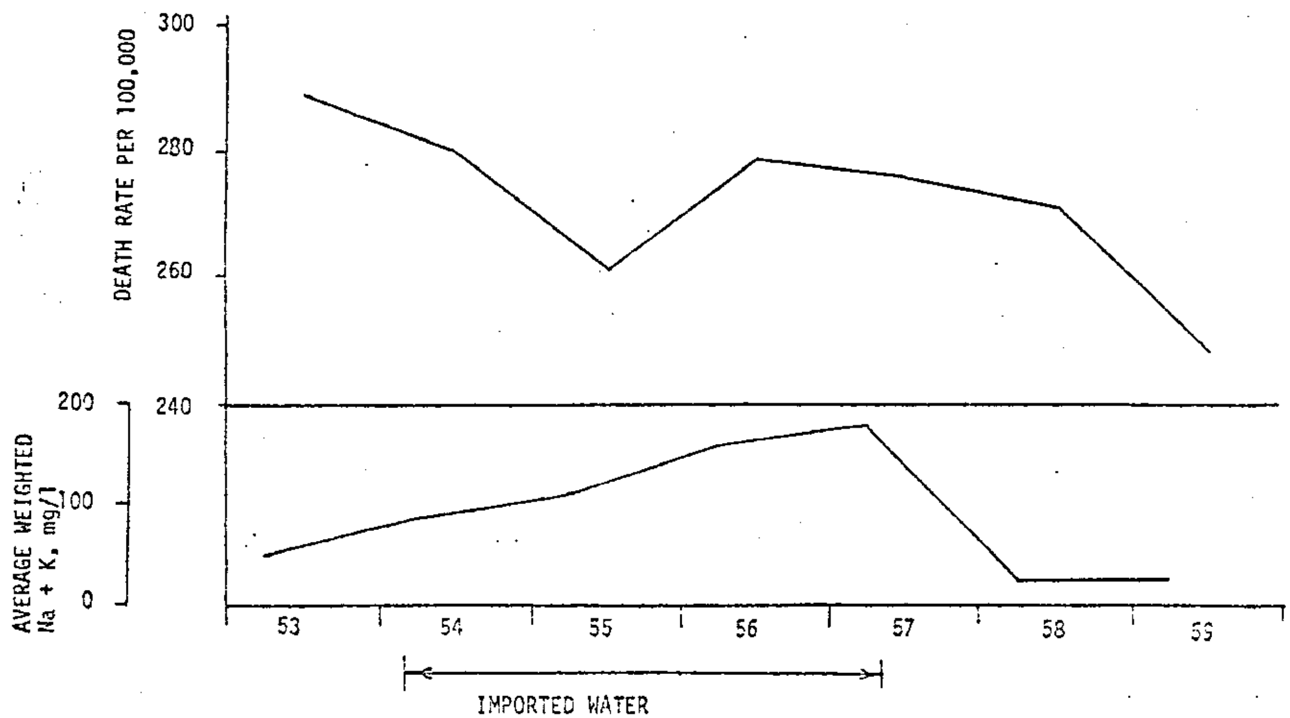


FIGURE 2 ARTERIOSCLEROTIC HEART DISEASE, INCLUDING CORONARY DISEASE

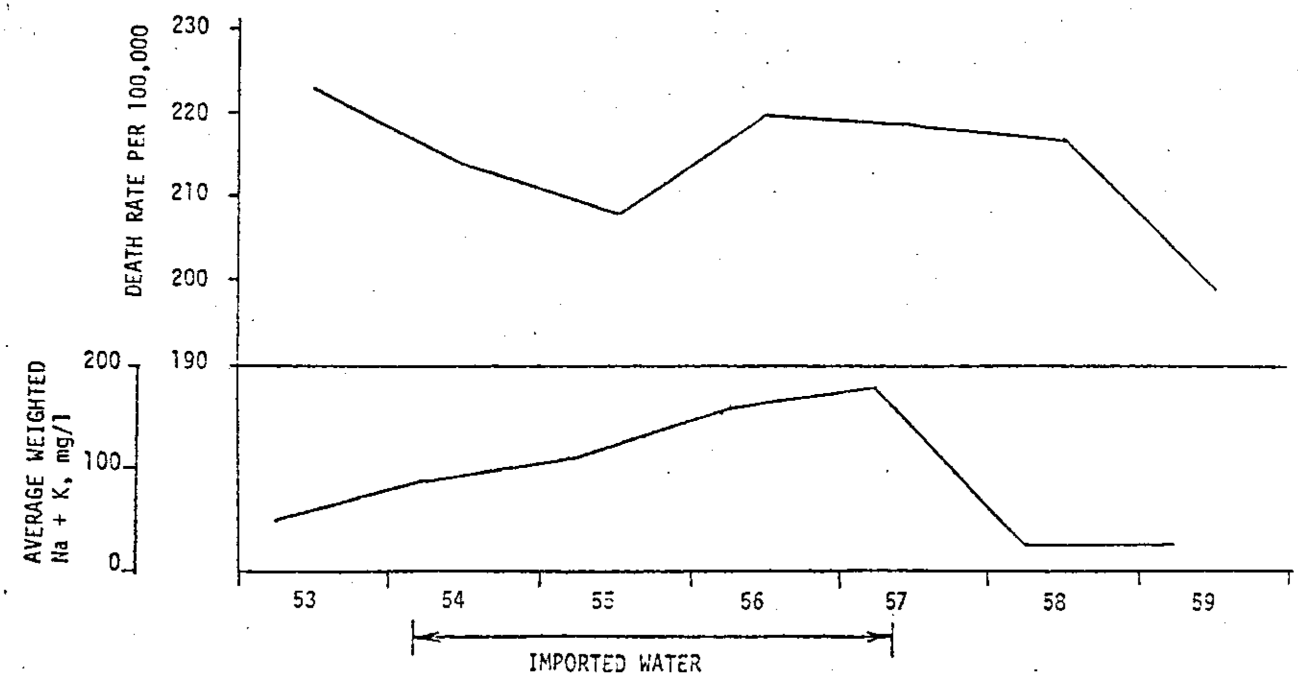
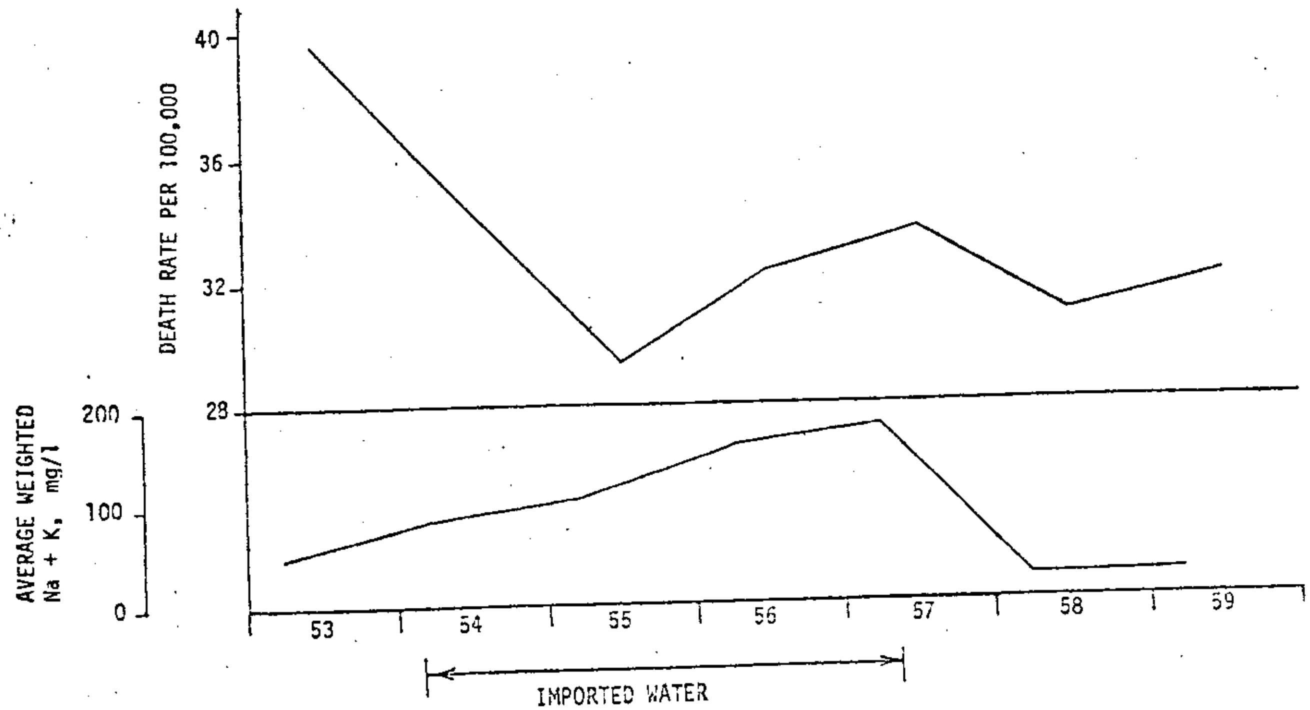


FIGURE 3 HYPERTENSIVE DISEASE



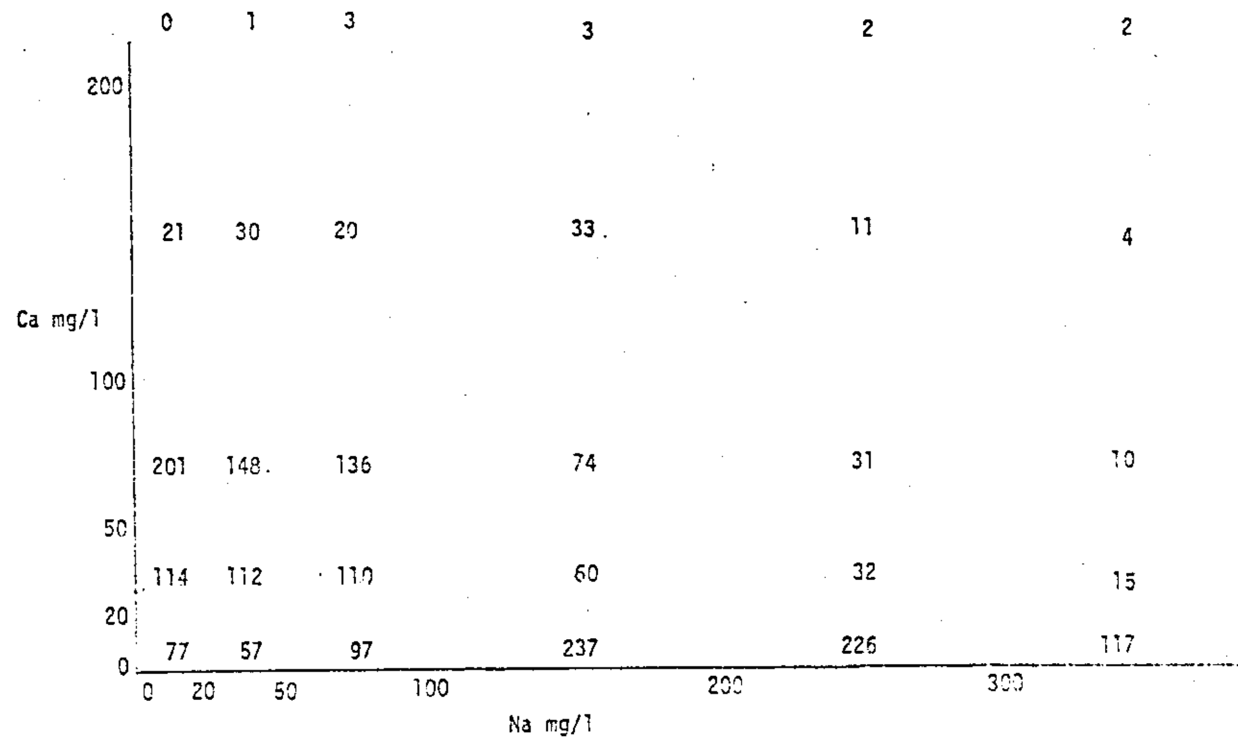


FIGURE 4 DISTRIBUTION OF Ca AND Na IN TEXAS PUBLIC WATER SUPPLIES

FIGURE 5 PERCENT OF TOTAL HEART DISEASE DEATHS (ICD 410-429) BY AGE GROUP IN SUBURBAN COMMUNITIES OF DALLAS COUNTY, TEXAS 1970 OCCURRING IN HI- AND LOW-SODIUM WATER SUPPLY AREAS

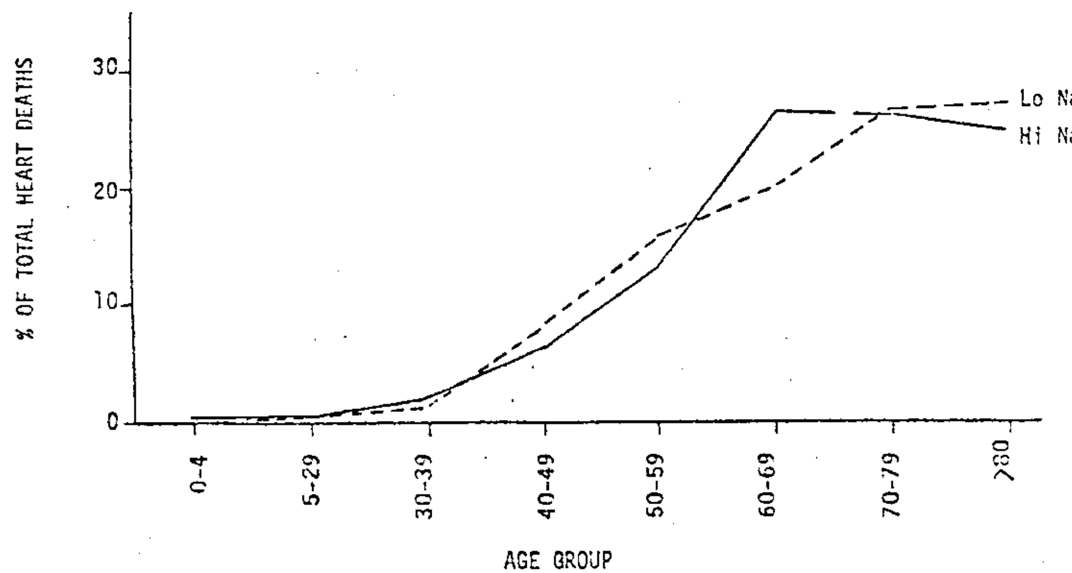
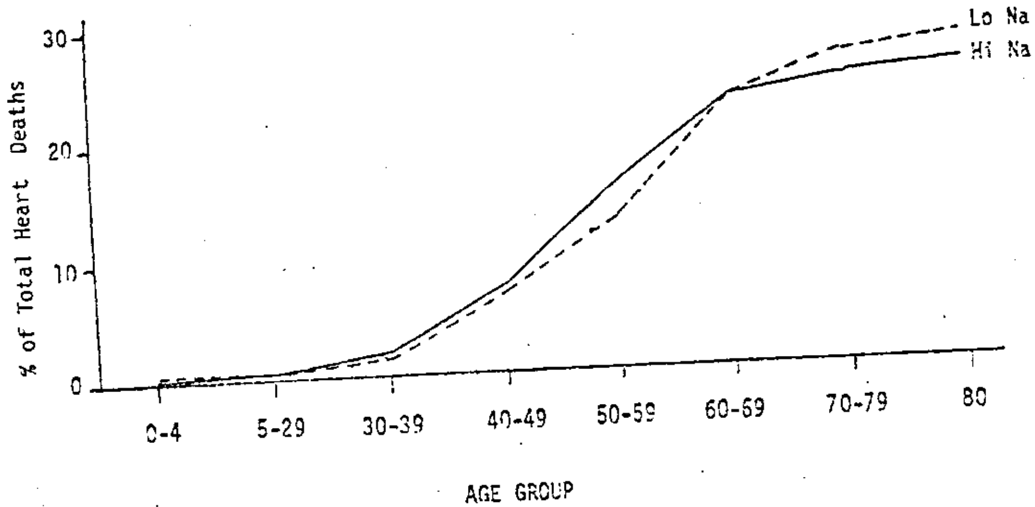
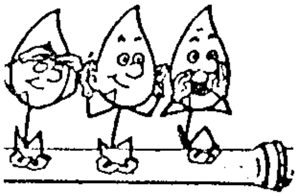


FIGURE 6 Pooled Deaths by Age Group

1969-1972





Percolation & Runoff

Research—Key to Quality Water Service in the '80s is the eme to which more than 100 speakers, upward of 6000 steners, and 150 exhibitors will be addressing themselves at WWA's 95th Annual Conference in Minneapolis, Jun. 8-13. etween the opening challenge by Dr. Joe Ling, research head the 3M Co., and the closing prognosis by Dr. Wilson Talley, search head of EPA, there will be extended discussion of the ndings of the priorities project conducted by AWWA's Re- arch Fdn. to determine what has to be studied, not only in ater quality but in management, distribution, and resources : well.

The research priorities there discussed, of course, will be iose that the industry sees as critical rather than those that ive been foisted upon it by the news media as a result of ir- sponsible speculation or extrapolation. This is not to say iat there cannot be parallels between the two, but it is clear iat politically controlled research funds flow these days to iose areas that the news media have built into crises—mer- iry, asbestos, and now chlorinated organics—whereas those ss glamorous projects seen as critical by the industry go beg- ng. The answer, of course, is "you pays your money, you kes your choice." If the industry wants to get done the re- arch it wants to get done, it had better be willing to pay for . Just one cent per person served per year would provide a ind of almost $2 million, which, through an agency such as ie Research Fdn., should be able to make significant progress oward "Quality Water Service in the '80s." If, on the other ind, we content ourselves with letting Uncle Sam do it, we e almost certain to spend many times that amount respond- ig to false alarms. As Abel Wolman pointed out in a recent ticle on health priorities in the *Bulletin of the Pan Ameri- in Health Organization,* "no public servant can be impervious public clamor, no matter how erroneous." A question ised by some utilities whose phones have been remarkably uiet following one frightening revelation after another is hether the clamor is really "public" or merely media melo- rama. The sales record of the bottled-water industry and the urgeoning interest in home water-treatment equipment, not mention the actions of Congress, would seem to indicate iat the public as a whole is doing a better job of putting the velations into proper perspective than the active minority. his being a day of minority rule, however, we would join bel in suggesting that the public will be best served if those ho serve it "strive to lead as well as to follow."

Leading as well as following are a couple of our Editors nonymous — *toward* proper perspective, that is, and *after* nplications of imperilment.

Having noted the "possible" relationship of high sodium ontent to heart disease, a Texas contributor decided to check ie sodium content of other beverages in comparison with ater. The results, unconfirmed and uninterpreted, are never- ieless not unimpressive to one who usually eats pretzels with is beer, but is smart enough to stay away from diet drinks ther than water:

Beverage	Sodium *mg/l*
Beer:	
Ballantine	50
	48
Budweiser	27
	26
Busch Bavarian	26
Coors	46
	42.5
	42.5
Falstaff	57
Michelob	24.5
Miller	64
Old Milwaukee	117
Pabst	224
	248
	160
	200
Pearl	113
Pearl Light	113
Schlitz	125
	110
	68

Beverage	Sodium *mg/l*
Soft Drinks:	
Coca Cola	57
	53
Dr. Pepper	96
Dr. Pepper (sugar-free)	132
Pepsi Cola	15.2
Pepsi Cola (diet)	160
7-Up	123
Sprite	164
Tab	122
Other:	
Coffee (black)	15.5
Coffee & sugar	14.0
Coffee, sugar, Cremora	42.0
Dallas tap water	15.5

As noted above, you pays your money, you takes your choice. Meanwhile, one of our Illinois operatives with a bad cold and a taste for the French Quarter made the following study of chloroform content of popular cough medicines compared with that of New Orleans water:

Brand	Chloroform Content			Max. Suggested Daily Dose	Record Daily Dose	Time to Obtain 70-Year Equiv. of New Orleans Water Supply†
	mg/l	*per cent*	*mg/tsp**	*tsp*	*mg*	*days*
REM	7000	0.7	35	16	560	6
Vicks	5000	0.5	25	15	375	9
Romilar III	5000	0.5	25	12	300	11
Breacol	5000	0.5	25	4	100	34
Pertussin	3000	0.3	15	16	240	14
Cheracol	3300	1.5 gr/fl. oz	16.5	8	132	26

*From the U.S. Pharmacopeia XVII, Sep., 1965, which indicates that 1 tsp, according to ASA (now ANSI), is 4.93 ± 0.24 ml.

†Chloroform content of New Orleans' area water supply from the EPA "Draft Analytical Report of New Orleans Water Supply Study" is 0.133 mg/l. The same report assumes that a person would normally consume 1 l of water per day. Based on this assumption, a 70-year equivalent has reference to the amount of water a person might consume in that period at the 1-l/day rate. Thus, a chloroform content of 133 μg/l would be equivalent to 0.133 mg/l, or 48.5 mg of chloroform per year, or 3 398 mg of chloroform in 70 years. Based on maximum daily dose.

Which is perhaps to suggest cough up or check out. At any rate it makes AWWA's 96th Annual Conference in New Orleans next year a little less frightening for us to contemplate.

The Frequency of Arterial Hypertension Among Persons Using Water With an Elevated Sodium Chloride Content

M. I. Fatula

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It has been established by clinical and experimental studies that steady useage over many years of a surplus quantity of sodium chloride leads to the development of arterial hypertension (Fukuda; Humphries; Dahl and Love).

Meneely, et. al., and Grollman obtained salt hypertension experimentally in animals.

However, a number of authors deny the role of sodium chloride in the origin of arterial hypertension (Schroeder; Winer).

In connection with this we conducted a study of the inhabitants of a settlement, part of whom use water with an elevated sodium chloride content during their entire lives. In the area of this settlement a stratum of rock salt more than 1200 meters thick is deposited at a depth of 0.5-6 meters from the surface of the ground.

A chemical analysis was made of the water from 150 wells in this region. According to international standards (VOZ, Geneva, 1954), the maximum allowable concentration of chlorides in drinking water is 600mg/1. In the wells studied the content of sodium chloride exceeded by 2-5 times the allowable standard. The concentration of other chemical elements in the water (calcium, magnesium, iron and others) was the same in all the wells and did not exceed the limits of the standard.

All the inhabitants of the given settlement from 14 years and older were subject to the study. It was conducted in the spring period in scheduled rounds.

In accordance with the recommendations of the Committee of Experts of VOZ (1962) the so-called chance pressure has been determined. With the one being examined sitting, his arterial pressure was measured by mercury manometer according to Korotkov's phonetic method. A pressure of 140/90mm was taken as the norm. Persons with arterial pressure of 160/95mm and higher were considered to be victims of hypertension. These criteria were employed for persons 20-60 years of age, for 16-19 year olds they were lower: by 10mm for systolic pressure, by 5mm for diastolic pressure. A special chart was filled out on all the inhabitants in whom elevated arterial pressure was displayed, and they were brought under dispensary observation. In all 3257 persons were studied. They were divided into three groups. In the first group were included people with normal arterial pressure, in whom, according to anamnesistic reports and the data of various documents, it had never before been elevated. In the second group were placed people, in whom the arterial pressure either a) was found to be from 140/90 to 159/94mm or b) was normal at the moment of observation but had authentic data on its elevation in the past and corresponding complaints in the direction of the cardio-vascular system. Patients having arterial hypertension in different stages with arterial pressure greater than 160/95mm comprised the third group.

General clinical analyses of the blood and urine and roentgenscopy of the organs of the chest cage were made on all the arterial hypertension patients and the majority of the persons in the second group. A neuropathologist and occulist consulted all the arterial hypertension sufferers, an EKG was recorded on them, the residual nitrogen in their blood was determined and Zimnitski's test was conducted. Patients with symptomatic hypertension and clinical manifestations of arterosclerosis were not taken into consideration.

Among the 1809 persons who were using water with a normal quantity of sodium chloride, 3.4% were victims of arterial hypertension. Persons in the second group turned out to be 4%, and in 92.6% of the individuals the arterial pressure was in the normal limits.

Out of 1448 persons using water with an elevated sodium chloride content, 12.4% were victims of arterial hypertension, 13.8% were individuals who were found to be in the danger zone, and 73.8% were found to be healthy with respect to arterial hypertension. The difference in morbidity to arterial hypertension between the groups is statistically reliable ($P<0.001$).

An exclusion to this appears to be the age group 25-29, where the difference in frequency of arterial hypertension is statistically unreliable ($P>0.5$).

Clinically, the arterial hypertension of the individuals who were using water with an elevated sodium chloride content proceeded severely with frequent crises and responded poorly to the action of hypertension preparations.

In 67 patients of the hypertion disorder, who were using water with an elevated soduim chloride content, we determined the chloride in the blood serum (according to Rushnyak) and in the urine (according to Mor). As a control these studies were carried out on fifteen healthy individuals. A daily extraction of the chlorides from the urine proved to be elevated. Thus in healthy persons it consisted of 10.7±0.8g, in patients in the first stage of arterial hypertension is was 19.7±1.2g, in second stage patients it was 23.1±1.3g, and in the third stage patients it was 30.9±2.0g. The difference is statistically reliable ($P<0.001$).

The chloride content of the blood serum was also elevated: in the healthy subjects it was 484±8.8mg%, in the patients in the first stage of arterial hypertension it was 528±9.2mg%, in the second stage patients it was 599±13.8mg% and in the third stage it was 634±14.7mg%. The difference is statistically reliable ($P<0.001$).

Thus our studies showed that persons who use water with an elevated sodium chloride content suffer arterial hypertension more frequently than persons using water with a normal content of this salt. A daily extraction of chlorides from the urine and also the content of chlorides in blood serum of arterial hypertension victims, who use water with an elevated sodium chloride content, are elevated.

Translated from the original Russian

by John Richard Hensley

VIEW Point

Softened Water Need Not Be A Danger

Harold Wolf

Director of Environmental Engineering, Civil Engineering Dept. Texas A&M Univ.

The topic appearing in this commentary was selected by the AWWA Publications Advisory Com. on the basis of its timeliness and importance to the field. The contributor was solicited on the recommendations of the committee. The viewpoints expressed are those of the author and are not intended to reflect Association policy. Equal space for refutation will be provided in future JOURNAL issues. You are invited to respond.

Whether one should or should not soften water has been an increasingly agonizing question for almost 20 years.[1,2] This concern relates to repeated observations by investigators in a number of different countries and areas that high drinking water hardness appears to effect lowered heart— and circulatory—diseases death rates. Although we still do not understand why such a relationship should exist, some progress has nevertheless been made in helping define the relationship further—at least, so this writer thinks. Accordingly, water can be softened, and it can be so done without harming health as long as the sodium content is not raised to unacceptable levels.

Hardness is caused predominantly by calcium and magnesium concentrations in water. Morris, Crawford, and Heady,[3] English investigators, on the basis of epidemiological studies were able to rule out magnesium as contributing to a health problem—the first major contribution to the study.

Then Canadian, Dr. T. Anderson,[4] observed that water hardness related most closely to ischemic heart disease, or the sudden-death syndrome, and that the relationship was more likely to be a detrimental effect from something present in soft water than a protective effect from something present in hard water. Shortly thereafter, Dr. Edward Lee Russell,[5] from a variety of water quality factors chose to study sodium. His conclusion was ". . . that 37.9 per cent of the residents of the . . . (southern California) district are served a domestic water supply containing 110 mg/l or more of sodium, an amount that would place in jeopardy all residents who have confirmed or incipient congestive heart disease, hypertension, renal disease, or cirrhosis of the liver."

Texas A & M researchers in Dallas with support from both the City of Dallas and the Texas Water Resources Inst.,[6] were able to show a rise in all categories of heart-disease deaths. This rise was coincidental with a drought period during which highly mineralized water from the Red River was imported for consumption. The high death rate persisted for a year following termination of water importation.

Although calcium, magnesium, alkalinity, and total dissolved solids increased during the importation period—all of which had been linked with a protective effect against heart-circulatory deaths—the deaths increased. Further, the increase occurred at the sodium levels suggested by Dr. Russell. Figure 1 (heretofore unpublished) shows the deaths for one of the categories of heart disease for both the cities of Dallas and Ft. Worth (the latter did not import water) uncorrected for increasing populations.

The evidence implicated high sodium concentrations. The writer wondered if, in general, sodium did not correlate inversely with water hardness, specifically with calcium. Plots of the sodium and calcium content of public water supplies in Texas show that this relationship does, indeed, exist: that most high sodium supplies are low in calcium and most high calcium supplies are low in sodium.[7] The observed negative correlations between hardness and heart-disease deaths could now be hypothesized as attributable to sodium content.

If sodium is, indeed, the culprit, some differences ought to be observable between cities using high- and low-sodium drinking water. Such a test was possible right in Dallas County, and with the additional help of the state department of health, this writer and B.J. Moore demonstrated a rather

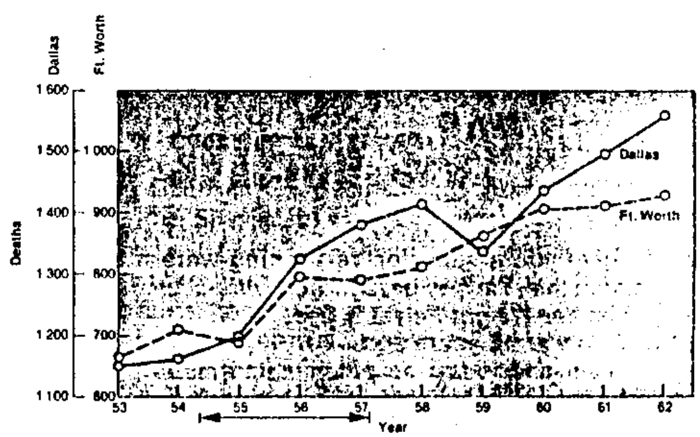

Fig. 1. Deaths Attributed to Arteriosclerotic Heart Disease Including Coronary Disease, Category 420, 7th Revision International Lists 1955.

(*Continued on page 23*)

(*Continued from page 15*)

massive difference, but it was confined to the older population and only at a low order of statistical significance.[7]

The writer has been reflecting on these studies and many others and upon their various anomalies. He offers the following hypothesis. Sodium content in drinking water in the range 100-200 mg/l impairs salt-taste acuity of individuals[8] who then unwittingly use more salt in their diet. This could explain both the persistence of deaths beyond the period of water import for Dallas and the low significance, yet massive, effect observed by this writer and Moore (the major contribution of sodium being from the diet, not the drinking water).

The writer does not intend to dismiss the potential role that water instability may play in drinking-water-health relationships. Nor is the writer suggesting that sodium contributes to arteriosclerosis. But regardless of the predisposing factors, the mechanism of actual death is apparently a sodium-mediated event, albeit indirectly, such as a congestive heart failure.

Based on this interpretation of the water factors, certainly lime softening would constitute a totally safe procedure. It contributes no sodium, and if well operated, will produce a pathogen-free water that is highly stable. Soda-ash processes contribute sodium, and, depending upon the amount contributed and the amount already present in the water, these processes should be reviewed on a case-by-case basis. Zeolite softening at the home level is perfectly amenable to Dr. Shaper's suggestion of allowing a drinking tap to bypass the softener.[9] (For economic reasons, one might also not want to flush toilets with softened water.) The main problem in the writer's view occurs with utility use of Zeolite processes. Many utilities might be well advised to convert to lime softening, or not soften at all and let the home owner soften individually. Any decision would have to be based on the amounts of sodium present in the finished waters, and it would certainly help if the agencies and associations that have responsibilities in the matter would get their heads out of the sand and develop the sodium criteria that are so badly needed.

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Recharge of Reclaimed Waste Water: Research Needs

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The water agencies of the State of California, viz., the Water Resources Control Board, the Department of Water Resources, and the Department of Health, have established a panel that is developing the material originally destined for presentation at this time. Since the panel's work is not yet complete, it cannot be presented. However, I would like to identify the panel membership, then present some of my own concerns about areas of needed research, and finally conclude with some of the general topic areas that the panel is developing.

The consulting panel on Health Aspects of Wastewater Reclamation for Groundwater Recharge includes, besides myself:

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Ten to 15 years ago I was an ardent, unequivocal supporter of ground water recharge using treated waste waters and surface-spreading, percolation techniques. After all, the process simply duplicates nature. Today, I am not so ardent. A review of the papers and work that prompt my apprehension speaks directly to the heart of the subject matter--research needs.

Physiological Research Findings

Certain compounds and metals have been observed to demonstrate carcinogenic properties. Bayland has proposed that perhaps 90 percent of the cancer in contemporary man is caused by chemical compounds (1). Demographic studies of the distribution of cancer prompted Oettle (2) to postulate that 80 percent or more of the cancers found in western races are induced by the environment, and therefore, are potentially preventable. Recognition that factors in the environment could be responsible for the initiation of tumors could incriminate both food and water as major vectors of environmental tumorigenic substances, since they represent two of the major environmental routes that man and animal must utilize.

Several hypotheses have been proposed on the mechanism of chemicals as tumorigenic agents. Harrington's review (3) of the literature is climaxed by a cancer-induction proposal involving interaction of a carcinogen directly with the sulf-hydryl active groups that function in the control of cell division. Free sulf-hydryl groups are needed for normal cell division; the formation of combinations with the sulf-hydryl groups could interfere with the process.

Using metals as an example, we find that most metallic ions are polyvalent, hence, they should not have much effect on enzymes that contain only one sulf-hydryl group. However, profound changes in enzyme activity can be expected if the enzyme in question has two groups arranged geometrically so that the metallic ion can combine with both to form an intra-sulfur-metal-sulfur-bond (4).

Such differing combinations could explain the observations of Public Health Service workers who reported some metals (at trace concentrations) to be stimulatory and others inhibitory to the activity of benzpyrene hydroxylase. This enzyme reportedly detoxifies the recognized carcinogen, benzpyrene, and inhibition of the enzyme activity would result in increased benzpyrene residence time and thus increase the carcinogenic risk (5).

Combinations of metals with sulf-hydryl groups are likely an additive-type activity. In the Soviet Union, Novakova reported that the concentration of sulf-hydryl groups in the blood and serum proved to be a most sensitive test for determining the combined effect of arsenic and lead when administered in drinking water. Her paper suggests that mercury, cadmium and silver are also sulf-hydryl active (6).

Since a number of metals, all present in trace concentrations, could be involved in an additive way with a mechanism that might interfere with enzyme systems protective against carcinogens, and since cancer of the bladder has been cited as increasing in recent years (and, hence, is potentially environmentally related) (7), the availability of a five-year summary of trace metals in rivers and lakes of the United States (8) enabled a comparison of urinary cancer death rates with the percent frequency of occurrence of the metals (less copper and zinc which are reported to be beneficial at the concentrations cited) (9). The resulting rank correlation was not significant, but the distribution remains suspicious. An Italian paper was published in 1970 that observed a significant statistical relationship between total metal ion content (iron, magnesium, aluminum, manganese, nickel, lead, copper, zinc, chromium, cadmium and tin) of drinking water and mortality from cancers of the digestive system, liver and pancreas (10).

None of the above can be even remotely construed as proof that metals in trace amounts might contribute to cancer. However, two major points of view that bear on the subject have been receiving increased emphasis in recent months. First, a number of metals are known to be cumulative over perhaps years of exposure. And second, there appears to be greater acceptance of an immunologic role in the genesis of cancer.

About six years ago, Dr. Conrad Straub of the University of Minnesota's environmental health program cited additive aspects that ought to be considered for substances in drinking water standards to the then Environmental Control Administration of the Public Health Service. The drinking water standards of the U.S.S.R. already do contain an additivity principle. Also, additivity is routinely utilized in occupational health activities.

Table I shows a comparison of the median concentrations of metals found in 25 to 46 samples of tap water, in activated sludge (1-1/2 years of record), and, in filtered activated sludge (based upon the same length of record but fewer samples) with the proposed limits suggested by EPA. Only chromium would prevent activated sludge effluent from being acceptable. The filtered activated sludge effluent meets the metals criteria quite handily. Were these waste waters applied to a recharge operation, one could expect the percolated waters to be of even higher quality because soil adsorption and other mechanisms absent in a filter come into play. Nevertheless, if it is assumed that the metals for which limits are proposed can act additively, then the calculation of Table 2 can be used. Here we see that tap water metals total only 64 percent of the total allowable concentration of metals, but the filtered effluent metals total up to 208 percent -- and would consequently fail acceptance.

Table 1

Tap Water and Waste Water Metals Concentrations[1]

Median Values, mg/l

Metal	EPA[2] Limit	Tap[3] Water	Activated Sludge[4] Effluent	Filtered[5] Effluent
As	0.05	0.0015	0.009	0.008
Cd	0.01	0.003	0.006	0.0045
Cr	0.05	0.003	0.06	0.036
Cu	-	0.029	0.051	0.040
Fe	-	0.088	0.35	0.115
Hg	0.002	0.0001	0.00015	0.0001
Mn	-	0.004	0.052	0.04
Ni	-	0.010	0.075	0.06
Pb	0.05	0.010	0.040	0.03
Se	0.01	0.000	0.001	0.001
Sr	-	0.185	0.83	0.635
Zn	-	0.011	0.11	0.07

1 Data from Dallas studies, soon to be published

2 Proposed Interim Primary Drinking Water Standards

3 25-46 samples

4 1-1/2 years of record

5 Same length of record as note 3 but fewer samples

Table 2

Percent of Metals Allowed

Metal	Tap Water	Filtered Activated Sludge
As	3	16
Cd	30	45
Cr	6	72
Hg	5	5
Pb	20	60
Se	0	10
	64	208

Quite obviously, a need exists to determine the justification for an additive role for metals in sulf-hydryl activity, in immunologic interference, in the genesis of cancer, and in the development of drinking water standards, particularly as these standards might be applied to waste water-recharged ground waters. However, such research should not overlook the possible contributions of organic agents, as for example the sulf-hydryl inhibiting beta-nitrostyrenes, vinyl ketones, vinyl sulfones, zinc dithiocarbamates and quaternary salts (11).

Although adsorption and other properties of soils can be expected to reduce the concentrations of most metals and organics in a percolated waste water effluent, very little effect may be expressed on some of the minerals. The preponderance of published statistical studies tend to support the observation that mineralized waters have a beneficial effect on human health through an unknown mechanism that appears to protect against heart disease deaths (12). One mineral, however, sodium, has been observed to relate in a detrimental way to heart disease and a hypothesis has been suggested that the previously observed protective effects of mineralized or hard waters are, in effect, simply reflections of the lack of detrimental levels of sodium (13).

Kobayashi of Japan (14) was the first to report a relationship of an aspect of cardiovascular disease with water mineral quality. He reported a higher incidence of deaths from cerebral hemorrhage in areas of Japan drained by lower alkaline, lower pH (less mineralized) waters. Schroeder observed a relationship indicating that areas supplied with hard drinking waters showed lower death rates from cardiovascular diseases than soft-water areas (15). His suggestion offered the first explanation for geographical differences in cardiovascular disease death rates observed by Enterline and Stewart (16) and then followed up by Sauer and Enterline (17). Schroeder reported significant protective correlations for calcium, magnesium, sulfate, dissolved solids and hardness, and lesser-significant correlations for bicarbonates, pH and a few others. Sodium and potassium analyzed together by the procedures then used showed no relationship. His source of water data was the 1954 USGS Water-Supply Papers 1299 and 1300 (18).

Dr. E. L. Russell was asked by the Orange County Water District of southern California to identify substances, if any, present in the underground waters which would, in quantity, be harmful to human beings. He reported that a domestic water supply containing sodium at a concentration of 110 mg/l or more "would place in jeopardy all residents who have conformed or incipient congestive heart disease, hypertension, renal disease, or cirrhosis of the liver" (19). His conclusion is based largely on the 500 mg/day sodium restriction diet which calculates out to an allowable sodium content in drinking water of 20 mg/l (20).

In 1967, a Russian study had been published which reported that in a group of 1809 persons (age 20-60) using a water supply containing a "normal" amount of sodium, 3.4 percent had arterial hypertension (defined as 160/95 mm or greater). On the other hand, in a group of 1448 similar persons using water with an "elevated" sodium content, the arterial hypertension rate was 12.4 percent, with a significance of $P < 0.001$. The paper is elusive as concerns sodium concentrations and also in the use of the word "arterial". For example, would 140/100 be considered "arterial" hypertension? The best one can estimate "normal" sodium concentration to be in this report is 263 mg/l or less (21).

Wolf and Esmond, in studying the production of potentially potable-quality waters from waste waters in Dallas, Texas, observed that sodium concentrations of the waste waters varied from 63 to 130 mg/l, with a median value of about 90 mg/l (22). The original tap water ranged from 11 to 25 mg/l. They were aware that in the 1950s the city imported water from the Red River for three consecutive drought-stricken years, and that this water was highly mineralized. For each of the disease groups reported in Vital Statistics, viz., Diseases of the Heart, Arteriosclerotic Heart Disease Including Coronary Disease, and Hypertensive Disease, increased deaths accompanied the period of water import. The average sodium plus potassium concentrations were calculated, and these peaked at about 180 mg/l.

Since virtually all the mineral constituents would have followed the same pattern as the sodium plus potassium curve but differed only in magnitude (for example, hardness rose from a base of about 50 mg/l to a peak of about 200 mg/l), it is interesting to note that these qualities did <u>not</u> protect against heart-circulatory deaths which might be predicted from Schroeder's -- and many others -- observations. Instead, death rates rose, as might be predicted by Dr. Russell's calculations concerning sodium, and in the "ball park" of the concentrations cited by him.

In 1969, Canadian scientists published the important observation that the higher death rates observed in soft-water areas were found to be entirely due to an excess of sudden deaths and that this correlation might be the result of an increased susceptibility to lethal arrhythmias among residents of soft-water areas (23). An equally important comment by one of the authors suggested that the hard, highly-mineralized waters tend to be the ones that are high in sodium.

While this is true for some surface streams such as the Red River, it is hardly true for ground waters in which base exchange can occur with some soils. In large areas of the country overlain with limestone, waters percolating through the formations pick up hardness and then lose it in underlying sands in exchange for sodium (18). Wolf plotted the Ca vs. Na concentrations reported for Texas public water supplies and clearly observed that high-sodium supplies were indeed low in calcium -- hence soft (24).

Wolf and Moore (13) conducted a study of the magnitude of difference in heart disease deaths between two groups of suburban communities, high-sodium vs. low-sodium drinking water, and observed no effect on young people but a massive effect on older people (over 60 years). Death rates among older women in the high-sodium areas were 42 percent higher, among men 23 percent higher. The percentages are lower for men only because the death rate is higher than for women. The actual difference in magnitude for both sexes is virtually the same.

Clearly, the amount of sodium contributed to water by municipal or even domestic use is substantial when viewed in terms of the sodium restriction diet. Additionally, the number of people at risk is substantial, the EPA estimating this as more than 10 percent of the population (25). A moral issue thus surfaces when recharge of ground waters by percolation with treated waste water effluents is contemplated: It is one thing to find oneself in the position of having to drink water with elevated sodium when that water is the only water mother nature has provided, but quite another when the elevated sodium is due to man's deliberate and knowing misconduct.

Another mineral, but of lesser importance to the recharge situation, is sulfate. The amount of sulfate added to water by domestic use is on the order of 15-30 mg/l (26), although Dallas observed an average of 58 mg/l (27). Israeli scientists suggested that a high rate of kidney stones among Arava Valley inhabitants might be attributable to drinking water sulfate content, but this content was about 900 mg/l (28). The same writers contend that even when sulfate is present at the former maximum recommended level of 250 mg/l (9), a hard-working laborer on a hot day may drink up to 20 liters of water during an eight-hour shift, and thus would ingest up to 5000 mg of sulfate daily, an amount that would produce gastrointestinal disturbances and extremely acid urine, and thus be associated with the formation of uric-acid stones (29).

Allowable drinking water sulfate content based upon the amount of water consumed by certain parts of the population would thus appear to constitute fruitful areas of study, but would not be a problem wrought specifically by a recharge operation.

Operational Processes

The City of Dallas, with initial support from the Public Health Service and later the Environmental Protection Agency, and with the assistance of Texas A&M University staff, conducted a lengthy and penetrating study of metals removals by various advanced waste treatment (AWT) processes. The base-line for operation of the preceding biological processes was nitrifying. A highly-nitrified effluent (defined as an effluent ammonia nitrogen content less than 1 mg/l) was the desired goal of this operation, but it could not always be achieved. Nevertheless, it was observed that the removal of organics as measured by the chemical oxygen demand (COD) procedure was considerably enhanced when the activated sludge system was nitrifying as compared to earlier experience at the pilot plant (30). It was observed that "a factor of import involves operation of the module at longer sludge ages (CRT). Increasing the sludge age, among other things, has permitted the development of nitrifying bacteria, whose growth rates are quite slow.

Certain heterotrophic bacteria with similar long generation times which possess the enzymes and/or oxidative mechanisms for utilizing a large portion of the refractory . . . (organics) may also respond positively to a longer sludge age. Whatever the cause, however, the effects . . . are not as visible in the activated sludge effluent as in the final tertiary effluent." Snoeyink and colleagues at the University of Illinois have since confirmed the observation and nailed it to the increased sludge age (31). Additionally, Culp's experience supports these observations (32).

Another observation related to nitrified operation that might have considerable impact on a recharge situation is still tentative. Dallas workers have observed that when ammonia is present, some of the metals behave in a more refractory manner to subsequent carbon adsorption processes. A possible explanation exists in that when ammonia is present some of the metals may exist as metal-ammine complexes. Carbon adsorption is not effective in the removal of ammonia, hence possibly not effective for the removal of metal-ammine complexes. In a highly nitrified effluent, however, these complexes may be oxidized to different species which are more amenable to adsorption-removal processes.

Additional tentative observations from Dallas indicate that better total metals removals are achieved by a nitrifying system and that fewer bacterial viruses are also present. The total metals observation is not as substantial as first observed, and at this point in time appears relatable almost solely to the increased removal of chromium. A possible explanation also exists to support this observation in that the longer exposure to reducing conditions in the secondary clarifier of a nitrifying operation results in more substantial precipitation of or conversion to reduced forms of chromium. The bacterial virus observations might well reflect fewer animal viruses, but this, too, must be substantiated.

All together, these observations are rather condemning of American practice and supportive of English practice. American practice has been aimed at the efficient removal of readily biodegradable carbonaceous organic materials, and this practice has been applied virtually nationwide. English practice has been aimed at oxidizing ammonia. The English try to manage the suspended solids problems often associated with a nitrifying operation by increased secondary clarifier capacity. The whole adds up to the need for a reappraisal of the American approach.

But nitrified operation has a much more immediate role in the recharge situation, particularly as concerns California state agency policy. If a thorough study of existing users of reclaimed waters shows there is absolutely no effect, then the amount of dilution waters presently required could be substantially reduced by conversion of the plants to highly nitrified operations.

Epidemiological Needs

The key word above, viz., " . . . a thorough study . . . shows there is absolutely no effect . . ." is, of course, simply stated but exceedingly difficult to carry out. How does one go about designing such a study? Additionally, suppose one could design and conduct such a study based upon today's knowledge. Tomorrow there would be new developments, and these too would have to be incorporated. The only alternative is to conduct a continuing study and to establish a permanent panel to advise on the conduct of the study, the significance of findings as they emerge, the need for and methods of altering the study to accommodate new information, and the provision of a continuing estimate of how well the present gap in knowledge is being closed.

Past (and present) practices of convening ad hoc committees to deal with major problems of a continuing nature might well be abandoned. As one example, EPA created an "Ad Hoc Study Group to Consider Organics in Drinking Water". The study group has completed its report (33) and it is unquestionably excellent. However, the problem still remains and it will continue for many decades. Why, then, terminate the service of such an excellent group? Were they to meet periodically they might provide an impetus for carrying out some of their recommendations.

The same criticism can apply to the California panel.. The panel's final report will in actuality be just the beginning of a highly interdisciplinary, complex, lengthy undertaking.

Recommended Research Topics

The consulting panel is preparing recommendations in the following general areas. The order of this listing must not be construed as an order of priority:

1. Characterization of the waste water to be applied to the soil and of the water to be withdrawn from the ground for drinking. Such characterization is most difficult for the organics, since the previously mentioned ad hoc study group stated that "the (organic) chemicals which have been measured account for only a few percent of the total organic content of drinking water."

2. Study of processes for the removal of potentially harmful organics. A recent Federal Register publication (34) identifies nearly 1,400 suspected carcinogens -- most of them organics. Although all need not be subject to study, a respectable program is still indicated.

3. Disinfection techniques and viruses. A great deal of needed information on viruses is still lacking. A recommendation for a broad and sustained research effort is likely to emerge.

4. Kinetics of the adsorption of potentially harmful organics on soils and sediments of the unsaturated zone. The unsaturated zone includes the biologically active soil mantle, and it is recommended that this study include interactions between organics and heavy metals via complexes or chelates that will affect removal or mobility.

5. Physical study of pollutants in the underground environment. Once a pollutant reaches the saturated zone what then happens to it? This effort will likely zero in on select organics because of their major concern and lack of previous study.

6. Methodology of risk assessment. Several aspects are suggested including studies of human variability, better information as to what humans are presently exposed to, analyses of biochemical and physiological pathways of various chemical species, gross tests for mutation potential, and extrapolation techniques in going from microorganisms to animals to humans.

7. Epidemiological studies. It is well to keep in mind Dubos' statement: "In the case of environmental pollution, the situation may well become unmanageable if the accumulation of convincing epidemiological evidence is made a prerequisite of social action" (34). Nonetheless, the need is urgent for epidemiological studies to ascertain whether existing drinking water qualities are impacting human health in any manner. Further, if these studies fail to find any effects, they should still be published. Such an accumulating data base will be invaluable to State of California agencies as they plan for the future.

8. Monitoring strategy. The sampling and analysis for many of the parameters of interest in this program are exceedingly expensive, and a substantial investment in research on developing a sound strategy for the monitoring of recharge projects is entirely appropriate in order to gain a maximum of useful results at least cost. The greatest effort should go into investment that would extract the maximum yields from projects now under way or likely to be initiated in the near future. The monitoring strategy should address not only the projects to be investigated, but sampling duration, frequency and site, the parameters to be measured, accompanying epidemiological surveillance of the population, effects on water systems or other water uses and the delineation of controls where possible.

A well-known economist once wrote, "One of the generally aminable idiosyncracies of man is his ability to expend a great deal of effort without much inquiry as to the end result" (35). True or not, it is something to keep in mind relative to the development and progress of the suggested studies.

Californians are fortunate, indeed, that their water agencies are so far ahead, yet still looking to the future. This surely illustrates the high quality of both leadership and agency personnel.

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WEDNESDAY, DECEMBER 24, 1975

PART IV:

ENVIRONMENTAL PROTECTION AGENCY

WATER PROGRAMS

National Interim Primary Drinking Water Regulations

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

[FRL 464-7]

PART 141—NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

On March 14, 1975, the Environmental Protection Agency (EPA) proposed National Interim Primary Drinking Water Regulations pursuant to sections 1412, 1414, 1415, and 1450 of the Public Health Service Act ("the Act"), as amended by the Safe Drinking Water Act ("SDWA," Pub. L. 93-523), 40 FR 11990. EPA held public hearings on the proposed regulations in Boston, Chicago, San Francisco, and Washington during the month of April. Several thousand pages of comments on the proposed regulations were received and evaluated. In addition, the Agency has received comments and information on the proposed regulations from the National Drinking Water Advisory Council, the Secretary of Health, Education, and Welfare, and from numerous others during meetings with representatives of State agencies, public interest groups and others.

The regulations deal only with the basic legal requirements. Descriptive material will be provided in a guidance manual for use by public water systems and the States.

The purpose of this preamble to the final regulations is to summarize the most significant changes made in the proposed regulations as a result of comments received and the further consideration of available information. A more detailed discussion of the comments and of changes in the proposed regulations is attached as Appendix A.

WATER SYSTEMS COVERED

The Safe Drinking Water Act applies to each "public water system," which is defined in Section 1401(4) of the Act as "a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals." Privately owned as well as publicly owned systems are covered. Service "to the public" is interpreted by EPA to include factories and private housing developments. (See generally, House Report, pp. 16-17.)

The definition of "public water system" proposed in the Interim Primary Drinking Water Regulations sought to explain the meaning of the statutory reference to "regular" service. It was proposed to interpret this term as including service for as much as three months during the year. Because the proposed definition would have excluded many large campgrounds, lodges, and other public accommodations which serve large numbers of tourists but which are open for slightly less than three months each year, the definition in the final version covers systems serving an average of at least twenty-five individuals at least 60 days out of the year. The use of a minimum number of days rather than months also makes clear that a system may qualify as a public water system even if it is not open every day during a given month.

Once "public water system" has been defined, it is necessary to define the two major types of public water systems—those serving residents and those serving transients or intermittent users. The possible health effects of a contaminant in drinking water in many cases are quite different for a person drinking the water for a long period of time than for a person drinking the water only briefly or intermittently. Different regulatory considerations may in some cases apply to systems which serve residents as opposed to systems which serve transients or intermittent users. Accordingly, § 141.2(e) makes clear that all "public water systems" fall within either the category of "community water systems" or the category of "non-community water systems." To make clear which regulatory requirements apply to which type of system, the category covered is specifically indicated throughout the regulations.

The proposed regulations defined a "community water system" as "a public water system which serves a population of which 70 percent or greater are residents." Reliance in the proposed definition on the percentage of water system users who are residents would result in treating some fairly large resort communities with many year-round residents as non-community systems. Therefore, the definition of "community water system" has been changed to cover any system which serves at least 15 service connections used by year-round residents or serves at least 25 year-round residents.

SMALL COMMUNITY WATER SYSTEMS

Many community water systems in the country are quite small. Since it is the intention of the Act to provide basically the same level of health protection to residents of small communities as to residents of large cities, and since a number of advanced water treatment techniques are made feasible only by economies of scale, the cost of compliance with the requirements of the Act may pose a serious problem for many small communities. The regulations seek to recognize the financial problems of small communities by requiring more realistic monitoring for systems serving fewer than 1,000 persons. Variances and exemptions authorized by the Act can also assist in dealing with economic problems of small community systems in appropriate cases, at least temporarily. EPA will provide technical assistance on effective treatment techniques which can be used by small systems.

These methods of dealing with the financial problems of some small community systems may not be sufficient in specific instances to make compliance with all applicable regulatory requirements feasible. EPA is commencing a study of potential problems faced by small community systems in meeting applicable requirements under the Act and these regulations, and, if necessary, will make additional adjustments in the Interim Primary Drinking Water Regulations prior to their effective date.

NON-COMMUNITY SYSTEMS

"Non-community systems" are basically those systems which serve transients. They include hotels, motels, restaurants, campgrounds, service stations, and other public accommodations which have their own water system and which have at least 15 service connections or serve water to a daily average of at least 25 persons. Some schools, factories and churches are also included in this category. It is conservatively estimated that there are over 200,000 non-community water systems in the country. However, it should be recognized that while their number is large, they normally are not the principal source of water for the people they serve.

The regulations as proposed would have applied all maximum contaminant levels to non-community systems as well as to community systems. This approach failed to take into account the fact that the proposed maximum contaminant levels for organic chemicals and most inorganic chemicals were based on the potential health effects of long-term exposure. Those levels are not necessary to protect transients or intermittent users. Therefore, the final regulations provide that maximum contaminant levels for organic chemicals, and for inorganic chemicals other than nitrates, are not applicable to non-community systems. An exception was made for nitrates because they can have an adverse health effect on susceptible infants in a short period of time.

Even without monitoring for organic chemicals or most inorganic chemicals, in the initial stages of implementation of the drinking water regulations, monitoring results from tens of thousands of non-community systems could overwhelm laboratory capabilities and other resources. This could delay effective implementation of the regulations with respect to the community systems which provide the water which Americans drink every day. To avoid this result, non-community systems will be given two years after the effective date of the regulations to commence monitoring. In the meantime, non-community systems which already monitor their water are encouraged to continue to do so, and the States are encouraged to take appropriate measures to test or require monitoring for non-community systems that serve large numbers of people.

Of course, non-community systems which pose a threat to health should be dealt with as quickly as possible. The maximum contaminant levels applicable to non-community water systems therefore will take effect 18 months after promulgation, at the same time as levels applicable to community systems. Inspection and enforcement authority will apply to non-community systems at the same time as to community systems.

SANITARY SURVEYS

EPA encourages the States to conduct sanitary surveys on a systematic basis.

These on-site inspections of water systems are more effective in assuring safe water to the public than individual tests taken in the absence of sanitary surveys. The regulations provide that monitoring frequencies for coliform bacteria can be changed by the entity with primary enforcement responsibility for an individual non-community system, and in certain circumstances for an individual community system, based on the results of a sanitary survey.

MAXIMUM CONTAMINANT LEVELS

Numerous comments were received by EPA on the substances selected for the establishment of maximum contaminant levels and on the levels chosen. Congress anticipated that the initial Interim Primary Drinking Water Regulations would be based on the Public Health Service Standards of 1962, and this Congressional intent has been followed. Comments received on the various levels did not contain new data sufficient to require the establishment of levels different from those contained in the Public Health Service Standards.

WATER CONSUMPTION

The maximum contaminant levels are based, directly or indirectly, on an assumed consumption of two liters of water per day. The same assumption was used in the 1962 Standards. This assumption has been challenged because of instances where much higher water consumption rates occur. EPA's justification for using the two-liter figure is that it already represents an above average water or water-based fluid intake. Moreover, while the factor of safety may be somewhat reduced when greater quantities of water are ingested, the maximum contaminant levels based on the two-liter figure provide substantial protection to virtually all consumers. If, as has been suggested, a water consumption rate of eight liters per day is used as the basis for maximum contaminant level, all of the proposed MCL's would have to be divided by four, greatly increasing the monitoring difficulties, and in some cases challenging the sensitivity of accepted analytical procedures. It could be expected, in such a case, that the maximum contaminant levels would be exceeded to a significant degree, and that specialized treatment techniques would be required to order that the contaminant levels would be reduced. The economic impact of a move in this direction would be enormous. It is not technically or economically feasible to base maximum contaminant levels on unusually high consumption rates.

SAFETY FACTORS

A question was raised about the fact that different safety factors are contained in various maximum contaminant levels. The levels are not intended to have a uniform safety factor, at least partly because the knowledge of and the nature of the health risks of the various contaminants vary widely. The levels set are the result of experience, evaluation of the available data, and professional judgment. They have withstood the test of time and of professional review. They are being subjected to further review by the National Academy of Sciences in connection with development of data for the Revised Primary Drinking Water Regulations.

MCL'S BASED ON TEMPERATURE

A question was also raised as to whether ranges of maximum contaminant levels should be established on the basis of the climate in the area served by the public water system, as was done with fluoride. EPA believes that the use of a temperature scale for fluoride is more appropriate than for other chemicals because of the studies available on the fluoride-temperature relationship and because there is a small margin with fluoride between beneficial levels and levels that cause adverse health effects.

MCL'S DELETED

Three proposed maximum contaminant levels have been eliminated in the final regulations because they are not justified by the available data. One of these is carbon chloroform extract (CCE), which is discussed separately below. The others are the proposed levels for the standard bacterial plate count and cyanide. In the case of the plate count, it is believed that the coliform limits contained in the regulations, combined with the turbidity maximum contaminant level, adequately deal with bacterial contamination. However, EPA continues to believe that the standard plate count is a valid indicator of bacteriological quality of drinking water, and recommends that it be used in appropriate cases in conjunction with the coliform tests as an operational tool.

The proposed maximum contaminant level for cyanide was eliminated because the possibility of cyanide contamination can be effectively addressed only by the use of emergency action, such as under Section 1431 of the Act. EPA's 1969 Community Water Supply Study did not reveal a single instance in which cyanide was present in a water system at a level greater than one-thousandth of the level at which cyanide is toxic to humans.

Available data indicate that cyanide will be present in water systems at toxic levels only in the event of an accident, such as a spill from a barge collision. Maximum contaminant levels are not the appropriate vehicle for dealing with such rare, accidental contamination.

Heptachor, heptachlor epoxide and chlordane have also been removed from the list of maximum contaminant levels at least temporarily in view of the pending cancellation and suspension proceedings under the Federal Insecticide, Fungicide and Rodenticide Act involving those pesticides. When the results of these proceedings are available, EPA will again consider whether maximum contaminant levels should be established for those three pesticides.

SODIUM AND SULFATES

A number of comments were received on the potential health effects of sodium and sulfates. The National Drinking Water Advisory Council has recommended that consideration be given to the monitoring of these constituents, but has not recommended the adoption of maximum contaminant levels because available data do not support the adoption of any specific levels. EPA has requested the National Academy of Sciences to include sodium and sulfates among the contaminants to be studied by NAS, and to include information on the health effects of sodium and sulfates in the report to be made by NAS in December 1976.

Since a number of persons suffer from diseases which are influenced by dietary sodium intake and since there are others who wish to restrict their sodium intake, it is desirable that the sodium content of drinking water be known. Those affected can, by knowing the sodium concentration in their drinking water, make adjustments to their diets or, in extreme cases, seek alternative sources of water to be used for drinking and food preparation. It is recommended that the States institute programs for regular monitoring of the sodium content of drinking water served to the public, and for informing physicians and consumers of the sodium concentration in drinking water.

A relatively high concentration of sulfate in drinking water has little or no known laxative effect on regular users of the water, but transcients using such water sometimes experience a laxative effect. It is recommended that the States institute monitoring programs for sulfates, and that transients be notified if the sulfate content of the water is high. Such notification should include an assessment of the possible physiological effects of consumption of the water

PCB'S AND ASBESTOS

An interagency comment expressed concern for asbestos and PCB's in the environment and noted the need for at least a monitoring requirement, if not for MCL's, for these contaminants. EPA is also concerned, but for the moment lacks sufficient evidence regarding analytical methods, health effects, or occurrence in the environment to establish MCL's. The Agency is conducting research and cooperating in research projects to develop criteria for establishing needed limits as quickly as possible. A monitoring study on a number of organic chemical contaminants, including PCB's, for which MCL's are not being established at this time, will be contained in an organic chemical monitoring regulation that is being promulgated with these regulations. Regarding asbestos, HEW and EPA are sponsoring a number of studies this year at an approximate cost of $16 million to establish health effects, anayltical methods and occurrence.

POINT OF MEASUREMENT

Other comments on maximum contaminant levels focused on the proposed requirement that such levels be tested at the consumer's tap. Concern was expressed over the inability of the public water system to control potential sources of contaminants which are under the control of the consumer.

The promulgated definition of "maximum contaminant level," § 141.2(d), retains the requirement that the maximum contaminant level be measured at the tap except in the case of turbidity, which should be measured at the point of entry to the distribution system. However, the definition has been expanded to make clear that contaminants added to the water by circumstances under the control of the consumer are not the responsibility of the supplier of water, unless the contaminants result from corrosion of piping and plumbing resulting from the quality of the water supplied. It should be noted, however, that this requirement should not be interpreted as to discourage local, aggressive cross connection control measures.

COLIFORM BACTERIA MCL's

The promulgated MCL's for coliform bacteria are basically the 1962 Public Health Service Standards, with minor refinements and clarifications. However, further changes may be desirable. For example, the MCL's for the membrane filter analytical method do not resolve the question of how many coliform bacteria are assumed to be present in a single highly contaminated sample. Some laboratories assume an upper limit of 50, while others seek to continue to count individual bacteria to a level of 100 or even higher in a single sample. The upper limit assumed will affect the monthly average which is calculated to determine compliance with the MCL's.

Another question relating to the coliform bacteria MCL's is the matter of possible spurious positive samples. As the regulations are written, all routine samples taken to determine compliance with the MCL's must be counted, regardless of the results of analysis of any check samples that may be taken. The reason for this is that bacterial contamination is often intermittent or transient, and as a result negative check samples taken a day or more after a positive sample cannot demonstrate that the positive result was in error. It may be possible, however, to prescribe a means of dealing with spurious positive results without compromising the integrity of the MCL's.

A third question concerning the MCL's for coliform bacteria is the relationship of monthly averages of coliform bacteria levels to monthly percentages of positive samples. For example, the monthly average MCL for the membrane filter method is violated if the monthly average exceeds one coliform bacterium per sample. However, for purposes of determining whether the monthly-percentage-of-positive-samples MCL is violated, a sample is counted as positive only if it contains more than four coliform bacteria. Thus, it is possible, particularly when a relatively small number of samples is taken, for a system to fail the monthly average MCL even when no single sample taken during the month is out of compliance with the limit.

These and other questions concerning the coliform bacteria MCL's will be reviewed further by EPA. If review indicates that changes in the MCL's are desirable, those changes will be made as soon as possible but within 6 months, in time to take effect at the same time as the initial Interim Primary Drinking Water Regulations.

ORGANIC CHEMICALS

The proposed maximum contaminant levels for organic pesticides, other than the three which are the subject of cancellation and suspension proceedings, have been retained. It is anticipated that additional organic pesticides will be added to the regulations if surveys of pesticides in drinking water being conducted by EPA indicate that this is needed.

The proposed regulations also contained a maximum contaminant level for organic chemicals obtained by the carbon chloroform extract (CCE) method. It was anticipated by Congress that organic chemicals would be dealt with primarily in the Revised Primary Drinking Water Regulations because of the paucity of accurate data on the health effects of various organic chemicals, the large number of such chemicals, uncertainities over appropriate treatment techniques, and the need for additional information on the incidence of specific organic chemicals in drinking water supplies. EPA thought that the CCE standard might provide an appropriate means of dealing with organic chemicals as a class pending action on the Revised Primary Regulations.

The CCE standard was originally developed as a test for undesirable tastes and odors in drinking water. As concern developed over the health effects of organic chemicals, the possibility of using CCE as a health standard rather than an esthetic standard was considered.

As pointed out by numerous comments, CCE has many failings as an indicator of health effects of organic chemicals. To begin with, the test obtains information on only a fraction of the total amount of organic chemicals in the water sampled. Furthermore, there is serious question as to the reliability of CCE in identifying those organic chemicals which are most suspected of adverse health effects. In addition, there are no existing data on which a specific level for CCE can be established on a rational basis. To establish a maximum contaminant level under these circumstances would almost certainly do more harm than good. It could give a false sense of security to persons served by systems which are within the established level and a false sense of alarm to persons served by systems which exceed the level. It also would divert resources from efforts to find more effective ways of dealing with the organic chemicals problem.

EPA believes that the intelligent approach to the organic chemicals question is to move ahead as rapidly as possible along two fronts. First, EPA is adopting simultaneously with these regulations a Subpart E of Part 141, containing requirements for organic chemical monitoring pursuant to Sections 1445 and 1450 of the Act.

The regulations require that designated public water systems collect samples of raw and treated water for submission to EPA for organics analysis. EPA will analyze the samples for a number of broad organic parameters, including carbon chloroform extract (CCE), volatile and non-volatile total organic carbon (VTOC and NVTOC), total organic chlorine (TOCl), ultraviolet absorbancy, and fluorescence. In addition, monitoring will be required for probably 21 specific organic compounds. Selection of the specific compounds has been based on the occurrence or likelihood of occurrence in treated water, toxicity data and availability of practical analytical methods. Laboratory analyses will be used to evaluate the extent and nature of organic chemical contamination of drinking water, to evaluate the validity of the general organic parameters as surrogates for measures of harmful organic chemicals, and to determine whether there is an adequate basis for establishing maximum contaminant levels for specific organics or groups of organics.

Second, EPA is embarking on an intensive research program to find answers to the following four questions:

1. What are the effects of commonly occurring organic compounds on human health?

2. What analytical procedures should be used to monitor finished drinking water to assure that any Primary Drinking Water Regulations dealing with organics are met?

3. Because some of these organic compounds are formed during water treatment, what changes in treatment practices are required to minimize the formation of these compounds in treated water?

4. What treatment technology must be applied to reduce contaminant levels to concentrations that may be specified in the Primary Drinking Water Regulations?

This research will involve health-effects and epidemiological studies, investigations of analytical methodology, and pilot plant and field studies of organic removal unit processes. Some phases of the research are to be completed by the end of this year, while much of the remainder are to be completed within the next calendar year.

As soon as sufficient information is derived from the monitoring program and related research, the Interim Primary Drinking Water Regulations will be amended so that the organic chemicals problem can be dealt with without delay. The monitoring process will be completed within 1 year.

During the interim period, while satisfactory MCL's for organic contamination in drinking water are being developed, EPA will act in specific cases where appropriate to deal with organic contamination. If the EPA monitoring program reveals serious specific cases of contamination, EPA will work with State and local authorities to identify the source and nature of the problem and to take remedial action. EPA will also aid the States in identifying additional community water supplies that require analysis.

PUBLIC NOTICE

The public notice requirements proposed in § 141.32 did not distinguish between community and non-community public water systems. They would have required that public notice of non-compliance with applicable regulations be made by newspaper, in water bills, and by other media for all public water systems. These requirements are inappropriate and ineffective in the case of most non-community water systems. Those systems principally serve transients who do not receive water bills from the system and who probably are not exposed significantly to the local media. A more effective approach would be to require notice that can inform the transient before he drinks the system's water, and thereby both warn the transient and provide an incentive to the supplier of water to remedy the violation. Accordingly, Section 141.32 as adopted provides that in the case of non-community systems, the entity with primary enforcement responsibility shall require that notice be given in a form and manner that will insure that the public using the public water system is adequately informed.

The proposed public notice requirements also failed to distinguish between different types of violations of the Interim Primary Drinking Water Regulations. Since the urgency and importance of a notice varies according to the nature of the violation involved, § 141.32 as promulgated seeks to match the type of notice required with the type of violation involved. Written notice accompanying a water bill or other direct notice by mail is required for all violations of the regulations, including violations of monitoring requirements, and for the grant of a variance or exemption. In addition, notice by newspaper and notification to radio and television stations is required whenever a maximum contaminant level is exceeded, or when the entity with primary enforcement responsibility requires such broader notice.

QUALITY CONTROL AND TESTING PROCEDURES

Section 1401(1) of the Act defines "primary drinking water regulation" to include "quality control and testing procedures." The promulgated regulations include testing requirements for each maximum contaminant level, including check samples and special samples in appropriate cases. The regulations also specify the procedures to be followed in analyzing samples for each of the maximum contaminant levels. These procedures will be updated from time to time as advances are made in analytical methods. For example, references to "Standard Methods for the Examination of Water and Wastewater" are to the current, 13th, edition, but these references will be changed to cite the 14th edition when it is available in the near future.

A key element of quality control for public water systems is accurate laboratory analysis. Section 141.28 of the regulations provides that analyses conducted for the purpose of determining compliance with maximum contaminant levels must be conducted by a laboratory approved by the entity with primary enforcement responsibility. EPA will develop as soon as possible, in cooperation with the States and other interested parties, criteria and procedures for laboratory certification. A State with primary enforcement responsibility will have a laboratory certified by EPA pursuant to the prescribed criteria and procedures, and in turn will certify laboratories within the State.

Record-keeping requirements and reports to the State also will assist in quality control efforts.

RECORD-KEEPING

Adequate record-keeping is necessary for the proper operation and administration of a public water system. It is also important for providing information to the public, providing appropriate data for inspection and enforcement activities and providing information on which future regulations can be based. Accordingly, a new § 141.33 has been added to the regulations to require that each public water system maintain records of sample analyses and of actions to correct violations of the Primary Drinking Water Regulations.

ECONOMIC AND COST ANALYSIS

A comprehensive economics study has been made of the Interim Primary Drinking Water Regulations. This study estimates the costs of the regulations, evaluates the potential economic impact, and considers possible material and labor shortages. The results of this analysis are summarized here.

Total investment costs to community water systems to achieve compliance with these regulations are estimated to be between $1,050 and $1,765 million. It is estimated that non-community systems will invest an additional $24 million. The range of the estimate is due to uncertainty as to the design flow that will be used in installing treatment facilities. Systems not in compliance will have to consider sizing their new components to reflect average daily flow conditions, or maximum daily flow conditions in cases where system storage is not adequate.

This investment will be spread over several years. Investor-owned systems will bear about one-fourth of these costs, and publicly-owned systems the remainder. It is not anticipated that systems will have difficulty financing these capital requirements.

In annual terms, national costs are expected to be within the following ranges:

	In millions
Capital costs	$146-247
Operations and maintenance	263-263
Monitoring (routine only)	17- 35
Total	$426-545

Although these aggregate figures are large, most water consumers will not be significantly affected. For those users in systems serving 10,000 persons or more, the average annual treatment cost per capita may increase from less than $1.00 for systems requiring disinfection and lead control, to between $15 to $35 for control of turbidity and heavy metal removal. For systems serving less than 100 persons, the average annual per capita costs of disinfection, lead control and fluoride/arsenic removal are estimated to be between $2.10 and $11.80. However, if turbidity control or heavy metal removal were required in a system of this size then costs are expected to range from $52 to $237 per year per capita. EPA is aware of the serious potential economic impact on users in these small systems. However, the legislative history specifies that the regulations should be based on costs that can be reasonably afforded by large metropolitan or regional systems. Further economic evaluation of these systems is being conducted, and realistic options for these small systems are being reviewed. Options that will be under consideration include less costly treatment technologies; formation of regional systems; and use of alternative water sources. Industrial and commercial users, whether providing their own water or using public systems, are not expected to be significantly affected by these regulations.

Possible constraints to the implementation of the interim primary regulations were examined. Although there will be an increase in demand for chemicals, manpower, laboratories, and construction of treatment facilities, it is not anticipated that any of these factors will be a serious obstacle to implementation of these regulations over a reasonable time frame.

For the reasons given above, Chapter 40 of the Code of Federal Regulations is hereby amended by the addition of the following new Part 141. These regulations will take effect 18 months after promulgation.

(It is hereby certified that the economic and inflationary impacts of these regulations have been carefully evaluated in accordance with Executive Order 11821)

Dated: December 10, 1975.

RUSSELL E. TRAIN,
Administrator.

Subpart A—General

Sec.
141.1 Applicability.
141.2 Definitions.
141.3 Coverage.
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Subpart B—Maximum Contaminant Levels

141.11 Maximum contaminant levels for inorganic chemicals.
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Subpart C—Monitoring and Analytical Requirements

141.21 Microbiological contaminant sampling and analytical requirements.

Sec.
141.22 Turbidity sampling and analytical requirements.
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Subpart D—Reporting, Public Notification, and Record-keeping

141.31 Reporting requirements.
141.32 Public notification of variances, exemptions, and non-compliance with regulations.
141.33 Record maintenance.

AUTHORITY: Secs. 1412, 1414, 1445, and 1450 of the Public Health Service Act, 88 Stat. 1660 (42 U.S.C. 300g-1, 300g-3, 300j-4, and 300j-9).

Subpart A—General

§ 141.1 Applicability.

This part establishes primary drinking water regulations pursuant to section 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act (Pub. L. 93-523); and related regulations applicable to public water systems.

§ 141.2 Definitions.

As used in this part, the term:

(a) "Act" means the Public Health Service Act, as amended by the Safe Drinking Water Act, Pub. L. 93-523.

(b) "Contaminant" means any physical, chemical, biological, or radiological substance or matter in water.

(c) "Maximum contaminant level" means the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

(d) "Person" means an individual, corporation, company, association, partnership, State, municipality, or Federal agency.

(e) "Public water system" means a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. A public water system is either a "community water system" or a "non-community water system."

(i) "Community water system" means a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

(ii) "Non-community water system" means a public water system that is not a community water system.

(f) "Sanitary survey" means an on-site review of the water source, facilities, equipment, operation and maintenance of a public water system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water.

(g) "Standard sample" means the aliquot of finished drinking water that is examined for the presence of coliform bacteria.

(h) "State" means the agency of the State government which has jurisdiction over public water systems. During any period when a State does not have primary enforcement responsibility pursuant to Section 1413 of the Act, the term "State" means the Regional Administrator, U.S. Environmental Protection Agency.

(i) "Supplier of water" means any person who owns or operates a public water system.

§ 141.3 Coverage.

This part shall apply to each public water system, unless the public water system meets all of the following conditions:

(a) Consists only of distribution and storage facilities (and does not have any collection and treatment facilities);

(b) Obtains all of its water from, but is not owned or operated by, a public water system to which such regulations apply;

(c) Does not sell water to any person; and

(d) Is not a carrier which conveys passengers in interstate commerce.

§ 141.4 Variances and exemptions.

Variances or exemptions from certain provisions of these regulations may be granted pursuant to Sections 1415 and 1416 of the Act by the entity with primary enforcement responsibility. Provisions under Part 142, *National Interim Primary Drinking Water Regulations Implementation*—subpart E (Variances) and subpart F (Exemptions)—apply where EPA has primary enforcement responsibility.

§ 141.5 Siting requirements.

Before a person may enter into a financial commitment for or initiate construction of a new public water system or increase the capacity of an existing public water system, he shall notify the State and, to the extent practicable, avoid locating part or all of the new or expanded facility at a site which:

(a) Is subject to a significant risk from earthquakes, floods, fires or other disasters which could cause a breakdown of the public water system or a portion thereof; or

(b) Except for intake structures, is within the floodplain of a 100-year flood or is lower than any recorded high tide where appropriate records exist.

The U.S. Environmental Protection Agency will not seek to override land use decisions affecting public water systems siting which are made at the State or local government levels.

§ 141.6 Effective date.

The regulations set forth in this part shall take effect 18 months after the date of promulgation.

Subpart B—Maximum Contaminant Levels

§ 141.11 Maximum contaminant levels for inorganic chemicals.

(a) The maximum contaminant level for nitrate is applicable to both community water systems and non-community water systems. The levels for the other inorganic chemicals apply only to community water systems. Compliance with maximum contaminant levels for inorganic chemicals is calculated pursuant to § 141.23.

(b) The following are the maximum contaminant levels for inorganic chemicals other than fluoride:

Contaminant	*Level, milligrams per liter*
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05

(c) When the annual average of the maximum daily air temperatures for the location in which the community water system is situated is the following, the maximum contaminant levels for fluoride are:

Temperature Degrees Fahrenheit	Degrees Celsius	Level, milligrams per liter
53.7 and below	12.0 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

§ 141.12 Maximum contaminant levels for organic chemicals.

The following are the maximum contaminant levels for organic chemicals. They apply only to community water systems. Compliance with maximum contaminant levels for organic chemicals is calculated pursuant to § 141.24.

	Level, milligrams per liter
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-hexachloro-6,7-epoxy-1,4, 4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8 - dimethano naphthalene).	0.0002
Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer).	0.004
Methoxychlor (1,1,1-Trichloro-2, 2 - bis [p-methoxyphenyl] ethane).	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67-69 percent chlorine).	0.005

(b) Chlorophenoxys:

2,4 - D, (2,4-Dichlorophenoxyacetic acid).	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid).	0.01

§ 141.13 Maximum contaminant levels for turbidity.

The maximum contaminant levels for turbidity are applicable to both community water systems and non-community water systems using surface water sources in whole or in part. The maximum contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system, are:

(a) One turbidity unit (TU), as determined by a monthly average pursuant to § 141.22, except that five or fewer turbidity units may be allowed if the supplier of water can demonstrate to the State that the higher turbidity does not do any of the following:

(1) Interfere with disinfection;

(2) Prevent maintenance of an effective disinfectant agent throughout the distribution system; or

(3) Interfere with microbiological determinations.

(b) Five turbidity units based on an average for two consecutive days pursuant to § 141.22.

§ 141.14 Maximum microbiological contaminant levels.

The maximum contaminant levels for coliform bacteria, applicable to community water systems and non-community water systems, are as follows:

(a) When the membrane filter technique pursuant to § 141.21(a) is used, the number of coliform bacteria shall not exceed any of the following:

(1) One per 100 milliliters as the arithmetic mean of all samples examined per month pursuant to § 141.21 (b) or (c);

(2) Four per 100 milliliters in more than one sample when less than 20 are examined per month; or

(3) Four per 100 milliliters in more than five percent of the samples when 20 or more are examined per month.

(b)(1) When the fermentation tube method and 10 milliliter standard portions pursuant to § 141.21(a) are used, coliform bacteria shall not be present in any of the following:

(i) more than 10 percent of the portions in any month pursuant to § 141.21 (b) or (c);

(ii) three or more portions in more than one sample when less than 20 samples are examined per month; or

(iii) three or more portions in more than five percent of the samples when 20 or more samples are examined per month.

(2) When the fermentation tube method and 100 milliliter standard portions pursuant to § 141.21(a) are used, coliform bacteria shall not be present in any of the following:

(i) more than 60 percent of the portions in any month pursuant to § 141.21 (b) or (c);

(ii) five portions in more than one sample when less than five samples are examined per month; or

(iii) five portions in more than 20 percent of the samples when five or more samples are examined per month.

(c) For community or non-community systems that are required to sample at a rate of less than 4 per month, compliance with paragraphs (a), (b)(1), or (b)(2) of this section shall be based upon sampling during a 3 month period, except that, at the discretion of the State, compliance may be based upon sampling during a one-month period.

Subpart C—Monitoring and Analytical Requirements

§ 141.21 Microbiological contaminant sampling and analytical requirements.

(a) Suppliers of water for community water systems and non-community water systems shall analyze for coliform bacteria for the purpose of determining compliance with § 141.14. Analyses shall be conducted in accordance with the analytical recommendations set forth in "Standard Methods for the Examination of Water and Wastewater," American Public Health Association, 13th Edition, pp. 662-688, except that a standard sample size shall be employed. The standard sample used in the membrane filter procedure shall be 100 milliliters. The standard sample used in the 5 tube most probable number (MPN) procedure (fermentation tube method) shall be 5 times the standard portion. The standard portion is either 10 milliliters or 100 milliliters as described in § 141.14 (b) and (c). The samples shall be taken at points which are representative of the conditions within the distribution system.

(b) The supplier of water for a community water system shall take coliform density samples at regular time intervals, and in number proportionate to the population served by the system. In no event shall the frequency be less than as set forth below:

Population served:	*Minimum number of samples per month*
25 to 1,000	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 9,400	10
9,401 to 10,300	11
10,301 to 11,100	12
11,101 to 12,000	13
12,001 to 12,900	14
12,901 to 13,700	15
13,701 to 14,600	16
14,601 to 15,500	17
15,501 to 16,300	18
16,301 to 17,200	19
17,201 to 18,100	20
18,101 to 18,900	21
18,901 to 19,800	22
19,801 to 20,700	23
20,701 to 21,500	24
21,501 to 22,300	25
22,301 to 23,200	26
23,201 to 24,000	27
24,001 to 24,900	28
24,901 to 25,000	29
25,001 to 28,000	30
28,001 to 33,000	35
33,001 to 37,000	40
37,001 to 41,000	45
41,001 to 46,000	50
46,001 to 50,000	55
50,001 to 54,000	60
54,001 to 59,000	65
59,001 to 64,000	70
64,001 to 70,000	75
70,001 to 76,000	80
76,001 to 83,000	85
83,001 to 90,000	90
90,001 to 96,000	95
96,001 to 111,000	100
111,001 to 130,000	110
130,001 to 160,000	120
160,001 to 190,000	130
190,001 to 220,000	140
220,001 to 250,000	150
250,001 to 290,000	160
290,001 to 320,000	170
320,001 to 360,000	180
360,001 to 410,000	190
410,001 to 450,000	200
450,001 to 500,000	210
500,001 to 550,000	220
550,001 to 600,000	230
600,001 to 660,000	240
660,001 to 720,000	250
720,001 to 780,000	260
780,001 to 840,000	270
840,001 to 910,000	280
910,001 to 970,000	290
970,001 to 1,050,000	300
1,050,001 to 1,140,000	310
1,140,001 to 1,230,000	320
1,230,001 to 1,320,000	330
1,320,001 to 1,420,000	340
1,420,001 to 1,520,000	350
1,520,001 to 1,630,000	360
1,630,001 to 1,730,000	370
1,730,001 to 1,850,000	380
1,850,001 to 1,970,000	390
1,970,001 to 2,060,000	400
2,060,001 to 2,270,000	410
2,270,001 to 2,510,000	420
2,510,001 to 2,750,000	430
2,750,001 to 3,020,000	440
3,020,001 to 3,320,000	450
3,320,001 to 3,620,000	460
3,620,001 to 3,960,000	470
3,960,001 to 4,310,000	480
4,310,001 to 4,690,000	490
4,690,001 or more	500

Based on a history of no coliform bacterial contamination and on a sanitary survey by the State showing the water system to be supplied solely by a protected ground water source and free of sanitary defects, a community water system serving 25 to 1,000 persons, with written permission from the State, may reduce this sampling frequency except that in no case shall it be reduced to less than one per quarter.

(c) The supplier of water for a non-community water system shall sample for coliform bacteria in each calendar quarter during which the system provides water to the public. Such sampling shall begin within two years after the effective date of this part. If the State, on the basis of a sanitary survey, determines that some other frequency is more appropriate, that frequency shall be the frequency required under these regulations. Such frequency shall be confirmed or changed on the basis of subsequent surveys.

(d)(1) When the coliform bacteria in a single sample exceed four per 100 milliliters (§ 141.14(a)), at least two consecutive daily check samples shall be collected and examined from the same sampling point. Additional check samples shall be collected daily, or at a frequency established by the State, until the results obtained from at least two consecutive check samples show less than one coliform bacterium per 100 milliliters.

(2) When coliform bacteria occur in three or more 10 ml portions of a single sample (§ 141.14(b)(1)), at least two consecutive daily check samples shall be collected and examined from the same sampling point. Additional check samples shall be collected daily, or at a frequency established by the State, until the results obtained from at least two consecutive check samples show no positive tubes.

(3) When coliform bacteria occur in all five of the 100 ml portions of a single sample (§ 141.14(b)(2)), at least two daily check samples shall be collected and examined from the same sampling point. Additional check samples shall be collected daily, or at a frequency established by the State, until the results obtained from at least two consecutive check samples show no positive tubes.

(4) The location at which the check samples were taken pursuant to paragraphs (d) (1), (2), or (3) of this section shall not be eliminated from future sampling without approval of the State. The results from all coliform bacterial analyses performed pursuant to this subpart, except those obtained from check samples and special purpose samples, shall be used to determine compliance with the maximum contaminant level for coliform bacteria as established in § 141.14. Check samples shall not be included in calculating the total number of samples taken each month to determine compliance with § 141.21 (b) or (c).

(e) When the presence of coliform bacteria in water taken from a particular sampling point has been confirmed by any check samples examined as directed in paragraphs (d) (1), (2), or (3) of this section, the supplier of water shall report to the State within 48 hours.

(f) When a maximum contaminant level set forth in paragraphs (a), (b) or (c) of § 141.14 is exceeded, the supplier of water shall report to the State and notify the public as prescribed in § 141.31 and § 141.32.

(g) Special purpose samples, such as those taken to determine whether disinfection practices following pipe placement, replacement, or repair have been sufficient, shall not be used to determine compliance with § 141.14 or § 141.21 (b) or (c).

(h) A supplier of water of a community water system or a non-community water system may, with the approval of the State and based upon a sanitary survey, substitute the use of chlorine residual monitoring for not more than 75 percent of the samples required to be taken by paragraph (b) of this section, *Provided*, That the supplier of water takes chlorine residual samples at points which are representative of the conditions within the distribution system at the frequency of at least four for each substituted microbiological sample. There shall be at least daily determinations of chlorine residual. When the supplier of water exercises the option provided in this paragraph (h) of this section, he shall maintain no less than 0.2 mg/l free chlorine throughout the public water distribution system. When a particular sampling point has been shown to have a free chlorine residual less than 0.2 mg/l, the water at that location shall be retested as soon as practicable and in any event within one hour. If the original analysis is confirmed, this fact shall be reported to the State within 48 hours. Also, if the analysis is confirmed, a sample for coliform bacterial analysis must be collected from that sampling point as soon as practicable and preferably within one hour, and the results of such analysis reported to the State within 48 hours after the results are known to the supplier of water. Analyses for residual chlorine shall be made in accordance with "Standard Methods for the Examination of Water and Wastewater," 13th Ed., pp. 129-132. Compliance with the maximum contaminant levels for coliform bacteria shall be determined on the monthly mean or quarterly mean basis specified in § 141.14, including those samples taken as a result of failure to maintain the required chlorine residual level. The State may withdraw its approval of the use of chlorine residual substitution at any time.

§ 141.22 Turbidity sampling and analytical requirements.

(a) Samples shall be taken by suppliers of water for both community water systems and non-community water systems at a representative entry point(s) to the water distribution system at least once per day, for the purpose of making turbidity measurements to determine compliance with § 141.13. The measurement shall be made by the Nephelometric Method in accordance with the recommendations set forth in "Standard Methods for the Examination of Water and Wastewater," American Public Health Association, 13th Edition, pp. 350-353, or "Methods for Chemical Analysis of Water and Wastes," pp. 295-298, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(b) If the result of a turbidity analysis indicates that the maximum allowable limit has been exceeded, the sampling and measurement shall be confirmed by resampling as soon as practicable and preferably within one hour. If the repeat sample confirms that the maximum allowable limit has been exceeded, the supplier of water shall report to the State within 48 hours. The repeat sample shall be the sample used for the purpose of calculating the monthly average. If the monthly average of the daily samples exceeds the maximum allowable limit, or if the average of two samples taken on consecutive days exceeds 5 TU, the supplier of water shall report to the State and notify the public as directed in § 141.31 and § 141.32.

(c) Sampling for non-community water systems shall begin within two years after the effective date of this part.

(d) The requirements of this § 141.22 shall apply only to public water systems which use water obtained in whole or in part from surface sources.

§ 141.23 Inorganic chemical sampling and analytical requirements.

(a) Analyses for the purpose of determining compliance with § 141.11 are required as follows:

(1) Analyses for all community water systems utilizing surface water sources shall be completed within one year following the effective date of this part. These analyses shall be repeated at yearly intervals.

(2) Analyses for all community water systems utilizing only ground water sources shall be completed within two years following the effective date of this part. These analyses shall be repeated at three-year intervals.

(3) For non-community water systems, whether supplied by surface or ground water sources, analyses for nitrate shall be completed within two years following the effective date of this part. These analyses shall be repeated at intervals determined by the State.

(b) If the result of an analysis made pursuant to paragraph (a) indicates that the level of any contaminant listed in § 141.11 exceeds the maximum contaminant level, the supplier of water shall report to the State within 7 days and initiate three additional analyses at the same sampling point within one month.

(c) When the average of four analyses made pursuant to paragraph (b) of this section, rounded to the same number of significant figures as the maximum contaminant level for the substance in question, exceeds the maximum contaminant level, the supplier of water shall notify the State pursuant to § 141.31 and give notice to the public pursuant to § 141.32. Monitoring after public notification shall be at a frequency designated by the State and shall continue until the maximum contaminant level has not been exceeded in two successive samples or until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective.

(d) The provisions of paragraphs (b) and (c) of this section notwithstanding, compliance with the maximum contaminant level for nitrate shall be determined on the basis of the mean of two analyses. When a level exceeding the maximum contaminant level for nitrate is found, a second analysis shall be initiated within 24 hours, and if the mean of the two analyses exceeds the maximum contaminant level, the supplier of water shall report his findings to the State pursuant to § 141.31 and shall notify the public pursuant to § 141.32.

(e) For the initial analyses required by paragraph (a)(1), (2) or (3) of this section, data for surface waters acquired within one year prior to the effective date and data for ground waters acquired within 3 years prior to the effective date of this part may be substituted at the discretion of the State.

(f) Analyses conducted to determine compliance with § 141.11 shall be made in accordance with the following methods:

(1) Arsenic—Atomic Absorption Method, "Methods for Chemical Analysis of Water and Wastes," pp. 95-96, Environ-

mental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(2) Barium—Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater," 13th Edition, pp. 210–215, or "Methods for Chemical Analysis of Water and Wastes," pp. 97–98, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(3) Cadmium—Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater," 13th Edition, pp. 210–215, or "Methods for Chemical Analysis of Water and Wastes," pp. 101–103, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(4) Chromium—Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater," 13th Edition, pp. 210–215, or "Methods for Chemical Analysis of Water and Wastes," pp. 105–106, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(5) Lead—Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater," 13th Edition, pp. 210–215, or "Methods for Chemical Analysis of Water and Wastes," pp. 112–113, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(6) Mercury—Flameless Atomic Absorption Method, "Methods for Chemical Analysis of Water and Wastes," pp. 118–126, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(7) Nitrate—Brucine Colorimetric Method, "Standard Methods for the Examination of Water and Wastewater," 13th Edition, pp. 461–464, or Cadmium Reduction Method, "Methods for Chemical Analysis of Water and Wastes," pp. 201–206, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(8) Selenium—Atomic Absorption Method, "Methods for Chemical Analysis of Water and Wastes," p. 145, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(9) Silver—Atomic Absorption Method, "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 210–215, or "Methods for Chemical Analysis of Water and Wastes", p. 146, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

(10) Fluoride—Electrode Method, "Standard Methods for the Examination of Water and Wastewater", 13th Edition, pp. 172–174, or "Methods for Chemical Analysis of Water and Wastes," pp. 65–67, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974, or Colorimetric Method with Preliminary Distillation, "Standard Methods for the Examination of Water and Wastewater," 13th Edition, pp. 171–172 and 174–176, or "Methods for Chemical Analysis of Water and Wastes," pp. 59–60, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

§ 141.24 Organic chemical sampling and analytical requirements.

(a) An analysis of substances for the purpose of determining compliance with § 141.12 shall be made as follows:

(1) For all community water systems utilizing surface water sources, analyses shall be completed within one year following the effective date of this part. Samples analyzed shall be collected during the period of the year designated by the State as the period when contamination by pesticides is most likely to occur. These analyses shall be repeated at intervals specified by the State but in no event less frequently than at three year intervals.

(2) For community water systems utilizing only ground water sources, analyses shall be completed by those systems specified by the State.

(b) If the result of an analysis made pursuant to paragraph (a) of this section indicates that the level of any contaminant listed in § 141.12 exceeds the maximum contaminant level, the supplier of water shall report to the State within 7 days and initiate three additional analyses within one month.

(c) When the average of four analyses made pursuant to paragraph (b) of this section, rounded to the same number of significant figures as the maximum contaminant level for the substance in question, exceeds the maximum contaminant level, the supplier of water shall report to the State pursuant to § 141.31 and give notice to the public pursuant to § 141.32. Monitoring after public notification shall be at a frequency designated by the State and shall continue until the maximum contaminant level has not been exceeded in two successive samples or until a monitoring schedule as a condition to a variance, exemption or enforcement action shall become effective.

(d) For the initial analysis required by paragraph (a) (1) and (2) of this section, data for surface water acquired within one year prior to the effective date of this part and data for ground water acquired within three years prior to the effective date of this part may be substituted at the discretion of the State.

(e) Analyses made to determine compliance with § 141.12(a) shall be made in accordance with "Method for Organochlorine Pesticides in Industrial Effluents," MDQARL, Environmental Protection Agency, Cincinnati, Ohio, November 28, 1973.

(f) Analyses made to determine compliance with § 141.12(b) shall be conducted in accordance with "Methods for Chlorinated Phenoxy Acid Herbicides in Industrial Effluents," MDQARL, Environmental Protection Agency, Cincinnati, Ohio, November 28, 1973.

§ 141.27 Alternative analytical techniques.

With the written permission of the State, concurred in by the Administrator of the U.S. Environmental Protection Agency, an alternative analytical technique may be employed. An alternative technique shall be acceptable only if it is substantially equivalent to the prescribed test in both precision and accuracy as it relates to the determination of compliance with any maximum contaminant level. The use of the alternative analytical technique shall not decrease the frequency of monitoring required by this part.

§ 141.28 Approved laboratories.

For the purpose of determining compliance with § 141.21 through § 141.27, samples may be considered only if they have been analyzed by a laboratory approved by the State except that measurements for turbidity and free chlorine residual may be performed by any person acceptable to the State.

§ 141.29 Monitoring of consecutive public water systems.

When a public water system supplies water to one or more other public water systems, the State may modify the monitoring requirements imposed by this part to the extent that the interconnection of the sysems jusifies treating them as a single system for monitoring purposes. Any modified monitoring shall be conducted pursuant to a schedule specified by the State and concurred in by the Administrator of the U.S. Environmental Protection Agency.

Subpart D—Reporting, Public Notification and Record Keeping

§ 141.31 Reporting requirements.

(a) Except where a shorter reporting period is specified in this part, the supplier of water shall report to the State within 40 days following a test, measurement or analysis required to be made by this part, the results of that test, measurement or analysis.

(b) The supplier of water shall report to the State within 48 hours the failure to comply with any primary drinking water regulation (including failure to comply with monitoring requirements) set forth in this part.

(c) The supplier of water is not required to report analytical results to the State in cases where a State laboratory performs the analysis and reports the results to the State office which would normally receive such notification from the supplier.

§ 141.32 Public notification.

(a) If a community water system fails to comply with an applicable maximum contaminant level established in Subpart B, fails to comply with an applicable testing procedure established in Subpart C of this part, is granted a variance or an exemption from an applicable maximum contaminant level, fails to comply with the requirements of any schedule prescribed pursuant to a variance or exemption, or fails to perform any monitoring required pursuant to Section 1445 (a) of the Act, the supplier of water shall notify persons served by the system of the failure or grant by inclusion of a notice in the first set of water bills of the system issued after the failure or grant and in any event by written notice within three months. Such notice shall be repeated at least once every three months so long as the system's failure continues or the variance or exemption remains in effect. If the system issues water bills less frequently than quarterly, or does not issue water bills, the notice shall be made by or supplemented by another form of direct mail.

(b) If a community water system has failed to comply with an applicable maximum contaminant level, the supplier of water shall notify the public of such failure, in addition to the notification required by paragraph (a) of this section, as follows:

(1) By publication on not less than three consecutive days in a newspaper or newspapers of general circulation in the area served by the system. Such notice shall be completed within fourteen days after the supplier of water learns of the failure.

(2) By furnishing a copy of the notice to the radio and television stations serving the area served by the system. Such notice shall be furnished within seven days after the supplier of water learns of the failure.

(c) If the area served by a community water system is not served by a daily newspaper of general circulation, notification by newspaper required by paragraph (b) of this section shall instead be given by publication on three consecutive weeks in a weekly newspaper of general circulation serving the area. If no weekly or daily newspaper of general circulation serves the area, notice shall be given by posting the notice in post offices within the area served by the system.

(d) If a non-community water system fails to comply with an applicable maximum contaminant level established in Subpart B of this part, fails to comply with an applicable testing procedure established in Subpart C of this part, is granted a variance or an exemption from an applicable maximum contaminant level, fails to comply with the requirement of any schedule prescribed pursuant to a variance or exemption or fails to perform any monitoring required pursuant to Section 1445(a) of the Act, the supplier of water shall given notice of such failure or grant to the persons served by the system. The form and manner of such notice shall be prescribed by the State, and shall insure that the public using the system is adequately informed of the failure or grant.

(e) Notices given pursuant to this section shall be written in a manner reasonably designed to inform fully the users of the system. The notice shall be conspicuous and shall not use unduly technical language, unduly small print or other methods which would frustrate the purpose of the notice. The notice shall disclose all material facts regarding the subject including the nature of the problem and, when appropriate, a clear statement that a primary drinking water regulation has been violated and any preventive measures that should be taken by the public. Where appropriate, or where designated by the State, bilingual notice shall be given. Notices may include a balanced explanation of the significance or seriousness to the public health of the subject of the notice, a fair explanation of steps taken by the system to correct any problem and the results of any additional sampling.

(f) Notice to the public required by this section may be given by the State on behalf of the supplier of water.

(g) In any instance in which notification by mail is required by paragraph (a) of this section but notification by newspaper or to radio or television stations is not required by paragraph (b) of this section, the State may order the supplier of water to provide notification by newspaper and to radio and television stations when circumstances make more immediate or broader notice appropriate to protect the public health.

§ 141.33 Record maintenance.

Any owner or operator of a public water system subject to the provisions of this part shall retain on its premises or at a convenient location near its premises the following records:

(a) Records of bacteriological analyses made pursuant to this part shall be kept for not less than 5 years. Records of chemical analyses made pursuant to this part shall be kept for not less than 10 years. Actual laboratory reports may be kept, or data may be transferred to tabular summaries, provided that the following information is included:

(1) The date, place, and time of sampling, and the name of the person who collected the sample;

(2) Identification of the sample as to whether it was a routine distribution system sample, check sample, raw or process water sample or other special purpose sample;

(3) Date of analysis;

(4) Laboratory and person responsible for performing analysis;

(5) The analytical technique/method used; and

(6) The results of the analysis.

(b) Records of action taken by the system to correct violations of primary drinking water regulations shall be kept for a period not less than 3 years after the last action taken with respect to the particular violation involved.

(c) Copies of any written reports, summaries or communications relating to sanitary surveys of the system conducted by the system itself, by a private consultant, or by any local, State or Federal agency, shall be kept for a period not less than 10 years after completion of the sanitary survey involved.

(d) Records concerning a variance or exemption granted to the system shall be kept for a period ending not less than 5 years following the expiration of such variance or exemption.