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TASTE & ODOR

Contaminant	In water as (taste/odor description)	MCL[1]/MRDL[2] (mg/L) or Secondary MCL (SMCL[3])
Chlorine, Chloramines, Chlorine Dioxide	Cl_2, HOCl, OCl^-, NH_2Cl, ClO_2 (chlorinous, bleach smell or taste)	Cl_2, HOCL, OCl^-, NH_2Cl: MRDL 4.0 mg/L and MRDLG[4] 4 mg/L (as Cl_2) ClO_2: MRDL 0.8 mg/L and MRDLG 0.8 mg/L(as ClO_2)
Geosmin **2-Methyl Isoborneol (MIB)**	$C_{12}H_{22}O$ – CAS# 19700-21-1 (earthy, dirt odor) $C_{11}H_{20}O$ – CAS# 2371-42-8 (musty, wet mulch odor)	(Not regulated)
Methyl tertiary-butyl ether (MTBE)	CH_3-O-$C(CH_3)_3$ (solvent, petroleum taste/odor)	National Secondary Drinking Water Standard Advisory Level: < 0.02 – 0.04 mg/L
Phenols/Chlorophenols **Petroleum Products – Gasoline, Diesel and Jet Fuels** **Chlorinated benzenes**	Phenol – C_6H_5-OH (medicinal odor/taste) Chlorophenols – $C_6H_{(5-x)}Cl_x$-OH (medicinal odor/taste) BTEX – Benzene, toluene, ethylbenzene, xylenes (other aromatics and aliphatics) (solvent odor) Chorobenzene, o-, p-dichlorobenzenes (DCBs) (solvent/moth ball odor)	(Most phenols and chlorophenols not regulated) MCL: pentachlorophenol 0.005 mg/L MCL: Xylenes (total) 10 mg/L MCL: Benzene 0.005 mg/L MCL: Ethylbenzene 0.7 mg/L MCL: Toluene 1 mg/L MCL: chlorobenzene 0.1 mg/L MCL: o-DCB 0.6 mg/L MCL: p-DCB 0.75 mg/L
Inorganics: **Hydrogen sulfide** **Iron, Manganese** **Minerals (TDS) and Metals** **Hardness, Chlorides, Sulfate** **Corrosion products – Aluminum, Copper, Zinc, suspended iron** **pH**	H_2S (rotten egg) Ferrous (Fe II) and Ferric (Fe III) (metallic taste, rust color) Mn II (metallic taste, brown/black color) Ca^{++}, Mg^{++} (salty/bitter taste) Cl^- (salty/mineral taste) $SO_4^=$(salty/mineral taste) $Al(OH)_3$, Cu^{++}, Zn^{++}, Iron-rust particles (Al – cloudy; Cu^{++}- metallic taste/green or blue color; Iron-rust – metallic taste, rust color) pH < 6.5 (acidic/bitter taste) pH > 8.5 (alkaline/slippery taste-feel)	**National Secondary Drinking Water Standards:** Hydrogen Sulfide: Not regulated Iron: 0.3 mg/L Manganese: 0.05 mg/L Chloride: 250 mg/L Sulfate: 250 mg/L TDS (Total Dissolved Solids): 500 mg/L (WHO TDS guideline: 1,000 mg/L) Aluminum: 0.05 to 0.2 mg/L Copper: 1.0 mg/L (Primary DWS for Copper-Advisory Level = 1.3 mg/L) Zinc: 5 mg/L pH: 6.5 – 8.5

Sources of Contaminant	• Water disinfection processes (chlorine) • Natural algal blooms in surface waters (geosmin/MIB) • Sulfate-reducing bacteria (hydrogen sulfide) • Industrial pollution (phenols/chlorophenols, MTBE, petroleum products) • Leaking petroleum tanks/pipelines (MTBE, petroleum products) • Distribution system, plumbing lines, fixtures, water heaters ($Al(OH)_3$, Cu^{+2}, Zn^{+2}, Fe^{+3}) • Ground water (H_2S, $Fe^{+2/+3}$, Mn^{+2}, Hardness, Cl^-, $SO_4^=$)
Potential Health Effects **(at higher levels above the SMCL or MCL)**	• Chlorine – mouth/skin irritation (disinfection byproducts (TTHM's, HAA5's, etc) – carcinogenic) • Geosmin/MIB – none documented • Chlorophenols – carcinogenic, liver/kidney damage • MTBE – none documented at < 0.04 mg/L (USEPA) • Petroleum products: Benzene, Xylenes – anemia, carcinogenic, nervous system damage • Copper – gastrointestinal distress, liver/kidney damage, Wilson's disease • Sulfate – laxative effects • Overall poor taste/odor – indirectly may contribute to dehydration due to low consumption of water • pH < 6.5 – corrosion by-products (lead, copper, etc)
Treatment Methods	• Reverse Osmosis • Strong Acid Cation Exchange (Na^+ form) • Distillation • Adsorption – granular activated carbon (GAC), solid Carbon Block and fine mesh carbon filters (i.e. properly designed submicron filtration with activated carbon and specialty adsorption media –e.g., titania, alumina, etc.) • Aeration • Ozonation and other oxidation (filtration is sometimes needed afterwards for non-volatile compounds) technologies – manganese greensand, manganese dioxide, potassium permanganate ($KMnO_4$), hydrogen peroxide (H_2O_2) • Acid/base neutralization, calcium carbonate • Corrosion control – buffering, polyphosphate

[1]MCL - Maximum Contaminant Level - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

[2]MRDL – Maximum Residual Disinfection Level: The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

[3]SMCL – Secondary Maximum Contaminant Level – Non-enforceable contaminant level established by the USEPA as guidelines to assist public water systems in managing aesthetic effects in drinking water, such as taste, color, odor and cosmetic effects. These contaminants are not considered to present a human health risk at or below the SMCL.

[4]MRDLG – Maximum Residual Disinfection Level Goal: The level of a drinking water disinfectant below which there is no known or expected risk to health.

WHO – World Health Organization

CONTAMINANT DETAILS

There are many causes and sources for taste and odor problems. The chemicals responsible for these problems in drinking water are mostly considered to contribute undesirable aesthetic effects, such as bad tastes, odors and off color or cloudiness. These contaminants and those covered under the USEPA National Secondary Drinking Water Regulations (NSDWRs) at the Secondary Maximum Contaminant Level (SMCL) are not considered to be a health concern. Most of these contaminants fall under the NSDWRs which set non-mandatory water quality standards (SMCLs) for 15 contaminants. However, some of the above listed chemicals do fall under the National Primary Drinking Water Regulations (NPDWRs), such as chlorine disinfectants, copper, some of the petroleum products and chlorinated organics. The USEPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt the NSDWRs as enforceable standards.

Chlorine residuals are the most common odor problem in North American drinking waters. This is because standard chlorination procedures are required by regulatory requirements to provide a measurable level of chlorine residual as free chlorine or chloramine at the taps of water consumers. This results in a chlorinous or bleach-like smell or flavor. The average person can smell/taste free chlorine (Cl_2, HOCl, OCl^- - at 0.5 – 1 mg/L) more so than monochloramine (NH_2Cl – at 3 mg/L).

Odor detection and measurement of organic-based odorants are rather subjective and can be very expensive if analytical instrumentation is utilized to accurately identify and quantify the odor-producing substance. Most public utilities utilize sensory panels to detect and determine a 'threshold odor number' (TON) or establish a category for the description of the contaminant in accordance with procedures in *Standard Methods for the Examination of Water and Waste Water* – 2170 Flavor Profile Analysis.

Surface waters tend to contain background odors typically described as earthy, musty, grassy, green vegetation, marshy, decaying vegetation and fishy. The odor-producing contaminants most often found in surface water sources, geosmin and 2-methylisoborneol (MIB), are usually caused by excessive blooms of cyanobacteria and their subsequent decay, usually during the mid-to-late summer months when water temperatures reach very warm levels. They are the two most common odor problems for drinking water utilities with surface water sources. They can reach concentrations up to 100-200 micrograms per liter (µg/L, ppb). Odor threshold levels (OTLs) for geosmin and MIB are reported to be in the very low µg/L level, e.g., 10-20 µg/L and 5-10 µg/L, respectively. There are no reports of adverse health effects associated with these compounds.

Though groundwater typically does not contain odors caused by organics, in many cases it can have the very unpleasant 'rotten egg' odor caused by hydrogen sulfide, H_2S. The two main reasons for the presence of H_2S in groundwater are: 1) metal sulfides reacting with low pH water generating H_2S; 2) Sulfate-reducing bacteria that assimilate sulfate ion ($SO_4^=$) and chemically reduce it to H_2S. Sulfate-reducing bacteria can be present in any drinking water source and can produce H_2S and other odorous organic sulfides even in finished chlorinated drinking water.

Industrial pollution can be a source for contaminants that cause objectionable tastes and odors. Petroleum products and by-products can contribute a solvent or gasoline smell, e.g., MTBE – methyl *tert*-butyl ether; BTEX – benzene, toluene, ethylbenzene, xylenes; other industrial solvents and chemicals. These usually are introduced into the groundwater or surface water from leaking storage tanks, pipelines and improper disposal.

Minerals, metals and variations in pH that contribute to off-tastes can be present in any source water and can be introduced inadvertently or intentionally by various means, such as high pH from lime-soda softening or chloramination, in groundwater from high TDS (total dissolved solids), high hardness,

salinity, and from distribution systems and household pipes (copper and iron), plumbing fixtures and appliances (e.g., water heater (magnesium and aluminum), improper setting/maintenance of a water softener). TDS is made up of the cations (positively charged) and anions (negatively charged) commonly found in water, e.g., for cations: calcium, magnesium, sodium and potassium, and for anions: sulfate, bicarbonate, carbonate, chloride and nitrate. High TDS usually contributes a salty or bitter taste. The US and Canada recommend a limit of 500 mg/L (SMCL). It has been reported that the best tasting water for most consumers contains about 10-100 mg/L total hardness as $CaCO_3$ and a TDS of about 150-250 mg/L (WHO).

HEALTH EFFECTS

Fortunately, most of the aesthetic contaminants do not cause adverse health effects as long as they remain at or near their SMCL. However, some at higher levels may cause direct health concerns, such as high sulfate concentrations (laxative effect). And some may indirectly create health concerns such as low pH contributing to dangerous levels of corrosion by-products, e.g., lead and copper, and high levels of chlorine generating excessive concentrations of disinfection by-products (TTHMs, HAA5, etc.). See the table above for reference to the specific health effects associated with each contaminant and the USEPA web site for other health effects information.

TREATMENT METHODS

Activated carbon is the primary treatment method for reducing the aesthetic contaminants causing the most common taste/odor issues (chlorine, geosmin and 2-MIB). For residential treatment, activated carbon can be utilized in both point-of-entry (POE – usually as GAC) and point-of-use (POU – as GAC and carbon block) water treatment devices to reduce these contaminants to below their TON. Municipalities having surface water sources utilize powdered activated carbon during algal blooms to help control geosmin and 2-MIB.

The treatment methods listed below are generally recognized as techniques that can effectively reduce the listed contaminants sufficiently to meet or exceed the relevant SMCL or MCL. However, this list does not reflect the fact that POU/POE devices and systems currently on the market may differ widely in their effectiveness in treating specific contaminants, and performance may vary from application to application. Therefore, selection of a particular device or system for aesthetic or health contaminant reduction should be made only after careful investigation of its performance capabilities based on results from competent equipment validation testing for the specific contaminant to be reduced.

As part of the installation procedure, system performance characteristics should be verified by tests conducted under established test procedures and water analysis. Thereafter, the resulting water should be monitored periodically to verify continued performance. The application of the water treatment equipment must be controlled diligently to ensure that acceptable feed water conditions and equipment capacity are not exceeded.

POU/POE water treatment devices can achieve certification under *NSF/ANSI Standard 42 – Drinking Water Treatment Units – Aesthetic Effects* for reduction of many of the taste and odor contaminants listed in the Contaminant table above, including those covered by the NSDWRs, e.g., chloride, iron, manganese, sulfate, TDS and zinc (see below). Also, some of the contaminants regulated by the

NPDWR can be tested for and have reduction claims under *NSF/ANSI Standard 53 – Drinking Water Treatment Units – Health Effects*, e.g., certain chlorinated phenols and petroleum products.

Best Applications for Treatment		
Municipal – Odors from:	geosmin	Powdered activated carbon (PAC)
	2-MIB	Powdered activated carbon (PAC)
	other organics	Powdered activated carbon (PAC), GAC
	chlorine	Blending, aeration
Tastes from:	minerals, salts	Blending, alternate source
	Iron, copper	Coagulation/precipitation, polyphosphate, pH adjustment
Residential – Odors from:	geosmin	Granular activated carbon (GAC), reverse osmosis, distillation, boiling/aeration
	2-MIB	"
	chlorine	
	hydrogen sulfide	Chlorination, manganese greensand, potassium permanganate ($KMnO_4$), ozonation
	other organics	Granular activated carbon (GAC), reverse osmosis
Tastes from:	iron	Manganese greensand, ion exchange softening, distillation
	manganese	

REGULATIONS

In the United States the EPA, under the authority of the Safe Drinking Water Act (SDWA), has set the Secondary Maximum Contaminant Levels (SMCLs) for aesthetic contaminants as established in the National Secondary Drinking Water Regulations (NSDWRs). At these SMCLs they are not considered to be a health concern. The table below lists the non-mandatory water quality standards (SMCLs) for 15 contaminants and water parameters.

List of National Secondary Drinking Water Regulations	
Contaminant	**Secondary Standard**
Aluminum	0.05 to 0.2 MG/L
Chloride	250 MG/L
Color	15 (color units)
Copper	1.0 MG/L
Corrosivity	noncorrosive
Fluoride	2.0 MG/L
Foaming Agents	0.5 MG/L

Iron	0.3 MG/L
Manganese	0.05 MG/L
Odor	3 threshold odor number
PH	6.5–8.5
Silver	0.10 MG/L
Sulfate	250 MG/L
Total Dissolved Solids	500 MG/L
Zinc	5 MG/L

Excerpt from http://water.epa.gov/drink/contaminants/index.cfm#List

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