UNTREATED CONTAMINATED DRINKING WATER VS.

TREATED CONTAMINATED DRINKING WATER:

THE CATCH 22 in H_2O

FINAL PROJECT
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INTRODUCTION

The water that we drink from the tap is usually quite a mystery to those who consume it everyday. One could assume that the average person does not know where their water comes from, whether or not that source is contaminated, the origin of the pollutants, or the manner in which the "raw" water is treated before it reaches their kitchen sink. It would probably surprise most people to find out just how contaminated their local water source is, and the diseases that they could potentially contract from the ritual eight glasses of water they drink daily to stay "healthy" are alarming, if not frightening. The techniques that are employed today to purify our water systems for domestic use are effective, yet not fool proof; it is not a rare occurrence in a hospital to receive a patient who has developed a disease resulting from contaminated tap water that has been improperly treated, poorly treated, or not treated at all. In addition, recent research indicates that the actual treatment processes themselves have negative effects on the chemical composition of the water, making water treated by the most modern and meticulous purifying techniques potentially hazardous to one's health. Consequently, many improvements in the quality of tap water must be made at all points along the way to the finished product: There must be a significant reduction in the sources and concentrations of contaminants in order to upgrade the quality of our surface and groundwater supplies; technology must devise a water treatment system that

will convert filthy water into a near pure state that is free from disease-causing agents; and finally, this treatment system should employ methods and chemicals that do not introduce injurious substances into the tap water. Once this idyllic plan is accomplished, hopefully in the near future, water should be safe to drink again.

DISCUSSION OF SAMPLE AND METHODS OF TESTING

The sample that I analyzed originated from a reservoir in New Rochelle, New York. The reservoir appears relatively clean to the naked eye, and you are not assaulted with appalling amounts of macro-litter around the periphery of the reservoir. It is nestled in a wooded area directly behind a housing complex equipped with a tennis court. The reservoir is extremely accessible to the residents of this neighborhood; there are no barriers or threatening precipices leading up to the reservoir that would discourage a person from talking samples or, if one ~~was~~ were so inclined, from tampering with the local water supply. This vulnerability is one of the most obvious disadvantages of a surface water supply: A groundwater source is more susceptible to contamination from landfill runoff and underground storage tanks, however, it is not subject to the high amounts of bacteria and direct contact with housing developments, roads, litter, sewage runoff, people, and other forms of human contamination that are inflicted upon surface water supplies. The sample I collected was a cloudy yellow-brown color, had

Do people swim in it?

particles suspended in it that resembled decayed plant matter, yet it had no obvious or offensive odor. I performed Ion Chromatograph, AA spectroscopy, pH, ANC, and total and fecal coliform tests to determine the chemical and biological state of the sample. The sample had to be diluted several times for the AA and IC analyses, which is a sure indication of some degree of pollution.

DATA AND COMPARISONS

The Safe Drinking Water Act has set maximum contaminant levels for drinking water sources to ensure that the contaminants do not occur in concentrations that will pose any threat to one's health before the water actually undergoes treatment. In comparison to the Maximum Contaminant Levels (MCL's) for drinking water supplies, my sample did not exceed the limits except in the case of sodium, which surpassed the MCL by 35.2 mg/L (See Graph 1). The total coliform count in the sample was far above the MCL as well, however, it was unclear whether the sampling methods and concentrations used to obtain the MCL correlate with those I employed in testing for coliforms. The reasons for such a high sodium content could be attributed to the close proximity of the reservoir to a major road which is salted during the winter months, in addition to contact with people. The pH was approximately neutral, and rest of the values appeared to be well within the range of a "normal" surface water source, one devoid of any contaminants found in

downhill from the road?

hazardous concentrations. In fact, the sample lacked fecal coliforms (0/100 ml of sample) entirely, which is an encouraging sign since fecal coliforms are most often present in heavily polluted waters.

However, the New Rochelle reservoir is not so "clean" in comparison to Rattlesnake Brook, Paul Brook, G.P. Well 1, G.P. Well 2 (both located on Cole road) and Sherman Spring, all water supplies located in Williamstown.(See Data Sheet) These sources have remarkably low levels of chloride, sodium, and nitrate, as much as 80 times lower than the value obtained for the reservoir. In fact, the reservoir tended to have higher levels of the contaminants than both Bridges Pond and Eph's Pond (See Graph 2). The wells are protected from surface sources of contaminants, which are very prevalent in the cases of Bridges and Eph's Pond, as well as the reservoir. The other sources used for comparison are surface waters, like the reservoir and the ponds, however they are moving bodies of water, therefore they are less likely to become "sinks" for pollutants than stagnant bodies of water. In addition, these sources, due to their isolated locations, are less subject to contamination from litter, waste products, and other forms of human abuse of the environment.

WATER CONTAMINANTS AND THEIR EFFECTS ON HEALTH

Water supply contaminants occur in all bodies of water to a certain degree, however, the concentration and nature of the

contaminant are the factors that determine whether the water is safe to be used as a drinking water source, and the extent to which the water may result in health complications. (See Figure 1). However, in linking a contaminant to a specific disease, one must always take into account the amount of the contaminant consumed, the length of exposure to the contaminant;, how often the person was exposed to it, the route it took to enter the body, and the susceptibility of the individual.[1] Biological contaminants include bacteria, algae, and other microscopic organisms, and they occur in greater densities in surface water than in groundwater. They result from animal wastes, the decomposition of plants and animals in the system, and leaching septic tanks. The consumption of untreated or poorly treated water containing an excess amount of bacteria and viruses can lead to gastrointestinal illnesses, cholera, tuberculosis, typhoid, and infectious hepatitis.[2] (See Figure 2)

Inorganic contaminants are of natural and human origin, and they consist of metals and salts, heavy metals such as arsenic, cadmium, copper, lead, and mercury being the most toxic. These metals do not break down easily and are excreted from the body very slowly, therefore they tend to build up in the body over periods of long exposure to the element. Nitrate, in particular, is a common and potentially dangerous inorganic contaminant that in excess can cause nervous system impairments, cancer, birth defects, and "blue-baby" syndrome.[3] Organic compounds, or those compounds that contain carbon, dominate 7/8 of the list of 200 listed groundwater contaminants.[4] These

contaminants come in the form of pesticides and solvents used in airports, gas stations, and dry cleaners. Solvents such as benzene, Trichloroethylene, acetone, and methylene chloride can be catalysts in impairments of the circulatory and nervous systems, as well as skin, nose, and throat damage.[5] Pesticides such as Endrin, Lindane, Toxaphene, and Methoxchlor can contribute to or cause liver damage, birth defects, sterility, cancer, genetic mutations, and spontaneous abortions in humans.[6]

The sources of water contamination are numerous and unfortunately, ever-increasing in number. Common causes of tainted water supplies are: landfills; surface impoundments or temporary storage sites for waste; underground storage tanks; waste disposal wells; pesticides and fertilizers; feces from livestock; military toxic chemicals; mining; septic systems; spills resulting from accidents involving vehicles transporting hazardous wastes or chemicals; and household hazardous wastes such as paint thinners, herbicides, and oven cleaners.[7]

WATER TREATMENT TECHNIQUES:POSITIVE AND NEGATIVE EFFECTS

The most common water treatment technique is disinfection using disinfectants such as chlorine, chloramines, ozone, and chlorine dioxide. The disinfectant is added at the inlet of the treatment plant (pre-oxidation) and then after the filtration process (post-disinfection). It is estimated that 79% of the U.S. population is exposed to water disinfected by chlorine, 18%

by chloramine, and 3% by an alternative disinfectant.[8] (See Figure 3) The pre-oxidation process disinfects the water, removes odor-causing compounds like sulfur, reduces the coagulant demand, and prevents the formation of slimes and algae. The post-disinfection process is extremely important because it thoroughly disinfects the water after other contaminant have been removed via filtration. Chlorination is responsible for destroying or inactivating bacteria in water, therefore it greatly reduces the outbreaks, spread, and actual incidences of waterborne diseases resulting from enteric pathogens such as salmonella, shigella, Hepatitis A, and Legionella. (See Figure 4) The negative effect that chlorination has on drinking water is that byproducts are formed that result from the reaction decayed plant matter and the chlorine. The byproducts of chlorination are called trihalomethanes or THM's. Studies have indicated that common THM's such as chloroform, bromoform, and dibrochloromethane can be found in the finished drinking water of most water suppies. In a ten city survey conducted by the Environmental Protection Agency, seven compounds were found in every water, and six other compounds occurred frequently.[9] (See Figure 5) The danger of chlorination is that studies indicate that longterm exposure to THM's result in an increased risk of cancer, in particular colon, rectum and bladder cancer.(See Figure 5) However, tests are still being performed to prove THM's as a viable carcinogen. There is the option of alternative disinfectants such as ozone, chloramines, and chlorine dioxide, which are less toxic and

produce less toxic byproducts. However, these disinfectants do not prove to be as effective as chlorine in primary disinfection.

The second most common water treatment process is called coagulation, flocculation, sedimentation, and filtration. The "process train" goes as follows: Chlorination of water and then filtration; in-line filtration where a coagulant is added after chlorination to make filtration easier; direct filtration in which floccuulation occurs before filtration followed by more chlorine; and finally, the conventional treatment -disinfection, coagulation, flocculation, sedimentation, filtration, and a final disinfection step.[10](See Figure 6) In coagulation, chemicals such as alum, ferric sulfate, and ferric chloride act as coagulants to alter the state of suspended particles. Then, during flocculation the particles are stirred, inducing collisions that result in larger particles. The large particles or aggregates settle via gravitation during sedimentation, and finally, rapid filtration acts to further separate out any remaining particles. Contaminants removed during this process accumulate into sludge, which is then disposed of in a landfill.[11] The conventional treatment is one of the safest techniques of water purification; there are minimal health risks from the chemicals used in the process. It effectively and efficiently removes dissolved inorganics, organics, some pathogens, and decreases turbidity, hence improving the clarity, taste, and smell of tap water.(See Figure 6)

There are other less common, but still widely used water

treatment techniques that cause concern in regards to their health risks. The corrosion of distribution systems is inevitable, and very dangerous since corrosion releases toxic heavy metals into the water supply. These metals, namely lead, cadmium, asbestos, zinc, and copper, are then flowing directly from the tap into the digestive system, where they can cause serious damage. High blood lead levels in children result in reduced hemoglobin synthesis, Frank anemia, and sometimes death.[12] Corrosion in distribution systems can be diminished by altering the pH and carbonate alkalinity of the water. This process is not entirely beneficial to the system because of the chemicals used during the treatment, especially the high levels of sodium, which could be a problem for people on sodium restricted diets.[13] However, the removal of extremely toxic substances like lead from drinking water far outweighs this slight hazard.

Lime softening, reverse osmosis, and ion exchange are three treatments designed to proportion the alkalinity and the "hardness" (the amount of calcium and magnesium), of the water. Lime softening removes soluble ionic groups and some inorganic contaminants. Reverse osmosis cleanses the water by straining it through a thin membrane at a high pressure, ridding it of most inorganic compounds and high molecular-weight organic compounds.[14] Ion exchange replaces one ion group with another, the cations usually being calcium, magnesium, iron, radium, and barium. Substitutes are also found for the anions nitrate and arsenic. The only objections to these processes are

the removal of essential nutrients such as calcium and magnesium from drinking water, and the increased sodium levels added during ion exchange.

Granular activated carbon (GAC) adsorption is a treatment that extracts organic compounds from the water that taint its' odor and taste. GAC can also be used to remove "volatile organic chemicals" or VOC's that contaminate the groundwater supply such as chloroform and benzene. The possible threats to the water supply due to GAC treatment are the introduction of organic compounds into finished water (carbon reacts with other compounds to produce toxic organics), and consequently, an influx of microorganisms. Finally, air stripping is a treatment that transfers VOC's from the water to the air. In the case of radon, a known carcinogen, it has yet to be determined whether radon is more toxic when inhaled or when digested. Future testing will provide more accurate information as to the effects of water treatment techniques on the water supply, and the health risks associated with consumption of treated water over long periods of time.

CONCLUSION

The water that flows through the taps of Williamstown is actually quite clean. The levels of organic, inorganic, and volatile organic chemicals fall well below the maximum contaminate level, and the only VOC that is detected in the tap water sample is chloroform at very low concentrations. (See Data

Sheet) It is possible that the absence of VOC's in the tap water is related to the fact that the water sources in Williamstown are treated with Sodium Hypochlorite instead of chlorine. Sodium Hypochlorite is a byproduct of chlorine that is used as a disinfectant, and recent studies have termed it non-carcinogenic. [15] It is a safer method of disinfection than chlorine, however chlorine still remains the most effective disinfectant. Conventional treatment has the ability to remove many contaminants, including some pathogens, yet the need for disinfection is still prevalent in the system. Disinfection, for some water supplies, is the only prevention of waterborne disease. A disinfection step is absolutely necessary, especially in the case of polluted water sources where a complete lack of disinfection would result in massive outbreaks of disease and fatalities comparable to those occurring today in third world countries. There are several possible solutions that should be considered: removal of the byproducts themselves from the finished water; a close monitoring of the amount of disinfectant used as well as residual disinfectant levels; modification of water systems that encourage the fostering of chlorine byproducts; develop new disinfectants that don't produce hazardous byproducts; and to reduce the amount of disinfectant needed by improving the quality of water sources. In order to accomplish this feat, permanent waste disposal methods must improve, and the careless use and disposal of contaminants must cease. In the meantime, it is up to the individual to ensure that the Safe Drinking Water Act

regulations for drinking water quality are being enforced by the state, as well as the E.P.A., by monitoring the contaminant levels in his/her tap water.

Lauren,

Interesting topic + well-researched. A bit light on the actual measurements that you did. A few other samples from different water supplies would have made for good comparison.

Sue

DATA SHEET

COMPILED DATA — Thu, May 10, 1990 11:49 PM

	SOURCE	CHLORIDE	SULFATE	NITRATE	SODIUM
1	MCL* mg/L	250.0	250.00	10.00	20.00
2	N.R.,N.Y. RES.	76.6	18.20	3.13	55.20
3	BRIDGES POND	33.4	7.83	2.46	22.97
4	RATTLESN. BR	<2.0	7.00	0.03	1.30
5	PAUL BROOK	<2.0	7.00	0.95	0.50
6	G.P.WELL 1	<2.0	13.00	0.08	3.50
7	G.P.WELL 2	<2.0	9.00	0.09	0.95
8	SHERMAN SPR	<2.0	5.00	1.13	0.65
9	EPHS POND	54	22.00	0.00	17.00

Good comparison data

DATA CONT... — Thu, May 10, 1990 11:52 PM

	SOURCE	CALCIUM	MAGNESIUM	POTASSIUM	PH	ANC	TOT COLIFORM
1	MCL* MG/L	75.0	85.00	----------	6.0-9.0	50-100	1-4/100ml
2	N.R.,N.Y. RES.	27.6	9.20	3.21	7.4	84	60
3	BRIDGES POND	25.42	13.01	----------	8.1	131.5	72.5
4	RATTLESN. BR	36.0	13.00	0.6	8.1	87	----------
5	PAUL BROOK	28.0	6.30	0.2	7.4	20	----------
6	G.P.WELL 1	6.7	1.10	1.0	8.0	124	----------
7	G.P.WELL 2	6.2	1.50	1.0	8.0	126	----------
8	SHERMAN SPR	10.0	2.60	2.3	7.7	95	----------
9	EPHS POND	38.0	14.00	----------	8.16	----------	39

? what is this ?

TAP WATER VS. MCL-INORG. — Fri, May 11, 1990 6:53 AM

	Column 1	Gross Alpha*	ARSENIC	BARIUM	CADMIUM	CHROMIUM	LEAD
1	TOWN TAP	0.350	<0.001	<0.05	<0.001	<0.001	<0.002
2	MCL mg/L	15.000	0.05	1.0	0.01	0.05	0.05

INORGANICS CONT. — Fri, May 11, 1990 7:03 AM

	Column 1	COPPER	MERCURY	NITRATE	SELENIUM	FLUORIDE	SILVER	SODIUM
1	TOWN TAP	0.000	<0.0002	<0.02	<0.001	0.100	<0.001	1.200
2	MCL mg/L	1.000	0.002	10.0	0.01	4.000	0.05	20.000

* pci/L

DATA SHEET CONT.

TAP VS. MCL -ORGANICS — Fri, May 11, 1990 7:14 AM

	Column 1	ENDRIN	LINDANE	METHOXCHLOR	TOXAPHENE	2,4-D	2,4,5TP
1	TOWN TAP	ND*	ND	ND	ND	ND	ND
2	MCL mg/L	0.0002	0.004	0.10	0.005	0.1	0.01

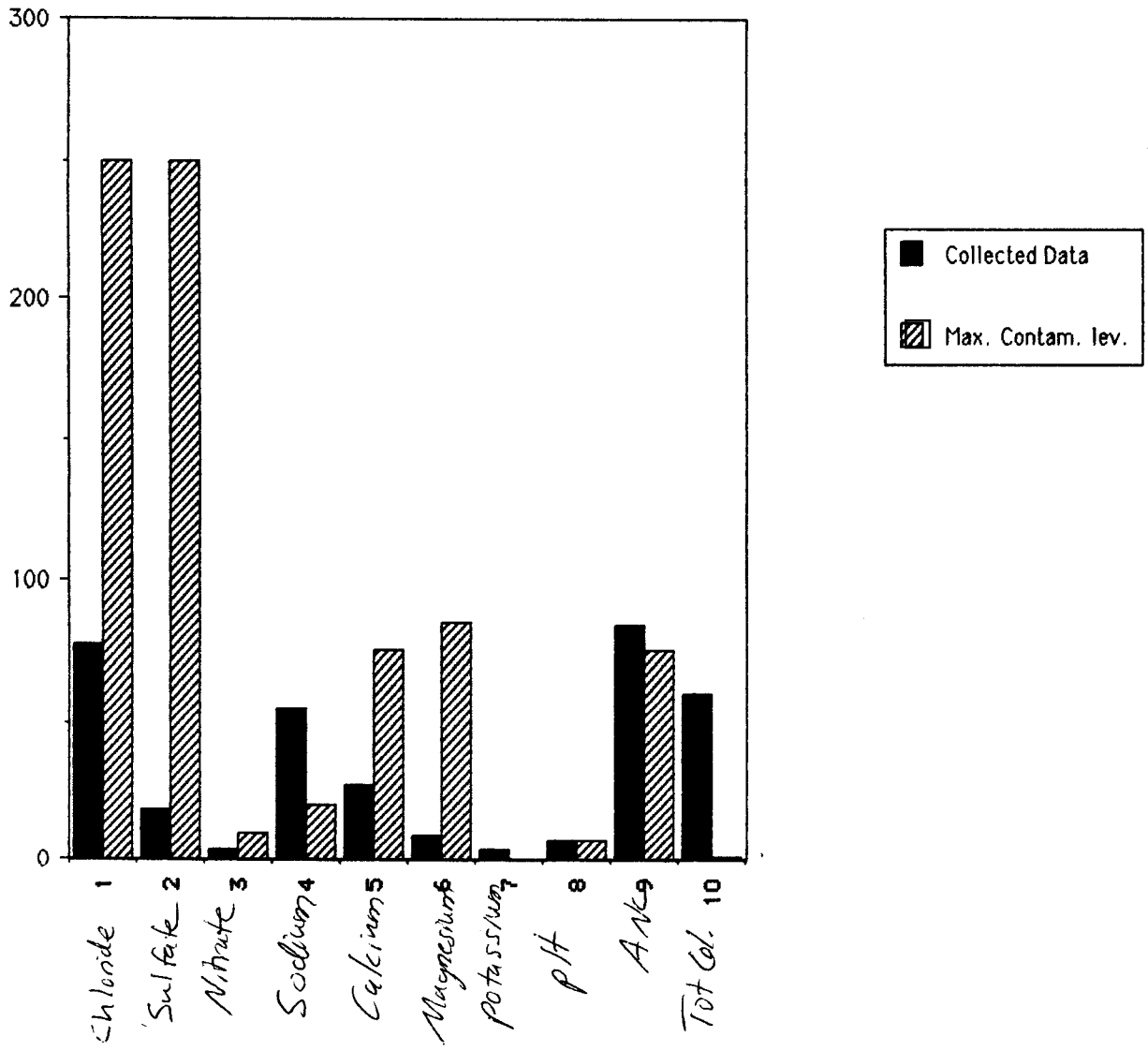
TAP WATER VS. MCL-VOC's — Fri, May 11, 1990 7:37 AM

	Column 1	CARBON TET*	VINYL CHLOR*	1,2	DICHLOROBEN*	1,1,1 TRICHL*	CHLOROFORM
1	TOWN TAP	ND	ND	ND	ND	ND	.0.003
2	MCL mg/L	0.005	0.002	0.005	0.075	0.2	..0.10

ND - Not detected
* Carbon Tetrachloride
* Dichlorobenzene
* 1,1,1 Trichloroethane
* Vinyl Chloride

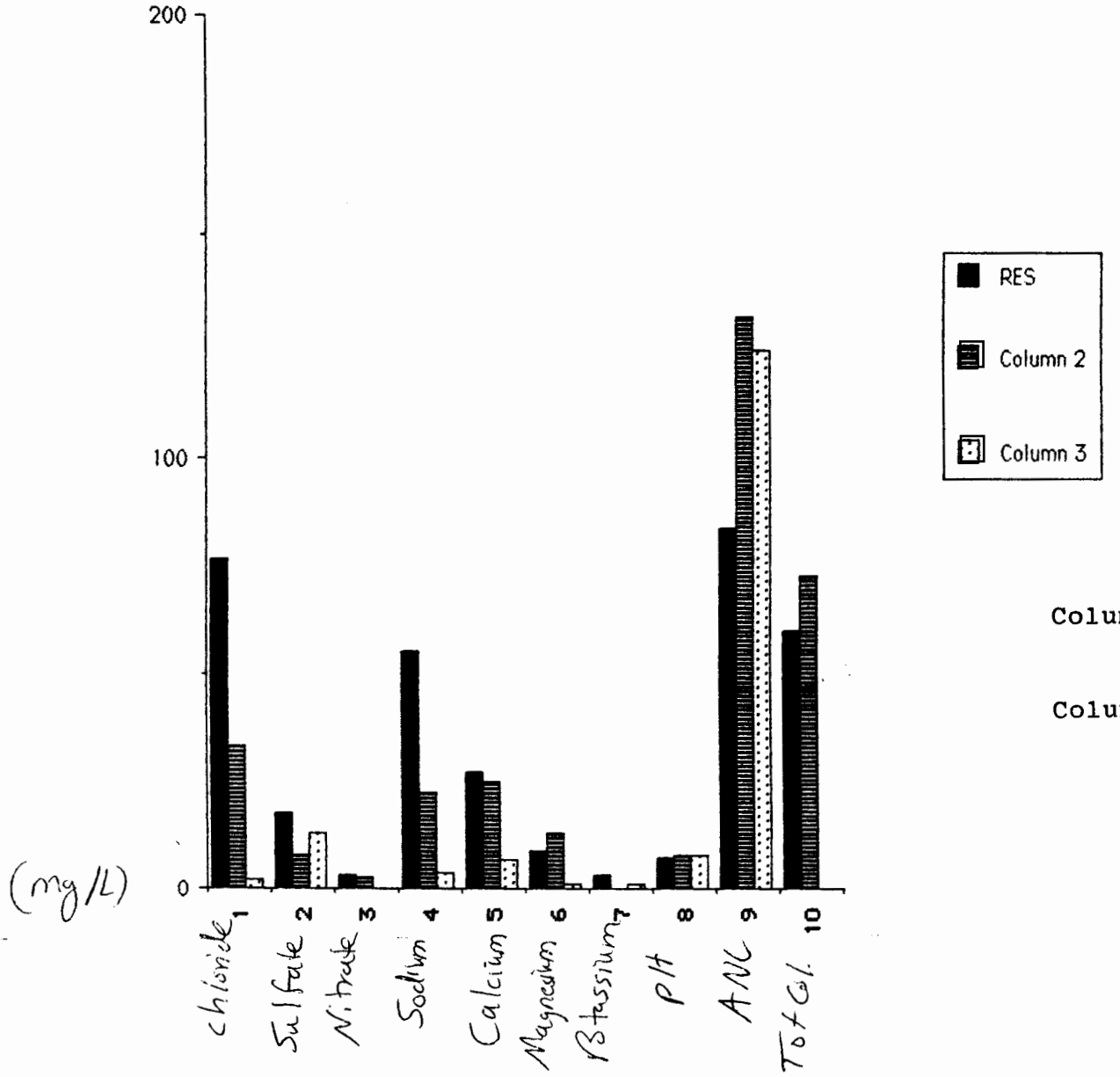
GRAPH 1

Data from New Rochelle Resevoir



GRAPH 2

RESERVOIR VS. BRIDGES POND VS. G.P. WELL 1



Column 2-Bridges Pond

Column- G.P. WELL 1

FIGURE 1

FIGURE 2.1
POTENTIAL HEALTH EFFECTS OF SUPERFUND CONTAMINANTS

Most commonly found groundwater contaminants at hazardous waste sites	Carcinogenicity	Mutagenicity	Teratogenicity	CNS effects	Cardiovascular effects	Kidney damage	Liver damage	Peripheral nervous system effects	Immunological effects	Gastrointestinal effects	Reproductive effects	Embryotoxicity	Lung/respiratory effects	Endocrine effects	Blood cell disorders	Upper respiratory tract irritation	Skin damage	Visual damage	Allergic sensitization	Eye irritation	Skin irritation
	Toxic Effects																				
1. Trichloroethylene	•			•	•	•	•					•		•							•
2. Benzene	•			•				•	•	•				•					•	•	•
3. Toluene				•	•	•	•								•					•	•
4. Lead	•			•						•				•							
5. Chloroform	•			•		•	•			•		•								•	•
6. 1,1,1-trichloroethane	•	•		•		•	•						•							•	•
7. Tetrachloroethylene	•			•		•						•	•		•					•	
8. Arsenic	•	•	•		•			•			•		•				•				
9. Phenol																					•
10. Trans-1,2-dichloroethylene	•			•	•	•	•					•	•	•						•	•
11. PCBs	•	•	•		•		•		•	•	•	•	•							•	•
12. Ethylbenzene				•		•	•								•					•	•
13. Methylene Chloride	Data not yet available—may pose a cancer risk to humans																				
14. Chromium	•	•	•				•					•	•						•		•
15. Xylene				•	•	•	•								•					•	
16. Cadmium	•	•	•	•		•				•	•	•									
17. Zinc and compounds										•			•	•						•	•
18. Vinyl Chloride	•	•		•		•	•							•							•
19. 1,1-dichloroethane				•		•	•					•									
20. Mercury				•	•	•							•					•			

SOURCE: *Adapted from ENVIRON Corporation, Approaches to the Assessment of Health Impacts of Groundwater Contaminants (Washington, D.C.: Office of Technology Assessment, 1983). Reprinted courtesy of The Conservation Foundation.*

FIGURE 13.1
THE ATSDR/EPA LIST OF THE 100 MOST HAZARDOUS CONTAMINANTS

Group 1*	Group 2*	Group 3	Group 4
Arsenic	Benzidine	Acrolein	Aniline
Benzene	BHC-1,2,3,4	Acrylonitrile	Benzoic acid
Benzo(a)anthracene	Bis(chloromethyl)ether	Ammonia	Bromomethane
Benzo(b)fluoranthene	Bis(2-chloroethyl)ether	Bromoform	2-Butanone
Benzo(a)pyrene	Bromodichloromethane	Chlorobenzene	Carbondisulfide
Beryllium	Carbon tetrachloride	Chlorodibromomethane	1,2-Dichlorobenzene
Bis(2-ethylhexyl)phthalate	Chlordane	Chloromethane	1,3-Dichlorobenzene
Cadmium	Chloroethane	Copper	Dichlorodifluoromethane
Chloroform	4,4-DDE, DDT, DDD	Di-N-butyl phthalate	2,4-Dichlorophenol
Chromium	3,3-Dichlorobenzidine	1,1-Dichloroethane	Diethyl phthalate
Chrysene	1,2-Dichloroethane	2,6-Dinitrotoluene	2,4-Diitrophenol
Cyanide	1,1-Dichloroethene	1,2-Diphenylhydrazine	Dimethyl phthalate
Dibenzo(a,h)anthracene	1,2-Dichloropropane	Endrin aldehyde/endrin	2,4-Dimethylphenol
1,4-Dichlorobenzene	2,4-Dinitrotoluene	Ethylbenzene	4,6-Dinitro-2-methylphenol
Dieldrin/aldrin	Isophorone	Hexachlorobenzene	1,4-Dioxane
p-Dioxin	Mercury	Indeno(1,2,3-cd)pyrene	Fluoranthene
Heptachlor/heptachlor epoxide	N-nitrosodimethylamine	Naphthalene	Fluorotrichloromethane
	N-nitrosodi-n-proplamine	Nitrobenzene	Hexachlorobutadiene
Lead	Pentachlorophenol	Oxirane	Hexachloroethane
Methylene chloride	Phenol	Silver	P-Chloro-m-cresol
Nickel	Selenium	Total xylenes	2-Pentanone, 4-Methyl
N-nitrosodiphenylamine	1,1,2,2-Tetrachloroethane	Toxaphene	Phenanthrene
PCB-1260,54,48,42,32,21,1016	Toluene	1,2-Trans-dichloroethene	Phenol,2-methyl
	1,1,2-Trichloroethane	1,1,1-Trichloroethane	Thallium
Tetrachloroethene	Zinc	2,4,6-Trichlorophenol	1,2,4-Trichlorobenzene
Trichloroethylene			
Vinyl chloride			

Tables obtained from "The Poisoned Well", Eric P. Jorgensen

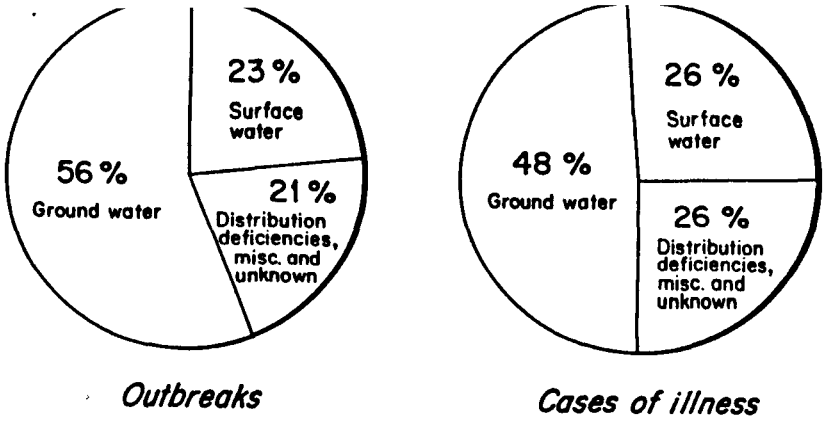


Figure 1-2. Waterborne disease outbreaks in the United States (1971–1977). *Source:* Craun, 1979.

Table 1-2. Water System Deficiencies Causing Outbreaks of Diseases, 1920-1983[a]

Public Water System Deficiencies	No. of Systems	% Deficiencies	No. of Cases of Illness
Contaminated, untreated ground water	661	43.2%	82,528
Inadequate or interrupted treatment	333	21.8%	224,973
Distribution network problems	233	15.2%	83,577
Contaminated, untreated surface water	158	10.3%	12,709
Miscellaneous causes or insufficient evidence	146	9.5%	11,542
Total	1,531	100.0%	415,329

[a]Data adapted from Craun (1986) cited in Geldreich (1986).

Table 1-1. Reported Waterborne Outbreaks, United States, 1984[a]

State	Month	Etiology[b]	Cases	Type of System[c]	Type of Deficiency[d]	Location of Outbreak	Location of Source
AK	Sep	*Giardia*	3	I	2	camp	stream
AK	Oct	*Giardia*	123	C	3	community	reservoir
CA	Nov	copper	1	I	4	high school	soda machine
CO	Nov	*Giardia*	13	C	3	community	river
CO	Mar	*Giardia*	400	NC	3	ski resort	pond
CO	Aug	AGI	50	C	3	community	river
ID	Mar	*Campylobacter*	6	C	3	community	spring
MA	Sep	Hepatitis A	7	I	2	household	well
MN	Mar	*Campylobacter*	9	I	2	household	well
MO	Oct	AGI	107	C	4	airport restaurant	sewage overflow
MO	Jun	*Entamoeba*	4	C	2	trailer park	well
MO	Jun	AGI	2	I	2	household	well
NC	Feb	copper	1	I	5	workshed	well
NY	Jun	*Campylobacter*	4	NC	2	amusement park	spring
OR	Jun	*Campylobacter*	22	C	3	community	wells, creek
OR	Jul	*Giardia*	42	C	3	community	river
OR	Aug	AGI	20	C	4	plywood mills	river
PA	Feb	*Giardia*	298	C	3	community	river
PA	May	AGI	8	I	2	picnic	well
PA	Aug	AGI	98	NC	2	resort	well
PA	Sep	AGI	34	I	2	bicycle race	private well
PA	Oct	AGI	18	I	2	industry	well
TX	May	Norwalk agent	251	C	3	community	well
TX	Jul	*Cryptosporidium*	117	C	3	community	well
WI	Mar	AGI	89	NC	4	restaurant	sewage overflow
VA	Mar	crude oil	28	C	5	community	spring

[a]Adapted from Centers for Disease Control (1985).
[b]AGI = acute gastrointestinal illness of unknown etiology.
[c]C = community (municipal); NC = noncommunity (semi-public); I = individual.
[d]1 = untreated surface water; 2 = untreated ground water; 3 = treatment deficiencies; 4 = distribution system deficiencies; 5 = miscellaneous.

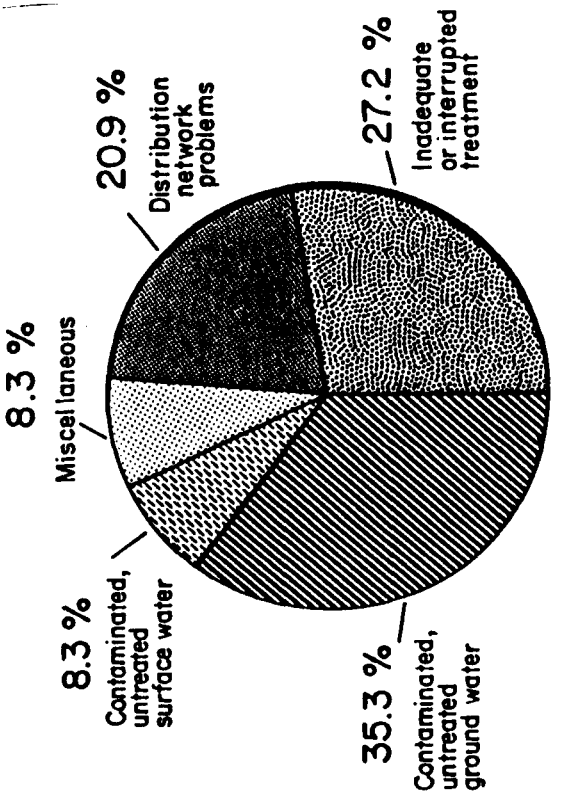


Figure 1-1. Waterborne disease outbreaks caused by deficiency in public water systems. *Source:* Lippy and Waltrip, 1984. Reprinted from *American Waterworks Association Journal*, Vol. 76, No. 2. (February 1984), by permission. Copyright 1984, American Waterworks Association.

FIGURE 2

"Figures 2-6 obtained from "Health Effects of Drinking Water Technologies." Please excuse the errors in citing.

Table 3-1. Chlorine, Chloramine, and Chlorine Dioxide Dosages for Various Drinking Water Sources

Dose mg/L	Lakes		Rivers		Ground Water		Total	
	No.	%	No.	%	No.	%	No.	%
Chlorine								
None	15	15.3	14	18.7	18	20.0	47	17.9
0.1–0.5	3	3.1	1	1.6	17	18.9	21	8.0
0.6–1.0	10	10.2	7	11.5	18	20.0	35	13.3
1.1–1.5	14	14.3	7	11.5	6	6.7	27	10.3
1.6–2.0	12	12.2	12	19.7	13	14.4	37	14.1
2.1–2.5	10	10.2	5	8.2	4	4.4	19	7.2
2.6–3.0	5	5.1	8	13.1	1	1.1	14	5.3
3.1–3.5	8	8.2	1	1.6	1	1.1	10	3.8
3.6–4.0	6	6.1	7	11.5	0	0.0	13	4.9
4.1–5.0	7	7.1	5	8.2	2	2.2	14	5.3
5.1–10.0	7	7.1	5	8.2	4	4.4	16	6.1
>10	1	1.0	3	4.9	6	6.7	10	3.8
Total	98		75		90		263	
Chloramine								
None	70	93.3	48	49.5	77	85.6	195	74.1
0.1–0.5	2	2.7	1	1.0	2	2.2	5	1.9
0.6–1.0	6	8.0	5	5.2	0	0.0	11	4.2
1.1–1.5	6	8.0	2	2.1	2	2.2	10	3.8
1.6–2.0	5	6.7	5	5.2	1	1.1	11	4.2
2.1–2.5	3	4.0	2	2.1	1	1.1	6	2.3
2.6–3.0	2	2.7	5	5.2	2	2.2	9	3.4
3.1–3.5	0	0.0	1	1.0	0	0.0	1	0.4
3.6–4.0	1	1.3	3	3.1	1	1.1	5	1.9
4.1–5.0	1	1.3	2	2.1	4	4.4	7	2.7
5.1–10.0	1	1.3	1	1.0	0	0.0	2	0.8
>10	1	1.3	0	0.0	0	0.0	1	0.4
Total	97		75		90		262	
Chlorine Dioxide								
None	90	93.8	65	86.7	90	100.0	245	93.9
0.1	0	0.0	2	2.7	0	0.0	2	0.8
0.2	0	0.0	1	1.3	0	0.0	1	0.4
0.3	1	1.0	1	1.3	0	0.0	2	0.8
0.7	1	1.0	0	0.0	0	0.0	1	0.4
0.8	0	0.0	2	2.7	0	0.0	2	0.8
1.0	2	2.1	3	4.0	0	0.0	5	1.9
1.3	0	0.0	1	1.3	0	0.0	1	0.4
1.6	1	1.0	0	0.0	0	0.0	1	0.4
3.0	1	1.0	0	0.0	0	0.0	1	0.4
Total	96		75		90		261	

Source: McGuire and Meadows (1987).

FIGURE 3

FIGURE 5

Table 3-5. Disinfection By-Products in EPA'S 26-City Survey[a]

Compound	Median Value (μg/L)	Range (μg/L)	No. of Samples Detected/ Analyzed
Chloroform	65.0	<0.7–360	24/25
Bromodichloromethane	8.7	<0.2–77	23/25
Chlorodibromomethane	2.4	<0.2–65	19/25
Dichloracetonitrile	1.0	<0.2–24	21/26
Bromochloroacetonitrile	0.5	<0.2–10	20/26
Chloropicrin	0.3	0.2–1.5	13/26
Bromoform	<0.5	<0.5–54	12/25
Dibromoacetonitrile	<0.3	<0.2–1.8	10/26
Total organic carbon (TOC)	3.6[b]	1.8–8.2[b]	18/18
Total organic halide (TOX)	215.0	10.0–560	18/18

[a]Reding et al. (1986).
[b]TOC is in mg/L.

Table 3-6. By-Products Found in All Samples of EPA'S 10-City Survey[a]

Compound	Median Value (μg/L)	Range (μg/L)	No. of Samples Detected/ Analyzed
Chloroform	28	2.6–594	10/10
Dichloroacetic acid (DCAA)	10–100	from <10->100	10/10
Trichloroacetaldehyde	10–100	from >10-<100	10/10
Chlorodibromomethane	7.6	0.3–31	10/10
Bromodichloromethane	6.8	4.4	10/10
Dichloracetonitrile (DCAN)	2.2	0.2–9.5	10/10
1,1,1-trichloropropanone	<10	All <10	9/9
Total Organic Carbon (TOC)	2.5[b]	<1-10[b]	7/7
Total Organic Halide (TOX)	130	30–1,600	7/7

[a]Stevens et al. (1987).
[b]TOC is in mg/L.

FIGURE 4

Table 3-9. Estimated Reductions in Waterborne Diseases Following Treatment of Water Supplies[a]

Disease	Estimated Reduction (%) in the Incidence as a Result of Improved Water Treatment[b]
Cholera	90
Typhoid	80
Leptospirosis	80
Viral hepatitis	10(?)
Enteroviruses	10(?)
Amoebic dysentery	50
Ascariasis	40
Legionella	—[c]

[a]Modified from Bradley (1977).
[b]The reductions were estimated by comparing the disease incidence during 1971 to 1977 with the incidence prior to improvements in drinking water treatment. Bradley (1977) compiled these figures using worldwide information (including U.S.). Water treatment improvements include disinfection and other typical treatment train technologies that are summarized in Figure 2-1.
[c]Legionella is primarily a problem in distribution systems rather than one of water sources.

FIGURE 5

Table 3-11. Summary of Evidence Concerning Mutagenicity and Carcinogenicity of Chlorine and Its By-Products

	Qualitative Data			Quantitative Data	
Chemical	In vitro Mutagenicity	In vivo Mutagenicity	In vivo Carcinogenicity	Cancer Risk Based on Consumption of Water	10^{-6} Cancer Risk (µg/L)
Hypochlorite	+[a]	–[b]	–[c]	NC[c,d]	
Trihalomethanes:					
Chloroform	–[e]	+[f]	++[g]	6.1×10^{-3}	6
Chlorodibromomethane	+[h]	–[h]	+[i,j]		
Bromodichloromethane	+[h,k]	–[h]	+[j]		
Bromoform	+[h,k]	–[h]	+[j]		
Chlorinated Acids:					
Dichloroacetic	–[l]	ND[m]	+[n]		
Trichloroacetic	–[l,o,p]	ND	+[n,q]		
Chlorinated Aldehydes:					
Trichloroacetaldehyde	+[r]	ND	+[s]	NE[t]	
2-Chloropropenal	+[u]	ND	ND	ND	
3,3-Dichloropropenal	+[u]	ND	ND	ND	
2,3,3-Trichloropropenal	+[u]	ND	ND	ND	
Haloacetonitriles:					
Dichloroacetonitrile	+[k,v]	–[w]	–[v]	ND	
Dibromoacetonitrile	–[v]	–[w]	+[v]	NE	
Bromochloroacetonitrile	+[v]	–[w]	+[v]	NE	
Trichloroacetonitrile	–[v]	–[w]	–[v]	ND	
Chlorophenols:					
2-Chlorophenol	ND	ND	ND	ND	
2,4-Dichlorophenol	–[x]	ND	ND	ND	
2,4,6-Trichlorophenol	±[y]	+[y]	+[y,z]	2×10^{-2}	175
Chlorinated Ketones:					
1,1-Dichloroacetone	[u]	ND	–[aa]	ND	
1,3-Dichloroacetone	[u]	ND	+[bb]	ND	
1,1,1-Trichloroacetone	[u]	ND	–[aa]	ND	
1,1,3,3-Tetrachloroacetone	[u]	ND	–[j]	ND	

[a]Rosenkrantz (1973) and Wlodkowski and Rosenkrantz (1975).
[b]Meier and Bull (1985).
[c]Carcinogenesis bioassays of chlorine have been conducted by Druckrey (1968), Hasegawa et al. (1986), and Kurokawa et al. (1986) without evidence of carcinogenic responses.
[d]NC indicates that appropriate long-term carcinogenesis bioassays have been conducted without evidence of carcinogenic effects.
[e]Reviewed by Bull (1986).
[f]Morimoto and Koizumi (1983).
[g]NCI (1976); Jorgenson et al. (1985); Roe et al. (1979).
[h]Ishidate et al. (1982).
[i]Dunnick et al. (1985).
[j]Theiss et al. (1977); Tumasonis et al. (1985).

[k]Simmon et al. (1977).
[l]Waskell (1978).
[m]ND indicates that no studies were identified that addressed the effect.
[n]Herren-Freund et al. (1987).
[o]Nestmann et al. (1980).
[p]Rapson et al. (1980).
[q]Parnell et al. (1986).
[r]Bignami et al. (1980).
[s]Rijhsingham et al. (1986).
[t]NE indicates that available data suggest that the chemical carcinogenic prop
not appropriate for making risk estimates.
[u]Meier et al. (1985a).
[v]Bull et al. (1985).
[w]Meier et al. (1985b).
[x]Rasanen et al. (1977).
[y]Fahrig et al. (1978).
[z]NCI (1979).
[aa]Bull and Robinson (1985).
[bb]Robinson et al. (1986).

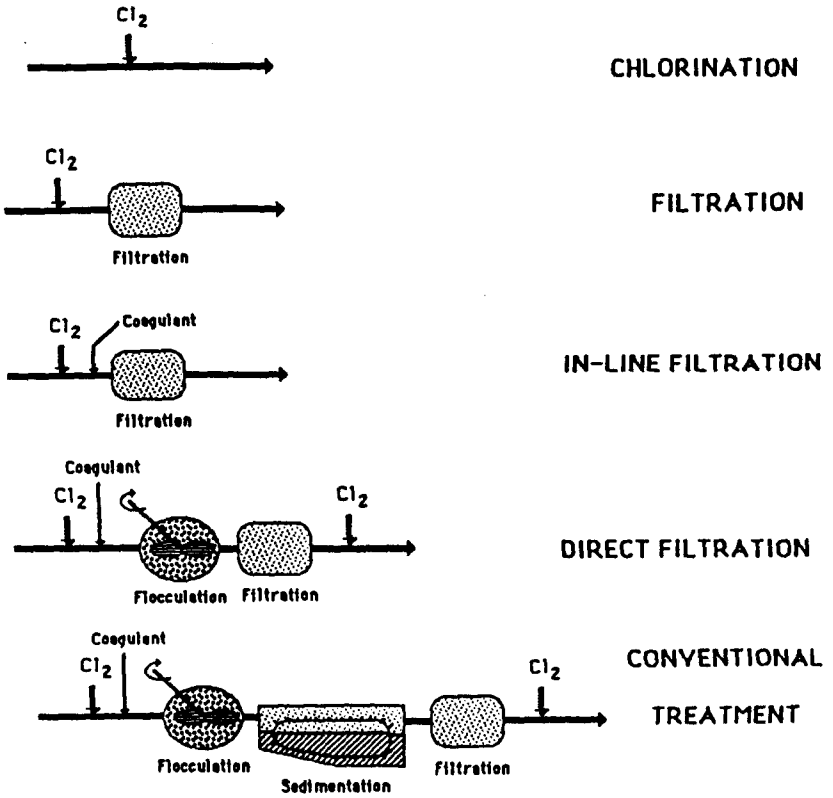


Figure 2-1. Typical water treatment process trains.

Table 4-1. Coagulation, Sedimentation, Filtration: Typical Removal Efficiencies and Effluent Quality

	Coagulation & Sedimentation (% Removal)	Filtration (% Removal)	Filtered Water Concentrations
Total coliform	74–97[a] 60–98[b]	50–98[a] 40–70[b]	<1/100 mL[a] (after disinfection)
Fecal coliform	76–83[a]		<1/100 mL (after disinfection)
Virus	88–95[a] poliovirus and Coxsackievirus	10–98 poliovirus (10^7/L applied)	
Giardia lamblia		97–99.9[d] through coag. sed., and filt.	
Giardia muris	58–99[a]		
Turbidity	40–96[a]		<1 NTU[e]
Trihalomethane formation potential		30–70[c] through coag. sed., and filt.[c]	
Asbestos		99+ through coag. sed., and filt.[f]	<0.5 × 10^6 fibers/L[f]

[a]Berger and Argaman, 1983.
[b]Haas et al., 1985.
[c]Based on TOC removal data summarized by Snoeyink and Chen, 1985.
[d]Al-Ani et al., 1986.
[e]NTU = nephelometric turbidity unit.
[f]McGuire et al., 1983.

FIGURE 6

[illegible] P. Jon[illegible]

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ENDNOTES

1 The Poisoned Well, p.46.

2 Ibid., p.15.

3 Ibid, p.17.

4 Ibid., p.18.

5 Ibid

6 Ibid.

7 Ibid., p.24.

8 Health Effects Of Drinking Water Treatment Technologies, p.44.

9 Ibid, p.47

10 Ibid., p.29

11 Ibid., p.89

12 Ibid., p.93

13 Ibid., p.100

14 Ibid., p.107

15 Ibid., p.63