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Cover Page Footnote

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Branden B. Johnson *

Introduction

The Safe Drinking Water Act Amendments of 1996 (SDWAA) required that all U.S. utilities, beginning in 1999, provide annual reports on drinking water quality to their customers. The U.S. Environmental Protection Agency (EPA) required that these reports include certain definitions, language, and information formats. As with many such government requirements, the EPA conducted little advance testing (although much more than usual) of how utility customers would react to such messages. This paper reports on experiments conducted to more systematically test such definitions, language, and formats, as part of a wider research program to explore customers' reactions to drinking water quality reports.[1] Aside from the generic need to evaluate risk communications, one rationale for this study is that states with primary enforcement responsibility for the Safe Drinking Water Act have the authority to "adopt . . . alternative requirements for the form and content of the reports" that "must provide the same type and amount of information . . . and must be designed to achieve an equivalent level

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1   This research included an earlier paper on the effect of alternative formats of the table of detected contaminants on public reactions. Examples of these tested formats included whole versus decimal numbers, zero versus positive Maximum Contaminant Level Goals (MCLG's), and large versus small Maximum Contaminant Levels (MCL's) — these latter terms are explained later in the current paper. *See* Branden B. Johnson, *Utility Customers' Views of the "Consumer Confidence Report" of Drinking Water Quality*, 11 Risk: Health, Safety & Environment 309 (2000).

of public information and education as would be achieved" by the federal regulations.[2] Thus, it is important to determine to what degree current requirements achieve "information and education."[3]

Background
EPA Requirements

The core of the SDWAA-required report on drinking water quality is a table of contaminants detected in the utility's finished water within the previous calendar year. The table includes detected levels (average and range found), the level of the enforceable public health standard (known as the Maximum Contaminant Level or MCL), the level of the Maximum Contaminant Level Goal (MCLG — an unenforceable target that the MCL should approach as closely as feasible; EPA currently sets the MCLG at zero for carcinogens, thus lower than the MCL, and usually equal to the MCL for non-carcinogens), and the generic sources of each contaminant (e.g., metal plating facilities, petrochemical factories, naturally radioactive rocks). If the detected levels violated the MCL, the report must explain the violation, its duration, action(s) taken to correct it, and the potential health effects that led the government to regulate the contaminant.[4]

This study examined six required aspects of these reports: (1) reporting ranges of contaminant amounts found in the water; (2) the explanation of health effects motivating regulation required when the MCL is violated; (3) an explanation of microbiological health threats; (4) definitions of the MCL and MCLG; (5) a statement that contaminants do not necessarily represent a health risk; and (6) a statement about contaminants found in drinking water.

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2   63 Fed. Reg. 44, 512 (Aug. 19, 1998).

3   Results of focus groups conducted earlier helped to motivate the quantitative tests reported here for all topics except ranges. Except for finding EPA's microbiological text unsatisfying compared to the alternative, the focus groups yielded responses similar to those found here, including the strong demand for any information whatsoever. *See* Branden B. Johnson, 'Consumer Confidence Reports' for Drinking Water Contamination: Initial Studies on Public Response, presented at the Society for Risk Analysis meeting (Dec. 10, 1997).

4   The report also must provide information on other violations (e.g., paperwork rules), and on opportunities to participate in utility decision-making and obtain more information (see Johnson, *supra* n. 1 for public demand regarding information on these opportunities). Utilities were encouraged by the EPA to include other information that might enhance customers' knowledge about their drinking water. These topics are not covered in this paper.

Evaluating EPA Required Language

The rationale for evaluating these particular texts is detailed below. Figures 1-6 present the EPA texts, as specified below:

Ranges. EPA's final regulation[5] required that utilities report ranges, as well as averages, of detected levels of contaminants. EPA initially felt that ranges could be confusing,[6] but "many" stakeholders felt averages did not adequately reflect variability in tap water quality. California utilities, required by state law to provide annual water quality reports to customers since 1990, claimed (without apparent evidence beyond the lack of customer queries) that ranges had not confused their customers. Yet MCL violations for almost all contaminants are based on an average of several measurements; exceeding the MCL in a single sample, or even several, is not necessarily a violation. Thus customers might think an MCL had been violated if the upper bound of the reported range fell above the MCL, making a test of their response to ranges prudent (Figure 1).

Health Effects. Congress required that reports describe "the health concerns that resulted in regulation of" any contaminant for which the MCL had been violated.[7] EPA distilled these required statements from already-written fact sheets for each of the eighty-five regulated contaminants.[8] Despite some professional concern as to whether proposed content was "appropriate risk information,"[9] EPA-contracted focus groups asked to read diverse "health warning messages" seemed to want this information and accurately rated "the relative risk of the various scenarios presented to them."[10] Tests of EPA's variant texts (Figure 2) could determine whether (1) its use of the phrase "some people" indeed conveyed "the probabilistic nature of the standard-setting process"[11]; (2) its use of "the words 'well in

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5   63 Fed. Reg. 44, 512 (Aug. 19, 1998).

6   63 Fed. Reg. 7, 606 (Feb. 13, 1998).

7   This is not an explanation of the health effects of the violation itself, which is not required, but a description of the reason that the substance was originally regulated, perhaps years or decades earlier.

8   63 Fed. Reg. 44512 (Aug. 19, 1998). See Appendix of the regulations.

9   63 Fed. Reg. 7606 (Feb. 13, 1998).

10 *Id*; Macro International, *Focus Groups on Consumer Confidence Reports: Focus Group Report* (submitted to the EPA Office of Ground Water and Drinking Water, April 27, 1998).

11 63 Fed. Reg. at 44523.

excess' [versus 'in excess']" indeed conveyed the agency's view that "the MCL is at least a thousand times lower than the level at which there have been any observed health effects"[12]; and (3) cancer effects, with EPA's permissive ("may") causal language, evoked different reactions than non-cancer effects, with the agency's enabling ("could") causal language.[13]

<div style="text-align:center">

Figure 1
Range-Plus-Explanation Stimulus

</div>

Next, we would like you to answer some questions about information that will appear in a water quality report, on what kinds of substances have been found in the drinking water and in what amounts, and comparing these amounts to the MCL and MCLG for each substance. The example below is a hypothetical example of how this information for one substance might appear (the report would feature a table showing this information for many different substances), and does not represent the actual quality of your drinking water:

Substance found in utility water (units in which numbers for this substance are reported)	Amount in utility water (average range found)*	Highest amount allowed (MCLG)	Ideal health goal (MCLG)	Potential sources of substances found
Butydin (parts per billion)	63 (47-110)	100	0	Discharge from chemical plants and other industrial activities

* Utilities are required to take quarterly (every three months) samples of water to test for these substances (the tests are done by state-certified laboratories) and report the results to state regulators. Those regulators determine whether the utility is meeting the MCL by comparing the annual average of these quarterly results to the MCL. The comparison of the MCL is to the average, rather than to the highest, result because the MCL is set to try to avoid health effects unless someone drinks water containing a substance in excess of the MCL over many years. What is critical is long-term exposure to levels of the substance much above the MCL; a short-term level above the MCL at one time or at one sampling location in the water system is not thought to be a health problem.

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12 *Id.*

13 The permissive-enabling distinction is courtesy of an anonymous reviewer.

Microbiological Warning. EPA required that utilities include a text about populations sensitive to microbiological contaminants (Figure 3). Although many microorganisms can be problematic, its primary motive was the protozoan parasite Cryptosporidium, which causes diarrhea that can kill people with compromised immune systems and that conventional treatment cannot easily remove from drinking water. The question here was whether this message was welcome and if it affected people's sense of vulnerability.

Figure 2
Experimental Texts on Health Effects

I: *Some people who drink water containing butydin in excess of the MCL over many years may have an increased risk of getting cancer.*

II: *Some people who drink water containing butydin in excess of the MCL over many years could have problems with their nervous system, kidneys, or liver.*

III: *Some people who drink water containing butydin well in excess of the MCL over many years could have problems with their nervous system, kidneys, or liver.*

Definitions. The agency's panels of risk communication experts and stakeholders felt that draft definitions of the MCLG and MCL were inadequate (e.g., over-simplified, did not convey health impacts of pollution between MCLG and MCL levels, did not explain how "safety" was determined), but they could not reach a consensus on solutions.[14] EPA-contracted focus groups saw various alternative definitions, all equally brief but varying the level of jargon and added information (e.g., "an adequate margin of safety"), and preferred a version similar to that finally adopted.[15] (See Figure 4.) This study examined whether these definitions were understandable.

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[14] 63 Fed. Reg. 7606 (Feb. 13, 1998).
[15] 63 Fed. Reg. 44512 (Aug. 19, 1998).

Health Risk. Congress required that the report include a statement to the effect that "the presence of contaminants . . . does not necessarily indicate that the drinking water poses a health risk."[16] EPA's draft language (Figure 5) received no comments and was not tested in focus groups or presented to the expert panel. It seemed prudent to explore whether this language was reassuring about the potential riskiness of one's water.

<div align="center">

Figure 3
Microbiological Texts

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EPA:

    Some people may be more vulnerable to contaminants in drinking water than the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. Environmental Protection Agency/ Centers for Disease Control guidelines on appropriate means to lessen the risk of infection by Cryptosporidium and other microbial contaminants are available from the Safe Drinking Water Hotline (800-426-4791).

Alternative:

    Cryptosporidium is a microscopic parasite that can cause intestinal distress. It can cause serious problems in people with weakened immune systems, a condition that can result from chemotherapy, dialysis, organ transplants, and HIV/AIDS. These patients should ask their doctor if they should take extra precautions, such as boiling their water, using bottled water whose treatment has most likely removed or killed these parasites, or using special filtering devices. People who think they have a problem with cryptosporidiosis (the medical problem caused by this parasite) should contact their doctor. Environmental Protection Agency/Centers for Disease Control guidelines on appropriate means to lessen the risk of infection by Cryptosporidium are available from the Safe Drinking Water Hotline (800-426-4791).

Contaminants. Congress required that the report include "a brief and plainly worded explanation regarding contaminants that may reasonably be expected to be present in drinking water, including bottled water."[17] EPA took this literally, recounting the different categories of contaminants that drinking water might contain (Figure

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[16] *Id.*

[17] *Id.*

6), but the author's experience suggests utility customers are less interested in this topic than such points as why there is contamination, who is responsible, and when it will be removed.[18] Thus audience evaluation of this message seemed desirable.

Figure 4
Experimental Texts for Definitions

Maximum Contaminant Level Goal

EPA:

Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.

Environmentalists:

Health Goal: This ideal goal, which if met guarantees full health protection with a margin of safety, is called a "maximum contaminant level goal," and is not legally enforceable.

Maximum Contaminant Level

EPA:

Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.

Environmentalists:

Highest Level Allowed: This enforceable "maximum contaminant level" is intended to protect your health, but in some cases is less strict than the ideal health goal, because it considers water treatment costs.

Evaluating Alternative Language

Although the study could have evaluated only EPA-required texts, testing alternative texts also seemed important because: (1) earlier research[19] found that utility customers wanted any information about their drinking water quality, suggesting the absolute quality of EPA-required texts might have little effect on audience reactions, and alternative texts would act as a control; and (2) the texts required by

18   Johnson, *supra* n. 1; Johnson, *supra* n. 3; Branden B. Johnson & Paul Slovic, *Presenting Uncertainty in Health Risk Assessment: Initial Studies of Its Effects on Risk Perception and Trust*, 15 Risk Anal. 485 (1995).
19   Johnson, *supra* n. 1; Johnson, *supra* n. 3.

EPA not only met legislative mandates, but were based on certain assumptions about how to communicate, and texts based on alternative assumptions might do as well or better.

Figure 5
Experimental Texts on Health Risks

EPA:

> Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the Environmental Protection Agency's Safe Drinking Water Hotline (800-426-4791).

Alternative:

> The presence of contaminants does not necessarily indicate that water poses a health risk. Government standards for contaminants that do not cause cancer are set with a safety margin, so that it is unlikely that someone will get sick even if that person drinks water for a lifetime with contamination at the same level as the standard, or even somewhat above the standard. At these "somewhat above" levels, the safety margin used to set the standard (often set as much as 1,000 times below levels found to have no adverse health effects in animals, for example) would be lessened somewhat, but not eliminated. Scientists do not yet know whether there is a level of a cancer-causing contaminant, other than zero, below which it would not cause cancer. For this reason, government standards for contaminants that cause cancer are set as low as feasible, and if that level is not zero for a particular standard, it will be set closer to zero as advances in technology make a stricter standard more feasible. More information about contaminants and potential health effects can be obtained by calling the Environmental Protection Agency's Safe Drinking Water Hotline (800-426-4791).

Alternative language might be derived from risk communication theory, from language suggested by other policy actors, or from the author's own experience or research results. Theory was little help regarding communication content. For example, the Carnegie-Mellon approach to "mental models" urges that messages correct misunderstandings and conceptual errors, relative to an "expert" model of the topic.[20] At the time of this research no "mental model" study of drinking water had been published. Although three such studies were

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[20]   Baruch Fischhoff et al., *Characterizing Mental Models of Hazardous Processes: A Methodology and an Application to Radon*, 48 J. of Soc. Issues 85 (1992); Cynthia J. Atman et al., *Designing Risk Communications: Completing and Correcting Mental Models of Hazardous Processes, Part I*, 14 Risk Anal. 779 (1994).

presented later (including one co-authored by this author), only one (on the parasite Cryptosporidium) offered evidence potentially relevant to even one of the topics explored here.[21] As with mental models, advice to explain why an erroneous belief is wrong before providing the correct view requires knowing those errors in advance of drafting messages.[22] Advice to tell people how they can reduce their risk, so that an increased sense of efficacy reduces fear[23] did not seem pertinent either. EPA intended that the water quality report "only" provide information, not stimulate action (although it also might put pressure on water purveyors to reduce contamination, as with the Right to Know rule on industry emissions).

As a result, suggestions from policy actors or the author's experience with citizens' views on drinking water were largely used as sources for alternative texts (with a few exceptions noted below). The use of policy actors' suggested language is particularly important, because academic researchers have tended to evaluate only their own suggested risk communication messages and practitioners have tended to evaluate their own proposed messages, if at all, with focus groups only (as with EPA's preparation for this regulation). Yet academics have no monopoly on the range of possible messages and cannot possibly test them all; meanwhile, practitioners (e.g., industry and government) communicate constantly, whether well or poorly, based upon "folk" hypotheses of communication that also deserve evaluation.

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[21] Anne J. Owen et al., *Risk Communication of Hazardous Processes Associated with Drinking Water Quality — A Mental Models Approach to Customer Perception, Part 1–A Methodology*, 39 Water, Sci. and Tech. 183 (1999); Felicia Wu & Mitchell J. Small, *Content, Accessibility, and Form of Existing Cryptosporidium Communication Instruments*, Presented at the Society for Risk Analysis meeting (Dec. 5-8, 1999); Caron Chess et al., *Beliefs About Utility, Private Well, and Bottled Water Quality and Management of New Jersey Residents*, Presented at the Society for Risk Analysis meeting (Dec. 5-8, 1999).

[22] Katherine E. Rowan, *Effective Explanation of Uncertain and Complex Science* in *Communicating Uncertainty: Media Coverage of New and Controversial Science* 201 (Sharon M. Friedman et al., Lawrence Erlbaum Associates 1999).

[23] Kim Witte, *Putting the Fear Back into Fear Appeals: The Extended Parallel Process Model*, 59 Commun. Monographs 329 (1992).

Figure 6
Experimental Texts on Contaminants in Drinking Water

EPA:

The sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants that may be present in source water include:

(A) Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.

(B) Inorganic contaminants, such as salts and metals, which can be naturally-occurring or result from urban storm runoff, industrial or domestic wastewater discharges, oil and gas production, mining, or farming.

(C) Pesticides and herbicides, which may come from a variety of sources such as agriculture, urban stormwater runoff, and residential uses.

(D) Organic chemical contaminants, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban stormwater runoff and septic systems.

(E) Radioactive contaminants, which can be naturally-occurring or be the result of oil and gas production and mining activities.

In order to ensure that tap water is safe to drink, the U.S. Environmental Protection Agency prescribes regulations which limit the amount of certain contaminants in water provided by public water systems. U.S. Food and Drug Administration regulations establish limits for contaminants in bottled water which must provide the same protection for public health.

Alternative:

All drinking water, including both utility-provided water and bottled water, can be expected to contain at least small amounts of some contaminants. Contaminants can come from natural sources as well as human sources. All original water sources are likely to have some level of contamination. This includes even rain water direct from the sky, due to natural and human air pollution that can be picked up by rain drops as they fall. Bottled water that comes from protected ground water sources usually has smaller amounts of such contaminants than the average utility water from a surface water source, but can have higher amounts of some contaminants in some cases (such as disease-causing microbes). Not all bottled water comes from protected ground water sources, and utility water often comes from ground water. All drinking water, including both utility-provided water and bottled water, must meet the same federal health standards.

Ranges. The hypothesis itself suggested at least two alternatives, in which the upper bound of the range was either above or below the MCL. In the spirit of "explaining errors" noted above, but with regard to a suspected rather than known error,[24] a third version attempted to

explain why having the upper bound exceed the MCL was neither a violation of the MCL nor likely to have health effects in most cases.

Health effects. EPA had several variants of its language, depending upon available data and risk assessment approaches; the three versions tested concerned the hypothetical contaminant "butydin," but otherwise used EPA's required language (Figure 2). Alternatives addressed either cancer (one version) or non-cancer effects on "nervous system, kidneys, or liver" (two versions); these were among the most-mentioned health endpoints across eighty-five regulated contaminants. They also varied the terms "in excess" (two versions) or "well in excess" (one of the non-cancer versions). Together the three stimuli allowed testing of the hypotheses discussed earlier.

Microbiological Warning. A utility-drafted (before the final rule by EPA) version[25] was modified to reflect a microbiologist's[26] knowledge about the protozoan's effects and to add the hotline number used in the EPA version (Figure 3). The EPA text begins with "contaminants," then segues to people "at risk from infections," and only towards the end refers to "Cryptosporidium and other microbial contaminants"; the alternative text gets straight to the point, and offers specific information about actions people can and should take, as advised by some risk communication researchers.[27] The alternative excludes children and the elderly, because the expert consulted believed that these categories of people were no more vulnerable to the parasite than others unless they also fell into the immuno-compromised groups cited in both versions. If utility customers attend to these differences, they should evaluate the alternative text more positively, as better meeting their information needs. Fewer readers also should see themselves as vulnerable, since the scope of at-risk groups is smaller than in EPA's version; although an obvious inference, such common sense is seldom tested — and sometimes wrong.

Definitions. This study could have tested another MCL or MCLG

[24] Fischhoff, *supra* n. 20.

[25] *See supra* n. 3.

[26] A NJDEP-Division of Science, Research and Technology colleague of the author, Dr. Thomas Atherholt.

[27] *See* Witte, *supra* n. 23. *See also* Ann Bostrom et al., *Evaluating Risk Communications: Completing and Correcting Mental Models of Hazardous Processes, Part II,* 14 Risk Anal. 789 (1994).

definition used in EPA's focus groups, but as noted above these did not vary widely. By contrast, an alternative offered by environmental activists[28] during the pre-regulation comment period (Figure 4) offered new information, such as the role of treatment costs in setting MCLs, which might alter reactions. It also was justified by activists as "plain English," a rationale often heard but little examined in policy debates (e.g., What constitutes "plainness" and does it have an observably distinct effect?). Its inclusion allowed a test of environmentalists' relative capacity as risk communicators.

Health Risk. An alternative text giving more detail on how the development of standards relates to possible health effects of contaminants seemed worth testing against EPA's brief assertion that the presence of contaminants in drinking water need not present risk.[29] As noted earlier,[30] health risk communication experts had been concerned about the lack of explanation of standard-setting in the MCL definition; some had suggested that a separate explanation, similar in content to the alternative tested here, be developed by EPA.

Contaminants. In contrast to EPA's focus on what contaminant types can be found in drinking water, the Congressional mandate to describe "contaminants that may reasonably be expected to be present in drinking water, including bottled water,"[31] could be interpreted as requiring an explanation that any drinking water will contain contaminants. Bottled and utility waters must meet the same water quality standards; the overwhelming majority of both kinds of water meet those standards, and the hundreds-of-times greater cost of bottled water might reasonably raise questions of economic efficiency and equity.[32] Bottled water consumption has been increasing in the United States, at least partly due to safety concerns.[33] Previous

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[28] A proposed template for the water quality table, including the definition language, was distributed by a member of the Consumer Confidence Report Working Group of EPA's National Drinking Water Advisory Council meeting on Feb. 20, 1997. The author was told by an EPA staffer that it was submitted by an (unnamed) environmentalist group.

[29] The author consulted with NJDEP colleagues who are risk assessment and drinking-water experts, Dr. Robert Hazen and Dr. Gloria Post, on this and the "contaminants" alternatives, but is solely responsible for any errors.

[30] 63 Fed. Reg. 7606 (Feb. 13, 1998).

[31] 63 Fed. Reg. 44512 (Aug. 19, 1998).

[32] 63 Fed. Reg. 7606 (Feb. 13, 1998).

research has indicated that utility customers are very interested in comparing their tap water's quality with that of bottled water.[34] Thus the alternative produced here stressed the point that both bottled and utility-provided tap water can be contaminated, if at levels in most cases below the relevant MCLs.[35]

Method
Instruments

Five versions of the instrument covered the suite of questions raised here. As detailed in Table 1, three versions tested one variant each on microbiological contamination,[36] health effects, and ranges;[37] two versions tested reactions to one variant, each on MCLG and MCL definitions, contaminants, and health risks, in those respective orders. Each questionnaire began with questions about drinking water quality, beliefs about the safety of tap versus bottled water, trust of the utility, and the personal importance of knowing more about one's drinking water quality. Order effects were not tested due to limited funding, but some orders were not appropriate (e.g. EPA's MCL definition includes the term "MCLG," so it had to follow the MCLG definition). After each experimental text were evaluation questions (see below) and demographic questions excluding ethnicity and income, by request of the collaborating utility.

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[33]   Robert E. Hurd, *Consumer Attitude Survey on Water Quality Issues,* AWWA Research Foundation and the American Water Works Association (1993).

[34]   Branden B. Johnson, *Risk Comparisons in a Democratic Society: What People Say They Do and Do Not Want,* 10 Risk: Health, Safety & Environment 221 (1999) (hereinafter "Johnson (1999)"); Branden B. Johnson, *Comparing Bottled Water and Tap Water: Experiments in Risk Communication* (submitted for publication 2001) (hereinafter "Johnson (2001)").

[35]   The message tested here did mention that bottled and utility water must meet the same standards, but did not include other potential messages (e.g., that experts consider any levels below the MCL to be equally safe or unsafe for either source). These were tested in Johnson (2001), *supra* n. 34.

[36]   Two of the three versions included the identical EPA-mandated language.

[37]   These three versions cited the EPA-mandated MCLG and MCL definitions after the introductory questions since these acronyms appeared later in some EPA-required language.

Table 1
Research Design and Sub-group Demographics

Experimental Texts	Instrument Versions				
	I	II	III	IV	V
Microbiological Warning	EPA	EPA	Utility	—	—
Health Effects	Cancer (in excess)	Non-cancer (in excess)	Non-cancer (well in excess)	—	—
Ranges (Upper Bound)	Below MCL	Above MCL	Above MCL & why it's not violation	—	—
MCLG/MCL Definitions	—	—	—	EPA	Activist
Contaminants	—	—	—	EPA	Author
Health Risk	—	—	—	EPA	Author

Demographics (N in brackets)

	I	II	III	IV	V
Sex (female)	70% [44]	60% [35]	50% [40]	51% [43]	45% [40]
Age (mean (s.d.))	51.5 (15.9) [44]	50.5 (15.6) [35]	51.2 (15.1) [40]	50.4 (16.8) [41]	52.7 (13.6) [41]
Education (% High School or Less)	24% [45]	26% [35]	20% [40]	29% [45]	32% [41]
Children at Home	38% [42]	53% [36]	54% [37]	44% [39]	56% [34]

For each version, topics are in their order in the instrument. "EPA" refers to required language; "Utility," "Activist," and "Author" refer to sources of alternative texts (see text for details). Except for Sex (I and III, and I and IV, $p < 0.10$; I and V, $p < 0.05$), there were no significant demographic differences among sub-samples with the t test for independent samples. Given the ten comparisons made among these five groups, a Bonferroni-corrected criterion of $p < 0.005$ would be needed to make the overall probability equal to 0.05 over ten tests (where a single difference significant at $p < 0.05$ has a 40.13% probability of occurring by chance).

Evaluation Questions

The primary measures concerned audience evaluation (i.e., self-reported understanding and helpfulness of the text and desire to have it appear in one's own water quality report) and dose-response consistency (i.e., self-reported concern and intention to use bottled water for all home drinking, given the information). Some texts had additional questions (e.g., the range texts had questions about whether there was a range of contaminant levels (a manipulation check) and whether the amount found in the water violated the MCL (a comprehension

measure)). The health effects texts had other comprehension measures about how the respondent interpreted terms used in those texts.[38]

Stimuli

Figures 1 through 6 show the range-plus-explanation version of the range tests, and all health effects, microbiological, definition, health risk, and contaminant versions, respectively.

Sample

A large New Jersey drinking water utility randomly selected residential customers from high, medium, and lower-income municipalities within three of its service areas, each of whom the author randomly assigned to receive one of the five questionnaire versions. Questionnaires were mailed by the utility and responses collected in April through June 1999.[39] The first wave had a cover letter, questionnaire, and a stamped return envelope addressed to the author; the second wave was a reminder; and the third wave had a new cover letter with another copy of the questionnaire and another return envelope. Of 357 in the original sample, 349 members were valid; 215 completed questionnaires made the response rate 61%. Respondents were 55.5% female and ranged in age from 28 to 92, with a median age of 49; 30% had children under 18 years of age living in the household. Modal education was college graduate, 33% (24% had some college, and 26% had a high school education or less). The five subsamples had no significant differences in demographics (see Table 1).

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[38] The italicized terms come from suggested categories of evaluation measures for risk communication. Neil D. Weinstein & Peter M. Sandman, *Some Criteria for Evaluating Risk Messages*, 13 Risk Anal. 103 (1993). The Weinstein-Sandman discussion of dose-response consistency stressed different levels of risk evoking different reactions. The corollary is that identical risks should evoke similar reactions. Mean risk did not vary across conditions in this study, so if different texts evoked different levels of concern, this indicates inconsistency, although these measures do not allow identification of which reactions are more consistent. The "intention" statement was used to plumb the depth of concern, not to predict actual behavior. At present, there is no evidence on the predictive value of this claim.

[39] The utility revealed to the author, after data collection, that it had mailed its first water quality report to customers in all but one of the zip codes covered by the survey in April 1999, and to the other zip code in June 1999. Despite the overlapping timing, no survey respondents mentioned receiving a water quality report. Their only comments on such a report were in response to the hypothetical situations posed in the survey.

Analysis

Responses were analyzed with STATISTICA 5.1 for Windows (StatSoft, Inc.). Principal components factor analysis, extracting all factors with eigenvalues greater than 1.0 and with varimax normalized rotation (some analyses extracted only one unrotated factor), was used to identify measures that might produce reliable scales, as indicated by reliability analysis. Because the number of respondents per treatment were few (about 40) due to resource constraints, raising a question of statistical power when comparing EPA to alternative language, differences are reported if significant at 90% (as well as the more conventional 95%) significance level. Most questions had a 4-item Likert response scale of "strongly disagree" (1) to "strongly agree" (4). "Don't know" responses were recoded as "3s" on a revised 5-item scale. Independent t tests for differences were conducted. Multiple regression analysis was used to identify the role that attitudes toward tap water quality and demographics played in reactions to the provided texts.

Results
General

All respondents answered the same initial questions. Over half (about 55% each) rated "the quality of the drinking water provided by your utility" as "excellent" or "good" overall, as well as aesthetics (taste, odor, clarity or color). The equivalent response for "safety" was smaller (49%); nearly one-third (29%) said they did not know. These three measures, over all respondents, loaded high (0.89-0.95) on the single, unrotated factor extracted from responses, which explained 84% of the variance; they produced a reliable Quality scale (Cronbach's standardized alpha=0.90; deletion of any item reduced the scale's reliability) for use in later multivariate analysis.[40]

Not surprisingly, given need for drinking water and possible social desirability bias, 72% said it was "very important" for them to personally know more about their water quality and another 23% rated

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[40]   Identical results occurred for the I-III and IV-V survey respondent subsets, although with lower loadings (0.73-0.88 and 0.79-0.87) and variances explained (69% and 67%), and lower reliabilities (alpha=0.78, deletion of the safety measure would increase alpha to 0.82 in the three-variant subset, and alpha=0.75).

it as "important." When asked about the safety "for people in general" of sources of drinking water, 14% said tap water was safer, 42% thought bottled water was safer, and 38% said they were "about the same." Seven percent did not know. Most respondents (69%) trusted their utility "very much" or "somewhat."

Ranges

The stimulus gave an introduction and a one-contaminant excerpt from a hypothetical water quality table (using the fake name "butydin" for the chemical to avoid framing effects[41]). Drafted with advice from state drinking-water regulators, Figure 1 shows the version of the stimulus explaining that an above-MCL upper bound did not indicate a violation.[42] The other versions tested were an above-MCL upper bound identical to Figure 1, but without the explanation, and a below-MCL upper bound (range 47 to 89).

Table 2 shows how people responded to the three versions of the range table. The majority of respondents rated this information as understandable, helpful, and desirable as part of a water quality report. Their concern was heightened by the information. Half of the readers of the first two versions and a third of those reading the third version claimed an inclination to switch to bottled water if this information appeared in their own water quality report. A majority accurately recognized that a range of contaminant levels occurred in each version, although a quarter of the readers of the second version said they did not know. People who disagreed, correctly, that a MCL violation had occurred comprised only 46% of those given the below-MCL range, 36% of those given the above-MCL range, and 60% of those given the above-MCL-range-with-explanation. The explanation lowered the proportion who incorrectly said that a violation had occurred, with a marginally significant difference (p < .10) between the two above-MCL versions. It also lowered the proportion who were concerned enough to claim they would switch to bottled water, though not significantly.

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[41] George L. Carlo et al., *The Interplay of Science, Values, and Experiences Among Scientists Asked to Evaluate the Hazards of Dioxin, Radon, and Environmental Tobacco Smoke*, 12 Risk Anal. 37 (1992).

[42] The last sentence of this explanation is generally true. If the exceedance of the MCL is very high, or if the person drinking this water is very vulnerable (e.g., people with compromised immune systems to certain contaminants), avoidance of health effects is less certain.

Table 2
Responses to Ranges of Contaminant Levels (Percentages)

Items	Agree			Don't Know/ No Opinion			Probability		
	I	II	III	I	II	III	I vs. II	I vs. III	II vs. III
I understand this information (N=39/45/41)	77	62	73	10	20	12	0.20	0.29	0.80
This information helps me understand how a substance in drinking water affects my health and safety (N=40/46/40)	65	52	73	8	17	5	0.43	0.78	0.23
This information increases my concern about drinking water quality (N=40/45/40)	88	82	80	5	11	10	0.65	0.21	0.39
Given this information, I'd use bottled water for all my home drinking (N=39/45/40)	49	56	33	21	11	18	0.88	0.19	0.12
The amount of butydin in the water violates the MCL (N=39/43/38)	36	40	24	18	23	16	0.72	0.16	*0.07*
The utility found a range of butydin levels in the water (N=39/44/38)	77	68	87	18	27	11	0.54	0.67	0.29
I want this information in my water quality report (N=40/45/38)	95	84	87	5	9	8	*0.06*	*0.05*	0.93

Bold-face italic indicates p <0.10. Note that no differences were significant at the Bonferroni-corrected level of p <0.01695, which corrects the overall significance criterion back to p < 0.05 when three tests are conducted; without this correction, there is a 14.26% chance of finding one or more significant differences by chance alone in three tests.
I = below-MCL upper bound
II = above-MCL upper bound
III= above-MCL upper bound with explanation that it does not indicate MCL violation or necessarily health effects.

Other Results

The responses to the other experiments were remarkably similar, so much so that they are reported in a single table to reduce repetition. Table 3 shows the percentage agreeing for each experimental text with several common questions. For example, the microbiological texts were

followed by statements with which respondents indicated their level of agreement (on a scale from 1 — Strongly Disagree, to 4 — Strongly Agree, with the option of answering Don't Know/No Opinion):

- "I understand this explanation" (Understand).
- "This explanation helps me understand how a substance in drinking water affects my health and safety" (Helps).
- "This explanation increases my concern about drinking water quality" (Concern).
- "Given this explanation, I'd use bottled water for all my home drinking" (Bottled).
- "I want this explanation in my water quality report" (Want).

The wording of these statements varied slightly across experiments. For example, "definition" substituted for "explanation" in the MCLG and MCL experiments, and understanding "how a substance in drinking water affects my health and safety" in one case would be "what substances I can expect to find in my drinking water" in another. However, these variations did not alter the pattern of response significantly, and that overall pattern is more important to convey here than slight changes in the wording of these questions.[43]

The overall pattern is as follows:

- People found all tested information to be understandable, helpful, and desired in a water quality report. As noted above, earlier studies[44] found very strong demand for any and all information related to drinking water quality; these results seem to bear that out. Responses that texts were understandable, helpful, and wanted formed moderately reliable additive scales for the MCLG definition (first factor extracted, 42% variance explained, standardized Cronbach's alpha=0.79), the contaminants texts (first, 38%, 0.71), and the risk texts (second, 31%, 0.70).[45]
- Most versions elicited strong reactions of concern. The proportion of people willing to claim that they would switch to bottled water entirely if this language appeared in their own utility's water quality report was much lower, but still substantial. Responses of concern,

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43 Interested readers can contact the author for exact wordings.

44 Johnson, *supra* n. 1; Johnson, *supra* n. 3.

45 Loadings of individual items on these factors and others discussed here are available from the author.

intentions to switch to bottled water, and wanting the text in local reports formed moderately reliable additive scales for the MCL definition (first factor extracted, 35% variance explained, standardized Cronbach's alpha=0.75), the contaminants texts (second factor extracted, 31%, 0.62), and the risk texts (first, 39%, 0.76).

• Very few significant differences were found between responses to the EPA texts and alternative texts. Of sixty-five comparisons, only four at $p < .05$ were significant, a proportion roughly equal to what might be expected by chance. The cancer effects text was more desired than the non-cancer effects texts.[46] This lack of differences was confirmed with discriminant function analysis, using the six scales identified above as independent variables to predict the grouping into the EPA texts and alternative versions of texts. Wilks' lambda, which is 1.0 if there is no discrimination among the groups on an independent variable and 0.0 if there is perfect discrimination, was 0.87 to 0.91 for these predictors (overall Wilks' lambda=0.87, $F (6, 64)=1.7$, $p < 0.15$).

Interpretations of the health effects language summed over all 128 respondents are of great interest, considering findings of widely varying interpretations of what it means to "share utensils" in the context of HIV transmission and of "portion size" in food labels and menus.[47] Choosing among multiple-choice answers, for example:

• Forty-three percent of respondents interpreted the "many years over which consumption might lead to health problems as meaning a term of "6-20 years," with 23% believing it meant "1-5 years." By contrast, only 5% each thought it meant either "21 years or more" or "immediately," and under 2% "less than a year"; 22% did not venture an opinion.

• Twenty-seven percent thought "[well] in excess of the MCL" meant it was "a small bit above the MCL," and 19% ten times the

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[46]   This study provides no direct evidence on why the first health-effects text was more desired than either of the other two. However, of the two elements that varied between these two pairs, stronger concern about cancer than the listed non-cancer effects is a more plausible explanation than the shift in causal language from "may" to "could."

[47]   Marilyn J. Quadrel et al., *Adolescent (In)vulnerability*, 48 Am. Psychologist 102 (1993); Lisa R. Young & Marion Nestle, *Portion Sizes in Dietary Assessment: Issues and Policy Implications*, 53 Nutrition Rev. 149 (1995).

MCL. Some 7% each thought it was equal to or 100 times the MCL, with 2% each thinking it was below or more than 100 times the MCL. A third had no opinion.

Table 3
Other Text Experimental Results (Percentages Agreeing)

	Understand	Helps	Concern	Bottled	Want
Health Effects I	85	73	100	49	98
Health Effects II	78	61	87	49	85**
Health Effects III	80	64	88†	43	85*
Microbiological—EPA	85*	76*	87	41	88
Alternative	98	95	83	33	98
MCLG Definitions—EPA	68*	57	84	72	77
Alternative	89	61	89	75	83
MCL Definitions—EPA	75	68	93	78	80
Alternative	71	67	92	75	89
Health Risk—EPA	86	68	75	42	85
Alternative	80	72	83	43	89
Contaminants—EPA	75	68	86	38	80
Alternative	83	64*	78	50	83

Differences were analyzed with t tests for independent samples. Note that only one difference for health effects was significant at the Bonferroni-corrected level of $p < .01695$, which corrects the overall significance criterion back to $p < 0.05$ when three tests are conducted; without this correction, there is a 14.26% chance of finding one or more significant differences by chance alone in three tests.
† $p < 0.10$
* $p < 0.05$
** $p < 0.01$

• With "don't know" responses removed (N=82), the version with the "well in excess" language evoked higher estimates of the level above the standard that might yield these health effects. The modal (34%) answer for "well in excess" was "ten times the MCL," whereas for "in excess" readers, the modal answer was "a small bit above the MCL" (38% and 31% in the two sub-samples seeing this phrase, for cancer and non-cancer effects respectively). Yet EPA intended the phrase "well in excess" to denote a level at least one-thousand times the MCL; only 7% of those reading this phrase said that it meant more than one-hundred times the MCL. There

appears to be an attenuation of customer judgments on the meanin of these phrases similar to that observed in lay estimates of risk, in which (relative to expert estimates) they seem to overestimate small risks and underestimate large ones.[48]

• Seventy-three percent thought that the phrase "some people" meant "anyone." Other respondents chose the options of "me" (8%), "don't know" (7%), "members of my family" or "people who are already sick" (4% each), or "people who don't take care of their health" (2%). No one chose the other proffered options of "children" or "the elderly."

A large majority in each case (84% to 95% across the three versions) agreed that these "health effects should be described in the water quality report even if the MCL for butydin was not exceeded," which is contrary to the EPA rule that they be described only after a violation has occurred.

A larger percentage of people disagreed that "I might be vulnerable to serious health problems of this kind" when reading the alternative language on microbiological contaminants (64%) than when reading the EPA text (44%). This was not a statistically significant difference, but might reflect the larger number of such vulnerable groups mentioned in the EPA text (including "some elderly," which would include far more people than the other categories mentioned).[49] Overall, those who said that they "might be vulnerable" were less likely than those who did not to say they understood the information (81% versus 95%; p < .01) and more likely to indicate an intent to switch to bottled water if this notice appeared in their own utility's water quality report (48% versus 24%; p < .01). Responses to the EPA version were similar (76% versus 95% on understanding (p < .01) and 34% versus 29% on bottled water (p < .05)). The alternative version elicited a significant distinction only on bottled water intentions (60% versus 17%, p < .01); there was no difference in self-reported understanding

48 Sarah Lichtenstein et al., *Judged Frequency of Lethal Events*, 4 J. of Experimental Psychol.: Human Learning and Memory 551 (1978); Detlof von Winterfeldt et al., *Cognitive Components of Risk Ratings*, 1 Risk Anal. 277 (1981).

49 About three-quarters of both groups said they "would call the hotline number for more information" if this information appeared in a water quality report from their own utility. The same proportion, after reading the health risk texts, said they would call the hotline number provided therein.

of this version between the allegedly vulnerable and non-vulnerable.

Discussion

Whether these results are good or bad news for the approach to reporting on drinking water quality that EPA mandated is likely to vary across observers.

Utility customers appear to have trouble translating the range and health effects language as intended by the agency, although how much trouble could be open to interpretation. Less than half of those reading the unexplained information on ranges of contaminant levels correctly said that no violation had occurred. The 60% figure for the explanation version is an improvement, but insufficient given that most utilities, particularly the larger ones, do not violate MCLs as "violation" is defined by regulators. As for the health effects language, the "well in excess" phrase evoked larger multiples of the MCL in readers' minds than did the "in excess" language, as EPA intended, but nowhere near as much as needed to reflect the actual differences in the agency's calculation of different standards. EPA intended the phrase "some people" to convey the probabilistic nature of affected populations. If a plurality of respondents said this phrase meant "anyone," was that mission accomplished? Is it appropriate that only 5% of the sample thought possible health effects occurring over "many years" meant more than twenty years? Customers prefered the cancer text for their own utility's water quality reports over the non-cancer texts, but this significant difference might have been due to chance.

Over all of the other variations tested, majorities of this sample of utility customers said that they found these definitions, explanations, and formats understandable and helpful and wanted them in a water quality report. These reactions mirror those of customers of another utility,[50] who strongly wanted every kind of water-quality-related information listed (all of those mandated under the EPA rules, plus two others), even the most abstruse kinds. Whether this enthusiasm for such information in the abstract will occur in practice remains to be seen, but for now it indicates a welcoming audience for the information Congress acted to provide.

[50]   Johnson, *supra* n. 1.

The strong concerns expressed, and the weaker but still substantial reported intentions to switch to bottled water evoked by these texts are harder to interpret. The "any news is bad news" hypothesis about even positive mass media coverage of a topic[51] could explain these reactions; people are concerned by this information because it makes potential risks of drinking water, however small, more available to their awareness than the absence of such information. If so, this raises larger questions about the overall impact of the annual water quality reports Congress required.

The impact of those reports, which in 2001 were issued only for the third time nationwide, remains to be seen. However, there is evidence that suggests that the concern expressed here, if evoked more widely, might not have substantial consequences. Focus groups under the aegis of the American Water Works Association[52] indicated that there was

> little relationship between actual utility compliance [with public health standards, etc.] and public confidence in drinking water safety. High levels of confidence and/or indifference were reported by customers served by water utilities that had recently experienced compliance problems; and [l]ow levels of confidence were reported in many cases in which the local water utility had no known history of compliance problems. A history of good customer relations and communications can apparently help build enough goodwill and trust to overcome an isolated water quality incident or problem. But a single report may not raise public confidence if it hasn't been preceded by positive customer relations and effective communications, especially when customers have been dissatisfied with water quality aesthetics (p. iii).

If this finding is generally true, then utilities with already good customer relations should have no problem with the concern-raising

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51   Allan Mazur, *The Dynamics of Technical Controversy*, 31 J. Commun. 106 (1981); Allan Mazur, *Nuclear Power, Chemical Hazards, and the Quantity of Reporting*, 28 Minerva 294 (1990).

52   Robert E. Hurd & J. Becker, *AWWA Focus Groups to Develop and Test Effective Water Quality Reports: Responding to CCR Requirements in the SDWA* (WITAF Project No. 408, Final Report)(Mar. 1998).

language tested in this study, much less with their water quality report as a whole. Utilities with already poor or mixed relations with their customers might find that issuing a water quality report showing compliance with MCLs worsens rather than improves those relations.

The caveat here is that some concerned people might switch to bottled water, despite the uncertainty that it is safer than tap water. At present there is no means to observe whether such an effect occurs,[53] and bottled-water comparisons do not appear to unequivocally improve attitudes toward tap water quality, at least in one-shot communications.[54]

Conclusions

Risk communicators have been calling for years for agencies and other organizations to test their messages with members of their prospective audiences before broadcasting the messages. The research summarized here suggests the value of experimental testing in exposing potential problems with the unexplained use of ranges to convey water monitoring results and seeming misinterpretations of health effect messages. What is less clear is whether the other results reported should reassure or alarm the institutions that manage drinking water quality. People wanted the provided information and did not vary their reactions to EPA-required language and to alternative texts produced by environmentalists, a utility, and a state government researcher. Possibly EPA did as well as could be expected in the short time it had available, although obviously experiments contrasting only two or three alternatives with small samples cannot demonstrate this conclusively. However, texts that sought to be reassuring, for example, EPA's (that the presence of contaminants does not necessarily entail health effects) or the author's (that a measurement of a contaminant above the MCL does not entail a violation), seemed to arouse concerns, as did the other texts tested here. Along with achieving better governance of drinking water quality, utilities and government agencies must do a better job of communicating this performance to consumers. The required texts

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[53]   In many service areas, overall demand for water might not drop much, if at all, even with substantial shifts to bottled water, since lawn watering is often the dominant usage by households, and even much in-house tap water is used for non-potable purposes.

[54]   Johnson (1999), *supra* n. 34; Johnson (2001), *supra* n. 34.

tested in this study might be necessary to that task, but we do not yet seem to know how to communicate in a way that is both accurate and appropriately reassuring (or alarming).