Stormwater Runoff Water Quality Newsletter
Devoted to Urban/Rural Stormwater Runoff Water Quality Management Issues

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This issue of the Newsletter is devoted to a review of **comparative risk** issues, as they relate to water quality management. Also, information is presented on the regulation of arsenic in drinking water. In general – except for a few constituents such as arsenic and trihalomethanes – carcinogens are regulated in aquatic systems and drinking water based on a risk assessment which considers the risk of acquiring cancer from consuming water or fish over an average person's lifetime (70 years), at a certain consumption rate. Depending on the regulatory agency, the allowed risk is one additional cancer in 10,000, 100,000 or a million people who consume two liters per day of water over their lifetime. The author and others have difficulty relating to a cancer risk of one in 100,000 or one in a million over a person's lifetime. As part of presenting lectures for the American Chemical Society (ACS) local section tour, the author has found that expressing "one in a million" in terms of everyday risk that the public generally considers acceptable is an approach that can help individuals gain a perspective on this level of risk.

Assessing Relative Risk

This Newsletter is a followup to the discussions in Newsletter 9-4 devoted to California OEHHA's recently proposed revised fish contaminant screening values for protection of human health. OEHHA has proposed to change the cancer risk screening levels for several chemicals that tend to bioaccumulate in edible fish tissue from one additional cancer in 100,000 people (i.e., the current screening level) to one additional cancer in 10,000 people. The discussions presented in this Newsletter may help establish a perception of what this factor of 10 change in the allowed cancer risk could mean, relative to risks that are routinely experienced by the public.

In connection with this issue, the author would like to recommend a book, Risk-Benefit Analysis, by Richard Wilson and Edmund A. C. Crouch, Second Edition, published by Harvard University Press (2001). This book is available from Harvard University Press in paperback for $25.00. It can be ordered online from http://www.hup.harvard.edu/catalog/WILRIS.html. Richard Wilson is Mallinckrodt Research Professor of Physics at Harvard University. Edmund A. C. Crouch is a Senior Scientist at Cambridge Environmental, Inc. This book presents a discussion of environmental and other risks and provides information on actually-measured risks for a number of activities, typically derived from insurance statistics.

Table 1 presents "one in a million" risks associated with certain activities. Table 2 presents the time to accumulate a one in a million risk for certain activities that may be somewhat similar to everyday activities experienced by the public. It is important to emphasize that the values presented in Table 1 are typically for a short period of time, such as a single event, compared to the risk associated with regulating carcinogens in drinking water, as well as the consumption of fish, which is based on a lifetime (70-year period) of exposure.

Table 1
Some Risks of "One in a Million"
Adapted from Wilson and Crouch (2001)

Time (or action) to accumulate a risk of one in a million from the cause indicated. These times could be infinite, or the quantity equal to the threshold dose, if there is a threshold in the dose response relationship. Uncertainties are about a factor of three in addition to the uncertainty of whether or not there is a threshold.

1. Smoking two cigarettes (risk of heart disease included)
2. Drinking thirty diet sodas with saccharin
3. Eating four tablespoons of peanut butter a year if one has hepatitis B1
4. Eating four tablespoons of peanut butter every ten days for a person without hepatitis B1
5. Eating one hundred fifty (1/2 lb.) charcoal broiled steaks (risk of benzopyrene and other aromatic hydrocarbons)
6. Eating one hundred 100 gram servings of shrimp (formaldeyde risk)
7. Eating one hundred 1 gram servings of brown mustard (allylisothiocyanate risk)
8. Eating thirty-five slices of fresh bread (formaldehyde risk)
9. Eating three hundred and fifty slices of stale bread (formaldehyde risk)
10. Eating one-half basil leaf (weighing 1 gram) (estragole risk).
11. Drinking seventy pints of Beer a year (Cancer risk of alcohol)
12. Exposed to Los Angeles or Sacramento water for fifteen years (chloroform risk only—arsenic risk additional)
13. Being exposed to radon in drinking water at typical California central valley levels for six months
14. Drinking water with EPA [former] limit of arsenic (50 ppb) for three days
15. Drinking Fresno water for three weeks (arsenic risk assuming linearity from known risks noted above)
16. One quarter of a typical diagnostic chest X-ray
17. Indoor air pollution risk for living in a typical Dutch house for two weeks (based upon average of four houses—organics only) (Tancrede et al. 1987)
18. Indoor air pollution risk for living in a Southern California house for two weeks, assuming exposures measured in first season of TEAM study; one month for exposures in the second season (Tancrede et al. 1987)
19. Nonsmoker living with average level (1.5 pCi/l) of radon gas in U.S. homes for one week
20. A nonsmoker living in a home with a smoker for two weeks
21. Forty days of living in Denver compared to Philadelphia (radiation)
22. Drinking one-half pint of milk per day for someone without hepatitis B1
23. Drinking one-half pint of milk a month for someone with hepatitis B1

All the above risks of consumption or inhalation are risks relevant to adults consuming this amount. Children consuming half this mount would be at comparable risk.

It is evident upon examination of the information presented in Tables 1 and 2 that the risk of acquiring cancer from chemicals in drinking water and/or fish in which they bioaccumulate from the food web is relatively low compared to many everyday activities of the public. Generally it is believed that many members of the public would not consider these everyday activities to be of sufficient risk to not participate in them.

Table 2
Some Risks of "One in a Million"
Adapted from Wilson and Crouch (2001)

Time (or Action) to Accumulate a Risk of One in a Million from the Cause Indicated (Historically Calculated)

Motor Vehicle Accident	100 miles
Falls (average over life)	6 days
Falls (average under 70)	15 hours
Drowning	19 days
Fires	13 days
Firearms	3 days
Electrocution	200 days
Tornadoes	5-1/2 year
Floods	2 years
Lightning	6 years
Occupational Risks—Working in:	
Manufacturing	100 days
Government	10 days
Transport	3 days
Agriculture	1-1/2 days
Construction	3 days
Coal mine accidents	1-1/2 days
Black lung disease	2 hours
Police officer	1-1/4 days
Pilot	3 days
Frequent Flying Professor	10 days

Note: the larger risks have a *smaller* number in this table!

Wilson and Crouch also present a ranking of the possible carcinogenic hazards from average US exposures to "rodent" carcinogens (from Gold et al. 2001) extrapolated to an estimated cancer risk in humans. Some of this information is presented in Table 3. The potential carcinogens listed in food items in Table 3 are naturally occurring carcinogens in that particular item of food.

It is evident from Tables 1, 2 and 3 that the public is exposed to carcinogens in water and food at a much higher cancer risk than is typically used to regulate carcinogens in drinking water. Further, for those carcinogens in drinking water that are regulated at a cancer risk of one additional cancer in a million people consuming two liters per day over a lifetime of 70 years, the public frequently experiences risks to their health (including death) at a much higher rate than consuming water with an MCL based on a one in a million lifetime cancer risk.

Regulating Arsenic in Drinking Water

The regulation of arsenic has been in a state of flux for a number of years with respect to protection of human health from consumption of arsenic in drinking water and in organisms that have developed in the water of concern. Until January 2006 the US EPA MCL for arsenic in drinking water was 50 µg/L. This concentration represents a significant human health cancer risk compared to the normal basis for establishing an MCL for a carcinogen in drinking water of one additional cancer in a million people consuming two liters per day over a lifetime of 70 years. Wilson and Crouch (2001) estimate that consuming two liters per day of water containing arsenic at 50 µg/L over three days is equivalent to a one in a million cancer risk (see Table 1).

Table 3
Ranking Possible Carcinogenic Hazards from
Average U.S. Exposures to Selected Rodent Carcinogens (Gold et al. 2001)
Adapted from Wilson and Crouch (2001)

HERP (%)*	Possible hazard	Average Daily Exposure
2.1	Beer, 257 g	Ethyl alcohol, 13.1 ml
1.4	Mobile home air (14 hrs./day)	Formaldehyde, 2.2 mg
0.5	Wine, 28.0 g	Ethyl alcohol, 3.36 ml
0.1	Coffee, 13.3 g	Caffeic acid, 23.9 mg
0.04	Lettuce, 14.9 g	Caffeic acid, 7.90 mg
0.03	Orange juice, 138 g	*d-Limonene*, 4.28 mg
0.03	Tomato, 88.7 g	Caffeic acid, 5.46 mg
0.03	Pepper, black, 446 mg	*d-Limonene*, 3.57 mg
0.02	Coffee, 13.3 g	Catechol, 1.33 mg
0.02	Apple 32.0 g	Caffeic acid, 3.40 mg
0.02	Coffee, 13.3 g	Furfural, 2.09 mg
0.007	Cinnamon, 21.9 mg	Coumarin, 65.0 µg
0.006	Coffee, 13.3 g	Hydroquinone, 333 µg
0.005	Carrot, 12.1 g	Aniline, 624 µg
0.004	Potato, 54.9 g	Caffeic acid, 867µg
0.004	White bread, 67.6 g	Furfural, 500 µg
0.003	Nutmeg, 27.4 mg	*d-Limonene*, 466 µg
0.003	Conventional home air (14 hrs./day	Benzene, 155 µg
0.002	Coffee, 13.3 g	4-Methylcatechol, 433µg
0.002	Carrot, 12.1 g	Caffeic acid, 374 µg
0.002	DDT: daily U.S. avg. (before 1972 ban)	DDT, 13.8 µg
0.001	Plum, 2.00 g	Caffeic acid, 276 µg
0.001	Pear, 3.29 g	Caffeic acid, 240 µg
0.0009	Brown mustard, 68.4 mg	Allyl isothiocyanate, 62.9 µg
0.0006	Bacon,11.5 g	Diethylnitrosamine, 11.5 ng
0.0004	Tap water, 1 liter (1987-92)	Bromodichloromethane, 13 µg
0.0003	Tap water, 1 liter (1987-92)	Chloroform, 17 µg
0.00008	PCBs, daily U.S. avg. (1984-86)	PCBs, 98 ng
0.00007	Toast, 67.6 g	Urethane, 811 ng

*The Human Exposure/Rodent Potency (HERP) is related to Risk by the following equation: Risk = HERP ln2/100

In November 2002, the US EPA (2002) issued its National Recommended Water Quality Criteria 2002. The Agency lists criteria for arsenic for protection of human health through consumption of drinking water as 0.018 µg/L for “Water + Organisms” and 0.14 µg/L for “Organisms Only.” These criteria are based on a cancer risk of one in a million. The water part of the criterion is based on consumption of two liters per day over a 70-year lifetime. The “Organisms Only” criterion applies to situations where individuals are eating aquatic life derived from water containing the arsenic criterion value. This criterion does not include the consumption of the water.

One of the problems with regulating arsenic the same as other potential carcinogens, such as many of the priority pollutants, is that arsenic occurs naturally in many surface and ground waters at concentrations that represent significant human health risks for causing cancer through drinking water. If the Agency followed a consistent approach for regulating arsenic as it uses for regulating many other carcinogens, it would cause large expenditures for treating domestic water supplies to remove arsenic. As a result, the US EPA's current MCL of 10 µg/L for arsenic in drinking water (US EPA 2006) is not necessarily based on risk, but incorporates economic factors as well. In the US EPA's (2006) statement on regulating arsenic in drinking water, it is stated that,

> *"Non-cancer effects can include thickening and discoloration of the skin, stomach pain, nausea, vomiting; diarrhea; numbness in hands and feet; partial paralysis; and blindness. Arsenic has been linked to cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate."*

However, the US EPA (2006) also stated,

> *"EPA has set the arsenic standard for drinking water at .010 parts per million (10 parts per billion) to protect consumers served by public water systems from the effects of long-term, chronic exposure to arsenic. Water systems must comply with this standard by January 23, 2006, providing additional protection to an estimated 13 million Americans."*

A critical review of the 10 µg/L arsenic drinking water MCL shows, however, that individuals consuming water containing arsenic at or just under 10 µg/L are exposed to a cancer risk of 1 in about 1,800, which is about 500 times higher than allowed for essentially all other carcinogens in domestic water supplies. Examination of Tables 1 and 2 shows that the US EPA's allowed risk level for arsenic in drinking water tends to be above what are normally acceptable risks. Further, as discussed below, naturally occurring arsenic in drinking water is one of the major threats to human health in California.

The US EPA (2006) has established a maximum contaminant level goal for arsenic in drinking water of 0 mg/L. The California Office of Environmental Health Hazard Assessment (OEHHA 2004) established a public health goal (PHG) for arsenic of 4×10^{-6} µg/L. It is evident that both agencies consider arsenic even at very low concentrations in drinking water to be a threat to human health.

One of the factors that played a major role in determining the 10 µg/L MCL was the cost of treatment of domestic water supplies to achieve a lower arsenic concentration (Frost et al. 2002). Even at 10 µg/L, there are about 4,000 domestic water supplies in the US that will need to reduce arsenic in their treated water, at an average household cost of about $32 per year, which translates to about 3 cents per person per day for large municipal systems. For small systems, the cost can be as high as 30 cents per person per day.

For several years, the author (G. F. Lee) was involved as a US EPA sponsored Technical Assistance Grant (TAG) advisor to the public on the Lava Cap Mine Superfund site, located near

Nevada City, California. The Lava Cap Mine is a former gold mine, in which the ore contained arsenopyrite. The mining and processing of this ore produced large amounts of tailings with greatly elevated concentrations of arsenic. Lee and Jones-Lee (2003) have published a summary of this situation. As they discuss, there are important questions about the appropriateness of the USEPA's (which is the lead agency for this Superfund site investigation/remediation) allowing arsenic in the discharge waters derived from the tailings at 10 µg/L (i.e., the current drinking water MCL), while proposing to clean up tailings-derived arsenic in soils based on a true risk-based human health risk assessment. This is an inconsistent approach for regulating arsenic. Further information on the Lava Cap Mine Superfund site investigation and remediation is available at http://www.epa.gov/superfund/sites/npl/nar1524.htm and at http://www.gfredlee.com/phazchem2.htm#lava.

California Comparative Risk Project

In the early 1990s, the author (G. F. Lee) participated in a state of California Comparative Risk Project organized by the Office of Environmental Health Hazard Assessment (OEHHA). The purpose of this Comparative Risk Project was to provide advice to the State on public health and ecological issues of greatest significance to the state of California, in terms of their impact on health and the environment. The Project was divided into a number of sub-projects, one of which was human health. Within the human health area, which is the area in which the author participated, consideration was given to assessing the comparative risk of contaminants in water, air and soil, as well as food risks with respect to pesticide residue impacts. The Human Health Committee (HHC) consisted of about 50 people, with representatives from health agencies, industry, university researchers and faculty, and consultants.

This Project resulted in a publication,

> California Comparative Risk Project, "Toward the 21st Century: Planning for the Protection of California's Environment," Final Report, Submitted to California Environmental Protection Agency, May (1994).

This report is available online at http://www.oehha.ca.gov/multimedia/pdf/comprisk1994.pdf. It provides insight into the relative significance of waterborne stressors, versus airborne or food-borne stressors. While the report was completed in the mid-1990s, the results are expected to be largely applicable to the situation today.

The purpose of the Project's human health activities was to provide a sense of the comparative risk of various chemicals in the environment, based on various routes of exposure. A number of position papers were developed by members of the HHC. Lee and Jones-Lee developed two project position papers:

> Lee, G. F. and Jones-Lee, A., "Impact of Municipal and Industrial Non-Hazardous Waste Landfills on Public Health and the Environment: An Overview," Report to State of California Environmental Protection Agency Comparative Risk Project, Berkeley, CA, 45pp, May (1994). http://www.gfredlee.com/cal_risk.htm

Lee, G. F. and Jones-Lee, A., "Public Health Significance of Waterborne Pathogens in Domestic Water Supplies and Reclaimed Water," Report to State of California Environmental Protection Agency Comparative Risk Project, Berkeley, CA, 27pp., December (1993). http://www.gfredlee.com/path-2.htm

which provide background information on the ultimate ranking that the HHC developed for human health stressors.

The primary conclusions of the HHC were:

"From the perspective of environmental stressors, the HHC found that exposures to toxic chemicals and agents have a significant impact on human health."

"From the perspective of environmental releases to media, the highest estimated human health risks are associated with various sources of air pollution."

"Most topic areas, including many ranked as generally low human health risks, can pose high risks to smaller populations."

Table 4 presents Human Health Risk Rankings of Environmental Health Stressors from the HHC report.

Table 4
Human Health Risk Rankings of Environmental Health Stressors[1]
(Populations of disproportionate risk of high impact indicated in parentheses)

High-ranked Risks

Environmental tobacco smoke (children with parents who smoke)
Inorganics (subsistence fishers; those with contaminated drinking water supplies or living near near emission sources)
Persistent organochlorines (subsistence/sport fishers)
Ozone (people with respiratory conditions; or those who work or exercise outdoors)
Particulate matter (children; people with respiratory conditions)
Radionuclides (natural sources)
Radon (smokers; those living in areas with high radon concentrations or with highly contaminated groundwater)
Volatile organics (those with contaminated drinking water supplies or living near emission sources; users of certain consumer products)

Medium-ranked Risks

Carbon monoxide (pregnant women; unborn fetus; those with cardiac conditions or using unvented combustion equipment)
Lead (children living in contaminated older housing or urban areas)
Microbiological contamination (those with compromised immune system or drinking contaminated or untreated drinking water supplies)

Table 4 (continued)

Pesticides - agricultural use (pesticide applicators; some subpopulations with high dietary intakes)

Pesticides - nonagricultural (pesticide applicators; those living in frequently treated home or workplace)

Low-ranked Risks

Radionuclides (anthropogenic sources)

SOx and NOx (those with respiratory conditions, children in homes with unvented gas appliances)

Substances that alter pH, salinity, and hardness

Total suspended solids, biological oxygen demand, and nutrients (children drinking high-nitrate water)

Unable to Rank, Not Ranked, or No Problem[2]

Asbestos (IN)
Greenhouse gases (IN)
Alteration of aquatic habitats (IN)
Alteration of terrestrial habitats (IN)
Stratospheric ozone depletors (IN)
Electromagnetic fields (IN)
Genetically engineered products or organisms (IN)
New chemicals (IN)
Non-native organisms (IN)
Thermal pollution (NP)
Oil/Petroleum (NR)

[1] Topics within each rank are ordered alphabetically.

[2] Topic area lacks sufficient toxicological or exposure data to reach a scientifically supportable evaluation.

(IN) Topic area lacks sufficient toxicological or exposure data to reach a scientifically supportable evaluation.

(NP) Not a problem.

(NR) Not ranked.

One of the objectives of this Project was to develop guidance on areas that need additional research, as well as a legislative agenda to control the high risks, especially in high-risk situations. It is of interest to find that, among the water pollutants, the HHC concluded that persistent organochlorines, such as legacy pesticides (DDT, dieldrin, toxaphene) and PCBs that bioaccumulate to excessive levels in edible fish and other aquatic life; disinfection byproducts (trihalomethanes); and radon in those areas where high radon concentrations occur in groundwater were areas of greatest risk to human health. Natural source releases to groundwater that lead to contaminated water supplies was the issue of greatest concern. Of particular concern would be radon and arsenic.

In the medium-risk category, microbial contamination of drinking water was the primary waterborne risk to human health. Anthropogenic source releases to groundwater that contaminate water supplies, inactive hazardous waste sites and non-point source releases to surface water were all considered to be of potential significance at particular locations as a source of pollutants that can be adverse to human health. With respect to the low-ranked risks, HHC concluded that industrial and municipal releases to surface waters, as well as treatment, storage and disposal facilities for hazardous wastes were not likely to be significant sources of pollutants that affect human health. However, the HHC also concluded that there are significant gaps in the information needed to evaluate the potential risks to human health associated with unregulated/unmonitored waterborne pollutants.

While the HHC addressed the issue of risks to human health, another committee considered ecological risks. The Ecological Health Committee concluded that, "*Some examples of the most sensitive ecological receptors for the highest ranked aggregate threats include:*

- *Atmospheric oxidants:* coniferous forests.
- *Introduced species:* geographically restricted or specialized native species.
- *Mining waste and drainage:* river communities; riparian communities.
- *Resource extraction from aquatic ecosystems:* river communities; anadromous fish populations; marine invertebrate populations.
- *Resource extraction from terrestrial ecosystems:* old-growth forest communities; hunted or collected species; forest communities.
- *Urban runoff:* aquatic populations near large cities.
- *Urban sprawl:* geographically restricted terrestrial populations near large cities.
- *Water diversion:* aquatic and terrestrial estuarine communities; river communities."

The Comparative Risk report should be consulted for additional information on both human health and ecological risk issues

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