

The columns' information specified in the Data Download (BETA) provided by the data's source, the USF Water Institute,¹ are as follows:

Download File - Columns

Each line in the file (or row, in a spreadsheet) represents one sampling event and has the following information (columns, in a spreadsheet):

DataSourceName

Name of the organization/program that collected the data

DataSourceCode

Code associated with that organization/program.

StationID

Code identifying a monitoring station, or the centroid of a randomized sampling area

ActualStationID

Secondary identifier for sample locations within a randomized sampling area

Latitude_DD

Latitude of the station in decimal format, to 5 decimal places

Longitude_DD

Longitude of the station in decimal format, to 5 decimal places

SampleDate

Date when the sample was collected

SampleTime

Time when the sample was collected

ActivityDepth

Depth at which the sample was collected

ActivityDepthUnit

Unit for Activity Depth, meters (m) or feet (ft)

Characteristic

What information was measured/collected. Examples: flow, elevation, turbidity, Total Nitrogen, Secchi depth

ResultValue

Value of sample, usually a numeric value; may be raw field data or the result of laboratory analysis

ResultUnit

Unit for ResultValue (mg/l, % concentration, degrees F, for example)

ValueQualifier

Quality assurance code used to flag any caveats, qualifiers, or special conditions. [See definitions.](#)

ResultComment

Quality assurance comment, used to flag derived/calculated values, or data that is suspect because it is out of range

WaterbodyID

Identifier used on the Water Atlas websites for the water body where the sample was collected

WaterbodyName

Name of the water body where the sample was collected

In analyzing complex water quality data as applied to the specific needs at issue, four types of parameters, can form the basis of analyzing water decisions based on water quality data: for certain parameters (a) limitations of a lower quantity are preferred, like for that of Faecal Coliform (FC); (b) a higher quantity is preferred, such as for Dissolved Oxygen (DO); (c) an acceptable range is specified such as where a non-trivial acceptable limit is directly specified, like the ranges specified for pH levels; and (f) generic quantities are outlined, which occurs where an acceptable limit is generally unknown and contextual, like temperature.² Likewise, end users should be informed of high levels such as in the context

¹ Orange County wateratlas, Data Download Help Documentation, <https://orange.wateratlas.usf.edu/data-download/beta/help/>; CHNEP wateratlas, Data Download (BETA), available at: <https://dev.chnep.wateratlas.usf.edu/data-download/beta/request/1106>

² Ellis, Jason, Biplav Srivastava, Rachel Bellamy, and Andy Aaron. "Water advisor-a data-driven, multi-modal, contextual assistant to help with water usage decisions." In Proceedings of the AAAI Conference on Artificial Intelligence, vol. 32, no. 1. 2018.

of drinking water, where parameters of dissolved oxygen, pH, FC-Faecal Coliform,³ and Chromium⁴ should be able to be visualized overtime and if applicable, values exceeding or out of range of safe limits should be highlighted for the user.⁵ A review of these parameters and the information necessary for their analysis follows in conjunction with an examination of the dataset provided for this problem that identifies whether or not the foregoing information is available along with metrics relevant to evaluating the predictions of the models of the two classification methods selected for this question by our group.

1. **Background:** Microbial testing is usually limited to indicator organisms as an index of faecal contamination or to measure the efficiency of control measures.
 - a. The use of indicator organisms as a hint of faecal pollution is established practice. The criteria determined for such organisms are
 - i. (i) they should not be pathogens themselves,
 - ii. (ii) they should be universally present in human/animal faeces,
 - iii. (iii) they should not multiply in natural waters,
 - iv. (iv) they should be preserved in water in a similar way to faecal pathogens,
 - v. (v) they should be present in larger numbers than faecal pathogens,
 - vi. (vi) they should respond to treatment processes in a similar way to faecal pathogens and
 - vii. (vii) they should be easily detected by simple and inexpensive methods.
 1. It has become evident that no one indicator fulfils all of the above criteria. The shortcomings
2. **Total coliform bacteria.** These bacteria include a wide variety of aerobic and facultatively Gram-negative, anaerobic, non-spore-forming bacilli. *E. coli* and thermotolerant coliforms are a subgroup of the total coliform group capable of fermenting lactose at higher temperatures. Conventionally, coliform bacteria were considered to fit into the genera *Escherichia*, *Citrobacter*, *Klebsiella* and *Enterobacter*, but the group is heterogeneous and includes a range of genera, like *Serratia* and *Hafnia*. ***The total coliform includes both faecal as well as environmental species.*** Total coliforms include microbes that can survive and grow in water. They are therefore not used as an index of faecal pathogens. However, they can be used as indicator of treatment effectiveness/cleanliness/integrity of distribution systems as well as the potential presence of biofilms. Total coliform bacteria excluding *E. coli* occur in sewage as well as natural waters. Some of these total coliform bacteria are excreted in human and animal

³ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at pp. 145-46 ("*Escherichia coli* and thermotolerant coliform bacteria. *E. coli* is recognized as the most suitable index with respect to faecal contamination as it provides evidence of the latest faecal contamination. Its detection should lead to deliberation of further action, like additional sampling and investigation. Total coliform bacteria capable of fermenting lactose at 44– 45 ° C are called thermotolerant coliforms. The predominant genus normally present is *Escherichia*. Other thermotolerant coliform include *Citrobacter*, *Klebsiella* and *Enterobacter*. *E. coli* is present in large numbers in human and animal faeces and is rarely found in the water bodies in the absence of faecal pollution, although it may grow in tropical soils.")

⁴ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 118 ("*Chromium* is widely present in the earth's crust. It exists in oxidation states of + 2 to + 6. Chromium and its salts are widely used in catalysts, leather tanning, pigments, paints, fungicides, ceramics, glass, photography, chrome alloy and electroplating, and corrosion control. Ingestion of 1– 5 g of 'chromate' results in severe acute effects including gastrointestinal disorders, convulsions, haemorrhagic diathesis and death (WHO, 2003g). Many parts of the developing world, where chrome plating has been extensively used without treatment, have heavily contaminated groundwater.").

⁵ Sandha, Sandeep S., Biplav Srivastava, and Sukanya Randhawa. "The gangawatch mobile app to enable usage of water data in every day decisions integrating historical and real-time sensing data." *arXiv preprint arXiv:1701.08212* (2017).

- faeces, but many coliforms are able to multiply in water as well as soil environments. **The existence of total coliforms in stored water supplies and distribution systems indicates contamination through entrance of foreign material or biofilm formation. The presence of total coliforms after disinfection indicates inadequate treatment.**
3. **Escherichia coli and thermotolerant coliform bacteria.** *E. coli* is recognized as the most suitable index with respect to faecal contamination as it provides evidence of the latest faecal contamination. Its detection should lead to deliberation of further action, like additional sampling and investigation. Total coliform bacteria capable of fermenting lactose at 44–45 °C are called thermotolerant coliforms. The predominant genus normally present is *Escherichia*. Other thermotolerant coliform include *Citrobacter*, *Klebsiella* and *Enterobacter*. *E. coli* is present in large numbers in human and animal faeces and is rarely found in the water bodies in the absence of faecal pollution, although it may grow in tropical soils.⁶
 4. **EPA's Revised Total Coliform Rule:** The Revised Total Coliform Rule (RTCR), 78 FR 10269, February 13, 2013, Vol. 78, No. 30, establishes a maximum contaminant level (MCL) for *E. coli* and uses *E. coli* and total coliforms to initiate a “find and fix” approach to address fecal contamination that could enter into the distribution system.⁷
 - a. Routine Sampling Requirements:
 - i. ► Total coliform samples must be collected by PWSs at sites which are representative of water quality throughout the distribution system according to a written sample siting plan subject to state review and revision.
 - ii. ► For PWSs collecting more than one sample per month, collect total coliform samples at regular intervals throughout the month, except that ground water systems serving 4,900 or fewer people may collect all required samples on a single day if the samples are taken from different sites.
 - iii. ► Each total coliform-positive (TC+) routine sample must be tested for the presence of *E. coli*.
 - iv. ► If any TC+ sample is also *E. coli*-positive (EC+), then the EC+ sample result must be reported to the state by the end of the day that the PWS is notified.
 - v. ► If any routine sample is TC+, repeat samples are required. – PWSs on quarterly or annual monitoring must take a minimum of three additional routine samples (known as additional routine monitoring) the month following a TC+ routine or repeat sample.
 - vi. ► Reduced monitoring may be available for PWSs using only ground water and serving 1,000 or fewer persons that meet certain additional PWS criteria.
 - b. Level 1 Assessment is triggered if any one of the following occurs:
 1. ► A PWS collecting fewer than 40 samples per month has 2 or more TC+ routine/ repeat samples in the same month.
 2. ► A PWS collecting at least 40 samples per month has greater than 5.0 percent of the routine/repeat samples in the same month that are TC+.
 3. ► A PWS fails to take every required repeat sample after any single TC+ sample.
 - c. Level 2 Assessment is triggered if any one of the following occurs:
 1. ► A PWS incurs an *E. coli* MCL violation.

⁶ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at pp. 145-46.

⁷ US EPA, Revised Total Coliform Rule: A Quick Reference Guide (2013), available at: <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100K9MP.txt>

2. ► A PWS has a second Level 1 Assessment within a rolling 12-month period.
3. ► A PWS on state-approved annual monitoring has a Level 1 Assessment trigger in 2 consecutive years.
5. **Heterotrophic plate counts.** The heterotrophic plate counts (HPCs) detect a variety of heterotrophic micro-organisms including bacteria and fungi that are sensitive to disinfection. Hence, the test is useful for monitoring treatment/disinfectant efficiency. Heterotrophic plate counts can include 'opportunistic' pathogens like *Acinetobacter*, *Flavobacterium*, *Klebsiella*, *Moraxella*, *Aeromonas*, *Serratia*, *Pseudomonas*, and *Xanthomonas*.
6. **Intestinal enterococci.** Intestinal enterococci are group within larger group of microbes called faecal streptococci. Intestinal enterococci consist of the species *Enterococcus faecalis*, *E. durans*, *E. faecium* as well as *E. hirae*. The presence of intestinal enterococci indicates recent faecal contamination.
7. ***Clostridium perfringens*.** *Clostridium* species produce spores that are extremely resistant to unfavourable conditions in water. Hence, they have been proposed as an index of enteric viruses and protozoa.
8. **Coliphages.** Bacteriophages are viruses that infect and replicate in bacteria. Coliphages use *E. coli* and other related species as hosts. Hence, there is high possibility of release from faeces of humans as well as other warm-blooded animals.
9. ***Bacteroides fragilis* phages.** The bacterial genus *Bacteroides* is present in the human gastrointestinal tract in numbers greater than *E. coli*. *Bacteroides* are inactivated by environmental oxygen, but *Bacteroides* bacteriophages are resistant to this. Hence, *Bacteroides* bacteriophages have been suggested as a possible index of faecal contamination.
10. **Enteric viruses.** Well known viruses that infect the human gastrointestinal tract, conveyed by the faecal-oral route, include the enteroviruses, orthoreoviruses, rotaviruses, astroviruses, enteric adenoviruses, caliciviruses and hepatitis A and E viruses. The survival of faecal bacteria during treatment differs noticeably from that of enteric viruses. Hence, water should be monitored for contamination by enteric viruses. Enteric viruses are excreted by worldwide by humans in huge numbers. However, the presence of different viruses varies due to variations in rates of infection as well as excretion. • • • • •

By way of background, the pH value of a water source is a measure of its acidity or alkalinity.⁸ pH level is defined as the negative logarithm of the molar concentration of hydrogen ions: $pH = -\log_{10}[H^+]$.⁹ A pH less than 7 is considered as acidic¹⁰; water with a low pH is said to be acidic.¹¹ A pH of more than 7 is considered as alkaline.¹² In contrast, a pH of 7 is considered to be neutral¹³

pH measure Background

The pH value of a water source is a measure of its acidity or alkalinity. The pH level is a measurement of the activity of the hydrogen atom, because the hydrogen activity is a good representation of the acidity or alkalinity of the water.¹⁴

- ✚ pH is a measure of the quantity of free hydrogen ions in water.
- ✚ It is defined as the negative logarithm of the molar concentration of hydrogen ions.¹⁵
- ✚ $pH = -\log_{10}[H^+]$.
- ⇒ A pH less than 7 is considered as acidic.¹⁶
 - Water with a low pH is said to be acidic.¹⁷
- ⇒ A pH of 7 is considered to be neutral¹⁸
- ⇒ a pH of more than 7 is considered as alkaline.¹⁹
 - **water with a high pH is basic, or alkaline.**²⁰
- ⇒ Measurement of pH is done by pH metre and pH paper. pH paper provides indicative values whereas the pH metre provides accurate pH values.²¹
- ⇒ Pure water would have a pH of 7.0, but water sources and precipitation tend to be slightly acidic, due to contaminants that are in the water.²²
- ⇒ Surface water typically has a pH value between 6.5 and 8.5, and groundwater tends to have a pH between 6.0 and 8.5.²³
- ⇒ The pH of a water source can vary naturally.

⁸ SDWF, TDS and pH Fact Sheet, <https://www.safewater.org/fact-sheets-1/2017/1/23/tds-and-ph> (hereinafter, "TDS and pH Fact Sheet")

⁹ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at pp. 125-27

¹⁰ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 126

¹¹ TDS and pH Fact Sheet

¹² Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 126

¹³ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 126

¹⁴ SDWF, TDS and pH Fact Sheet, <https://www.safewater.org/fact-sheets-1/2017/1/23/tds-and-ph> (hereinafter, "TDS and pH Fact Sheet")

¹⁵ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at pp. 125-27

¹⁶ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 126

¹⁷ TDS and pH Fact Sheet

¹⁸ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 126

¹⁹ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 126

²⁰ TDS and pH Fact Sheet

²¹ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 126

²² TDS and pH Fact Sheet

²³ TDS and pH Fact Sheet

- Some types of rock and soil, such as limestone, can neutralize acid more effectively than other types of rock and soil, such as granite.
- Or, when there are a large number of plants growing in a lake or river, they release carbon dioxide when they die and decompose. When the carbon dioxide mixes with the water, a weak carbonic acid is formed; this can then cause the pH of the water body to decrease.²⁴

Analysis of Features to Test Accuracy and Reliability of Classification Models' Respective Predictions:

- Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (PPM).²⁵
- **(1) Acidity increases as pH values decrease; low pH → increased acidification**
 - **Background:** The pH of water affects the solubility of many toxic and nutritive chemicals; the availability of these substances to aquatic organisms is therefore affected.
 - As acidity increases, most metals become more water soluble and more toxic. Toxicity of cyanides and sulfides also increases with a decrease in pH (increase in acidity). Ammonia, however, becomes more toxic with only a slight increase in pH.²⁶
 - The pH also affects corrosivity of the water: the lower the pH higher the potential level of corrosion.²⁷
 - **Background cont'd:** Acidity increases as pH values decrease and alkalinity increases as pH values increase. Most natural waters are buffered by a carbon dioxide-bicarbonate system because the carbon dioxide in the atmosphere serves as a source of carbonic acid.

$$\text{H}_2\text{CO}_2 \rightarrow \text{HCO}_3 + \text{H} + \text{pK} \sim 7.5$$
 - This reaction tends to keep pH of most waters around 7–7.5, unless large amounts of acid or base are added to the water
 - **(A) **Look for high values of or increases to the values of measured levels of aluminum, lead, and mercury – since higher levels can indicate low pH values**
 - ****Note:** Aluminum (ug/l); Lead – Dissolved (ug/l) and Lead (ug/l); and Mercury (ug/l) are all features available within the data source

EPA Listed Contaminant ²⁸	EPA Limitation (MCL or TT (mg/L)):	Regulatory Source	Additional Notes:
			Definitions • 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 and are non-enforceable public health goals. • Maximum Contaminant Level (MCL): The highest level of a contaminant that is

²⁴ TDS and pH Fact Sheet

²⁵ EPA, National Primary Drinking Water Regulations, n. 2, available at: <https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations>

²⁶ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at pp. 130-31

²⁷ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 127

²⁸ Source for the information set forth in the table is as follows: EPA, National Primary Drinking Water Regulations, available at: https://www.epa.gov/sites/default/files/2016-06/documents/npwdr_complete_table.pdf

			<p>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.</p> <p>• Maximum Residual Disinfectant Level Goal (MRDLG): The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.</p> <p>• Maximum Residual Disinfectant Level (MRDL): 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.</p> <p>• Treatment Technique (TT): A required process intended to reduce the level of a contaminant in drinking water.</p>
Aluminum	0.05 to 0.2 mg/L	Secondary Maximum Contaminant Level	
Lead	TT5; Action Level=0.015	MCL or TT (mg/L)-National Drinking Water Primary Regulations	Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10 percent of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.
Mercury (inorganic)	0.002	MCL or TT (mg/L)-National Drinking Water Primary Regulations	

- Support: As the pH decreases and the acidity increases, fewer and fewer organisms can survive.²⁹
 - Acidic water is synergistic, which means that a combination of a low pH and an increased concentration of certain substances is far more harmful than the sum of the parts.
 - For example, aluminum, lead, and mercury are potentially dangerous substances, but when the pH of the water source is already low, these substances can have extremely detrimental consequences for aquatic life.³⁰
 - (B)**Look for high values of Iron, Manganese, copper, lead and zinc – can indicate low pH values because of the increase in acidification the ion leaching of these chemicals present
 - Iron – Dissolved (mg/l) and Iron (ug/l); Manganese – Dissolved (mg/l) and Manganese (ug/l); Copper – Dissolved (mg/l) and Copper (ug/l); Lead – Dissolved (mg/l) and Lead

²⁹ TDS and pH Fact Sheet

³⁰ TDS and pH Fact Sheet

(ug/l); and Zinc (ug/l) are each parameters available to us for analysis from the CHNEP.WaterAtlas.org data source³¹

EPA Listed Contaminant ³²	EPA Limitation (MCL or TT (mg/L)):	Regulatory Source	Additional Notes:
Iron	0.3 mg/L	National Secondary Drinking Water Regulation	
Manganese	0.05 mg/L	National Secondary Drinking Water Regulation	
Copper	1.0 mg/L	National Secondary Drinking Water Regulation	
Zinc	5 mg/L	National Secondary Drinking Water Regulation	
Lead	TT; Action Level=0.015	National Primary Drinking Water Regulation	Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10 percent of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

- Support: While slightly acidic water is not dangerous, on its own, it can be quite dangerous when combined with other compounds. Water with a pH that is less than 6.5 can leach metal ions, including iron, manganese, copper, lead and zinc from plumbing fixtures and pipes. This, in return, can be quite dangerous.
 - On the other end of the pH scale, water that has a pH greater than 8.0 can be difficult to disinfect.
 - The World Health Organization recommends that the pH of the water be less than 8.0, because basic water does not allow for effective chlorination.
 - (C)**Look for high values of Barium compounds – can indicate low pH values
 - Barium (ug/l) is a parameter value available to us for analysis from the CHNEP.WaterAtlas.org data source³³

³¹ CHNEP wateratlas, Data Download (BETA): Download Files-Columns, available at: <https://dev.chnep.wateratlas.usf.edu/data-download/beta/request/1106> (Modify Selected Parameters: shows all available parameters)

³² Source for the information set forth in the table is as follows: EPA, National Primary Drinking Water Regulations, available at: https://www.epa.gov/sites/default/files/2016-06/documents/npwdr_complete_table.pdf

³³ CHNEP wateratlas, Data Download (BETA): Download Files-Columns, available at: <https://dev.chnep.wateratlas.usf.edu/data-download/beta/request/1106> (Modify Selected Parameters: shows all available parameters)

EPA Listed Contaminant ³⁴	EPA Limitation (MCL or TT (mg/L)):	Regulatory Source	Additional Notes:
Barium	2	MCL or TT (mg/L)-National Drinking Water Primary Regulations	See Definitions above

- Support: Barium → Igneous and sedimentary rocks contain barium as a trace element. Barium compounds are used in the rubber, electronics, plastics, textile, ceramic, glass, brick, paper, pharmaceuticals, cosmetics, steel, oil and gas industries. Barium in water normally comes from natural sources. **The solubility of barium compounds will increase as the pH level diminishes** (USEPA, 1985). Barium is not vital for human nutrition (Schroeder et al. , 1972). It causes vasoconstriction at higher concentrations (Stokinger, 1981a). Death may occur in a few hours/days depending on the dose/solubility of the barium salt (WHO, 2004a).³⁵
- (D)**Look for high values of Chlorine – can indicate low pH values
 - **??Are Chlorine and Chloride (mg/l) comparable?? Chloride (mg/l)??**
 - **Answer: No --** Even though these two pose quite the tongue twister, Chlorine and Chloride could not be more different. They are similar to siblings that share the same DNA but remain two entirely different people. The limitations for both are set forth below.³⁶ The yellow highlighted measures and limits should be analyzed.

EPA Listed Contaminant ³⁷	EPA Limitation (MCL or TT (mg/L)):	Regulatory Source	Additional Notes:
Chloride	250 mg/L	Secondary Maximum Contaminant Level: NATIONAL SECONDARY DRINKING WATER REGULATION	See Definitions above
Chlorine dioxide (as ClO ₂)	MRDL=0.8	MCL or TT (mg/L)-National Drinking Water Primary Regulations	See Definitions above
Chlorine	MRDL=4.0	MCL or TT	See Definitions above

³⁴ Source for the information set forth in the table is as follows: EPA, National Primary Drinking Water Regulations, available at: https://www.epa.gov/sites/default/files/2016-06/documents/npwdr_complete_table.pdf

³⁵ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 115.

³⁶ <https://www.eldoradosprings.com/blog/chlorine-vs.-chloride>

³⁷ Source for the information set forth in the table is as follows: EPA, National Primary Drinking Water Regulations, available at: https://www.epa.gov/sites/default/files/2016-06/documents/npwdr_complete_table.pdf; see also CalEPA has established a chronic reference exposure level of 0.00006 milligrams per cubic meter (mg/m³) based on respiratory epithelial lesions in rats. The CalEPA reference exposure level is a concentration at or below which adverse health effects are not likely to occur. EPA, Chlorine, Hazard Summary, 7782-50-5, available at: <https://www.epa.gov/sites/default/files/2016-09/documents/chlorine.pdf>

(as Cl ₂)		(mg/L)-National Drinking Water Primary Regulations	
Chloramines (as Cl ₂)	MRDL=4.0	MCL or TT (mg/L)-National Drinking Water Primary Regulations	<u>See Definitions above</u>
Carbon tetrachloride	0.005	MCL or TT (mg/L)-National Drinking Water Primary Regulations	<u>See Definitions above</u>
Chlorite	1.0	MCL or TT (mg/L)-National Drinking Water Primary Regulations	<u>See Definitions above</u>

- **Support:** Chlorine → Chlorine is used as a disinfectant and bleach in households, industries and swimming pools. It reacts with water to form hypochlorous acid and hypochlorites. **At a pH above 4.0, little molecular chlorine exists in dilute water.** It reacts with ammonia and amines to form chloramines. A residual chloride of 0.2– 1 mg/l is maintained to act on microbes that could enter water during distribution and storage. An intake of bleach results in a burning sensation in the mouth and throat as well as irritation of the esophagus.³⁸
 - (E)**Look for high values of cyanides and sulfides – can indicate low pH values
 - **??Does this category of sulfides include "Sulfur, sulfate (SO₄) as SO₄ (mg/l)"???**
Answer: Yes, the inclusion of these categories may indicate an oxidation of sulfides in the water

EPA Listed Contaminant ³⁹	EPA Limitation (MCL or TT (mg/L)):	Regulatory Source	Additional Notes:
Cyanide (as free cyanide)	0.2 MCL or TT (mg/L)	Secondary Maximum Level: NATIONAL SECONDARY DRINKING WATER REGULATION	<u>See Definitions above</u>
Sulfate	250 mg/L	Secondary Maximum Level: NATIONAL SECONDARY	<u>See Definitions above</u>

³⁸ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 117.

³⁹ Source for the information set forth in the table is as follows: EPA, National Primary Drinking Water Regulations, available at: https://www.epa.gov/sites/default/files/2016-06/documents/npwdr_complete_table.pdf; see also CalEPA has established a chronic reference exposure level of 0.00006 milligrams per cubic meter (mg/m³) based on respiratory epithelial lesions in rats. The CalEPA reference exposure level is a concentration at or below which adverse health effects are not likely to occur. EPA, Chlorine, Hazard Summary, 7782-50-5, available at: <https://www.epa.gov/sites/default/files/2016-09/documents/chlorine.pdf>

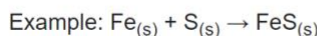
		DRINKING WATER REGULATION	
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- Support: Toxicity of cyanides and sulfides also increases with a decrease in pH (increase in acidity).⁴⁰
- Sulfur is a soft, bright yellow element also known as brimstone because it will burn, producing sulfur dioxide (SO₂) and giving off a characteristic odor.
- Sulfur has many oxidation states in compounds but the most common and of interest to us are -2, -1, and +6. If there is very little oxygen available, sulfur will be reduced to an oxidation state of -2 or -1 and form sulfide compounds. In pyrite (FeS₂) the sulfur has an oxidation state of -1 while in hydrogen sulfide (H₂S) the sulfur has an oxidation state of -2. If there is abundant oxygen available, sulfur will be oxidized to an oxidation state of +6 and form sulfate (SO₄⁼) compounds such as gypsum (CaSO₄•2H₂O) and sulfuric acid (H₂SO₄).⁴¹
- *Sulfides are stable in low oxygen environments whereas sulfates are stable in high oxygen environments. Things get interesting when sulfides are exposed to a high oxygen environment or when sulfates move into a low oxygen environment because in changing to a more stable form in the new environment, they can end up in water.*
- *Sulfides, with one important exception, are very insoluble in water. However, should they be exposed to the air, they can weather, oxidize, and release sulfate anions into water.* Pyrite, a sulfide mineral, is commonly associated with coal. Coal mining breaks up the pyrite where much of it ends up in rock waste piles (locally known as culm banks) where it is exposed to air and water. The pyrite breaks down in this oxygen-rich environment, releasing large amounts of dissolved iron and sulfuric acid into the mine water; the sulfuric acid (H₂SO₄) is the acid in acid mine drainage. The acid quickly and completely dissociates in water to produce H⁺ (the acid part) and the sulfate anion (SO₄⁼). The acid can be neutralized but the sulfate remains in solution.
- Elevated levels of sulfates are typically associated with elevated levels of Sodium, calcium, magnesium, high Alkalinity, and in some cases brine or very salty water.

Preparation [\[edit \]](#)

Sulfide compounds can be prepared in several different ways:^[7]

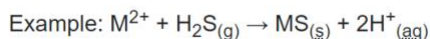
1. Direct combination of elements:



2. Reduction of a sulfate:



3. Precipitation of an insoluble sulfide:



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⁴⁰ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at pp. 130-31

⁴¹ Water Research Center; Get Informed| Sulfate, Hydrogen Sulfide, Sulfate-Reducing Bacteria, and Sulfur, <https://www.knowyourh2o.com/indoor-6/sulfur-hydrogen-sulfide-sulfate-and-sulfate-reducing-bacteria>

⁴² Wikipedia, Sulfide, available at: <https://en.wikipedia.org/wiki/Sulfide>

• (2) Alkalinity increases as pH values increase.⁴³

- Background: An alkali is a basic, ionic salt of an alkaline earth or alkali metal element. **Alkalinity measures the ability of a solution to neutralize acids.** Alkalinity is sometimes incorrectly used to mean basicity. A base is a substance that ionizes to give a hydroxide ion.⁴⁴
- Alkalinity value parameters available to us for analysis from the CHNEP.WaterAtlas.org data source⁴⁵ include: Alkalinity, Carbonate as CaCO₃ (mg/l); Alkalinity, Total (Dissolved) - Dissolved (mg/l CaCO₃); and Alkalinity, Total (mg/l CaCO₃)
- In the many waters data set, alkalinity as measured in the samples' valueQualifier field are indicated as presented in units of Total (total hydroxide+carbonate+bicarbonate) (476 entries); mg/l (19 entries); or this unit is blank (57 entries).
- (A) ****Look for higher values of carbonate, borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, and sulfide to predict higher levels of pH**
 - we have values for silicate [Silicate (mg/l)]
 - **?? is borate comparable to Boron (ug/l)?? Answer: Yes**
 - Boron, the fifth element in the periodic table, does not occur in nature in its elemental form. Rather, boron combines with oxygen as a salt or ester of boric acid. There are more than 200 minerals that contain boric oxide but relatively few that are of commercial significance. In fact, three minerals represent almost 90% of the borates used by industry: borax, a sodium borate; ulexite, a sodium-calcium borate; and colemanite, a calcium borate.⁴⁶
 - Refined borates are usually sold on the basis of their B₂O₃ content and defined by their water or hydration content; borax pentahydrate or “5 mol,” borax decahydrate or “10 mol,” and boric acid are the three most commonly sold borate products.
 - Support: Carbonate, borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, sulfide and conjugate bases of some organic acids contribute to the alkalinity of water. **Alkalinity is measured in mEq/L (milliequivalent per litre) or ppm.** As rain falls on the earth, water droplets become saturated with carbon dioxide and the pH is lowered. The carbon dioxide concentration will increase due to bacterial processes in the soils as they react with rock formations containing carbonates, resulting in increased alkalinity, pH and hardness.

⁴³ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 128

⁴⁴ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at pp. 130-31

⁴⁵ CHNEP wateratlas, Data Download (BETA): Download Files-Columns, available at: <https://dev.chnep.wateratlas.usf.edu/data-download/beta/request/1106> (Modify Selected Parameters: shows all available parameters)

⁴⁶ Kirk-Othmer Encyclopedia of Chemical Technology. Copyright John Wiley & Sons, Inc.

- (B)**Look for marginally higher values of Ammonia (or marginal increases to Ammonia values), which indicate increases in pH values
 - Ammonia value parameters available to us for analysis from the CHNEP.WaterAtlas.org data source⁴⁷ include: ammonia (NH₃) as NH₃ (ug/l); Nitrogen, Ammonia + Ammonium as N (ug/l); and Nitrogen, ammonia as N (ug/l)
 - Support: Ammonia, however, becomes more toxic with only a slight increase in pH.⁴⁸
 - Support: Ammonia → In the context of water pollution, the term 'ammonia' includes nonionized form (NH₃) as well as the ammonium cation (NH₄⁺) unless otherwise stated. Its threshold odor concentration in water is about 1.5 mg/l. In water, ammonia forms the ammonium cation and hydroxyl ions. The extent of ionization depends on the pH, the temperature, and the concentration of dissolved salts in the water. Ammonia is toxic if the intake is more than the capacity to detoxify (WHO, 2003c).⁴⁹
- (3) Increases in CO₃²⁻ levels should be monitored to ensure that increases in Alkalinity levels are not being masked
 - Alkalinity value parameters available to us for analysis from the WaterAtlas.org data source⁵⁰ include: Alkalinity, Carbonate as CaCO₃ (mg/l); Alkalinity, Total (Dissolved) - Dissolved (mg/l CaCO₃); and Alkalinity, Total (mg/l CaCO₃)
 - Support: The natural buffering capacity of a stream may mask the presence of acidic or basic pollutants. Therefore, simply measuring a stream's pH may not be sufficient. For a more complete assessment of water quality, most scientists also measure stream water alkalinity. Alkalinity is measured to determine the ability of a stream to resist changes in pH. That is to say alkalinity allows scientists to determine a stream's buffering capacity.
 - Alkalinity values of 20-200 ppm are common in freshwater ecosystems. Alkalinity levels below 10 ppm indicate poorly buffered streams. These streams are the least capable of resisting changes in pH, therefore they are most susceptible to problems which occur as a result of acidic pollutants.⁵¹
- Alkalinity results from the dissolution of calcium carbonate (CaCO₃) from limestone bedrock which is eroded during the natural processes of weathering.
 - The carbon dioxide (CO₂) released from the calcium carbonate into the stream water undergoes several equilibrium reactions.
 - Equilibrium reactions are those that go in either direction, depending on what compounds are present in the largest concentrations.
 - The following set of reactions is referred to as the bicarbonate **buffering** system:
$$\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \leftrightarrow 2\text{H}^+ + \text{CO}_3^{2-}$$
 - As depicted in the above set of reactions, carbonate (CO₃²⁻) and bicarbonate (HCO₃⁻) ions act as hydrogen ion absorbers. This causes the reactions of the

⁴⁷ CHNEP wateratlas, Data Download (BETA): Download Files-Columns, available at: <https://dev.chnep.wateratlas.usf.edu/data-download/beta/request/1106> (Modify Selected Parameters: shows all available parameters)

⁴⁸ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at pp. 130-31

⁴⁹ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 114

⁵⁰ CHNEP wateratlas, Data Download (BETA): Download Files-Columns, available at: <https://dev.chnep.wateratlas.usf.edu/data-download/beta/request/1106> (Modify Selected Parameters: shows all available parameters)

⁵¹ Wheeling Jesuit University/NASA-supported Classroom of the Future, Exploring the Environment: Water Quality-- Water Quality Assessment: Chemical: Alkalinity (last updated Nov. 10, 2004), <http://www.cotf.edu/ete/modules/waterq3/WQassess3b.html>

bicarbonate buffering system to shift left or right while maintaining a relatively constant pH. If hydrogen ions are added to the solution, they combine with available bicarbonate or carbonate ions, causing the reactions to shift to the left and eventually liberate carbon dioxide and water molecules. **The addition of carbonate to the solution causes the hydrogen ions to be occupied and shifts the reactions to the right. In this way, an alkaline stream with a large buffering capacity is able to "hold" more acidic pollutant without displaying a significant decrease in pH.**⁵²

- **(4) High level of TDS → indicates a low pH**

- ****High levels of (combinations of) calcium, magnesium, potassium and sodium and carbonates, nitrates, bicarbonates, chlorides and sulfates may indicate a low pH level**
- Value parameters available to us for analysis from the CHNEP.WaterAtlas.org data source⁵³ include the following for this check:
 - for calcium, magnesium, potassium and sodium → Calcium - Dissolved (mg/l) and Calcium (mg/l); Magnesium - Dissolved (mg/l) and Magnesium (mg/l); Potassium (mg/l); Sodium - Dissolved (mg/l) and Sodium (mg/l)
 - for nitrates → Nitrogen, Nitrate (NO₃) as N (ug/l) and Nitrogen, Nitrite + Nitrate as N (ug/l); Nitrogen, Nitrate (NO₃) as N (ug/l), Nitrogen, Nitrite (NO₂) as N (ug/l), and Nitrogen, Nitrite + Nitrate as N (ug/l); Nitrogen, ammonia (NH₃) as NH₃ (ug/l), Nitrogen, Ammonia + Ammonium as N (ug/l), and Nitrogen, ammonia as N (ug/l)
 - for sulfates → Sulfur, sulfate (SO₄) as SO₄ (mg/l)
 - for chlorides → Chloride (mg/l)
 - for sulfates → Sulfur, sulfate (SO₄) as SO₄ (mg/l)
- **Support: When a water source has a high level of TDS or a low pH, it is likely that there are other harmful contaminants in the water.**⁵⁴
 - TDS stands for total dissolved solids, and TDS represents the total concentration of dissolved substances in water. TDS is made up of inorganic salts, as well as a small amount of organic matter. **Common inorganic salts that can be found in water include calcium, magnesium, potassium and sodium, which are all cations, and carbonates, nitrates, bicarbonates, chlorides and sulfates, which are all anions.** Cations are positively charged ions and anions are negatively charged ions.
 - The United States Environmental Protection Agency (EPA), which is responsible for drinking water regulations in the United States, includes TDS as a secondary standard, meaning that it is a voluntary guideline in the United States. While the United States set legal standards for many harmful substances, TDS, along with other contaminants that cause aesthetic, cosmetic and technical effects, has only a guideline.

Level of TDS (milligrams per litre)	Rating
Less than 300	Excellent
300 - 600	Good
600 - 900	Fair
900 - 1,200	Poor
Above 1,200	Unacceptable

Taste of Water with Different TDS Concentrations;
http://www.who.int/water_sanitation_health/dwc

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⁵² Wheeling Jesuit University/NASA-supported Classroom of the Future, Exploring the Environment: Water Quality-- Water Quality Assessment: Chemical: Alkalinity (last updated Nov. 10, 2004), <http://www.cotf.edu/ete/modules/waterq3/WQassess3b.html>

⁵³ CHNEP wateratlas, Data Download (BETA): Download Files-Columns, available at: <https://dev.chnep.wateratlas.usf.edu/data-download/beta/request/1106> (Modify Selected Parameters: shows all available parameters)

⁵⁴ TDS and pH Fact Sheet

⁵⁵ TDS and pH Fact Sheet

- If something is happening to a water, such as pollution, chances are both TDS and pH levels will change so keeping track of those changes can act as an early warning signal that something is happening to the water. For these reasons, it is important to monitor the TDS and pH levels, so that if they change, action can be taken immediately.
 - **Nitrates are a form of nitrogen, which is found in several different forms in terrestrial and aquatic ecosystems. These forms of nitrogen include ammonia (NH₃), nitrates (NO₃), and nitrites (NO₂).** Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. **Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators.** Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L) or higher) under certain conditions. The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L); in the effluent of wastewater treatment plants, it can range up to 30 mg/L.
 - Sources of nitrates include wastewater treatment plants, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors.⁵⁶
 - **Sulfates occur naturally in numerous minerals, including barite (BaSO₄), epsomite (MgSO₄·7H₂O) and gypsum (CaSO₄·2H₂O)** (Greenwood & Earnshaw, 1984). These dissolved minerals contribute to the mineral content of many drinking-waters.⁵⁷
 - Reported taste threshold concentrations in drinking-water are 250–500 mg/litre (median 350 mg/litre) for sodium sulfate, 250–1000 mg/litre (median 525 mg/litre) for calcium sulfate and 400–600 mg/litre (median 525 mg/litre) for magnesium sulfate (NAS, 1977). In a survey of 10–20 people, the median concentrations that could be detected by taste were 237, 370 and 419 mg/litre for the sodium, calcium and magnesium salts, respectively (Whipple, 1907). Concentrations of sulfates at which 50% of panel members considered the water to have an “offensive taste” were approximately 1000 and 850 mg/litre for calcium and magnesium sulfate, respectively (Zoeteman, 1980).⁵⁸
- **(5) An increase in CO₂ concentration will lower pH and a decrease in CO₂ will raise the pH**
 - **Support:** The pH in natural waters is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system. An increase in CO₂ concentration will lower pH and a decrease in CO₂ will raise the pH.
 - **(6) Color**
 - **A Characteristic of Color is indicated in 53 samples for which 2 of these 53 samples indicate the Result Unit is measured in PCU.**
 - Color is commonly present in surface water due to the absorption of color released by humus but absent in groundwater. Apart from humus, the presence of algae, soil particles and reflection of the environmental setting contributed to water bodies. With a rapidly changing

⁵⁶ EPA, Water: Monitoring & Assessment, at § 5.7: Nitrates, available at: <https://archive.epa.gov/water/archive/web/html/vms57.html>

⁵⁷ Sulfate in Drinking-water: Background document for development of WHO Guidelines for Drinking-water Quality World Health Organization 2004, available at: https://www.who.int/water_sanitation_health/dwq/chemicals/sulfate.pdf

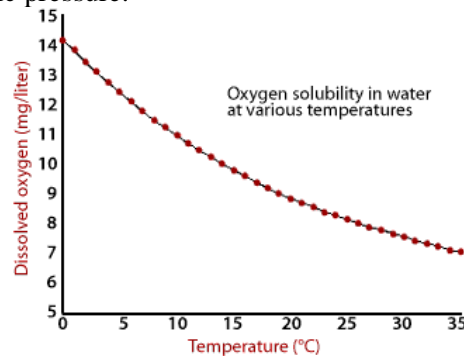
⁵⁸ Id.

environment, color can be observed in groundwater due to entry of effluents from industries. Color is a direct indicator of imbalance in the environment and an indication of contamination.⁵⁹

- Color in natural settings is not considered for recording and comparison of water quality. Color contributed by dissolved solids after filtering out suspended matter is called true color. True color is measured by comparison with standardized colored material. Color comparison with a series of standards is used for direct comparison of filtered water to remove apparent color. Results are expressed as true color units (TCUs), where one unit is equivalent to the color produced by 1 mg/l of platinum in the form of chloroplatinate ions. In fieldwork, instruments employing glass disks that are calibrated with color standards are used. True color units are used for only yellowish-brown hues, which is the color formed during degradation of humus in nature. For colors other than yellowish brown hues arising from industry, special photometric techniques are used. The analysis report is expressed at pH 7.6 as well as at the original pH in terms of dominant wavelength, hue (e.g., blue, blue-green, etc.), luminance (as a percentage) and purity (as a percentage).⁶⁰

• (7) Temperature increases – N/A bc we do not have these values

- Temperature will affect the carbon dioxide–bicarbonate–carbonate equilibrium, thereby altering pH.
- In pure water, pH will decrease by about 0.45 with increase in 25° C.⁶¹
- Oxygen is essential for the survival of nearly every living thing — even those living in water. The two main sources of dissolved oxygen in stream water are the atmosphere and aquatic plants. Atmospheric oxygen is mixed into stream water as waves crash along the riffles. Aquatic plants introduce oxygen into stream water as a byproduct of photosynthesis. The amount of oxygen that can dissolve in water is limited by physical conditions such as temperature and atmospheric pressure.



- One unit of measure of dissolved oxygen in water is parts per million (ppm), which is the number of oxygen (O₂) molecules per million total molecules in a sample. Calculating the percent saturation is another way to analyze dissolved oxygen levels. Percent saturation is the measured dissolved oxygen level divided by the greatest amount of oxygen that the water can hold at that particular temperature and atmospheric pressure, then multiplied by 100.
 - Dissolved oxygen levels below 3 ppm are stressful to most aquatic organisms. Levels below 2 ppm will not support fish at all.

⁵⁹ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 111

⁶⁰ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 111

⁶¹ Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 127

- Low dissolved oxygen levels can be the result of elevated temperature and thus the inability of the water to hold the available oxygen. **Low dissolved oxygen levels can also indicate an excessive demand on the oxygen in the system.** Some pollutants such as acid mine drainage produce direct chemical demands on oxygen in the water for certain oxidation-reduction reactions. Other pollutants such as sewage or agricultural runoff result in the build up of organic matter and the consumption of dissolved oxygen by microbial decomposers as they break down the organic matter.
- The pH of drinking water lies within the range 6.5– 8.5.⁶²

- **(8) Outstanding Task: Exclude problematic samples due to collection issues, etc.**

- Using the Water Atlas Quality Assurance Code Definitions, we are informed that we also need to check which entries are unique to the data provider by looking for a value in the ValueQualifier/QA column of the dataset that indicates that an issue with the quality of the sample or the process by which the sample was collected has been noted, which entries should be considered in determining whether any samples should be excluded prior to the models' applications to the dataset.⁶³

Samples with Value Qualifiers indicating exclusion as input is warranted:

⁶² Chandrappa, Ramesha, and Das, Diganta B. 2014. Sustainable Water Engineering: Theory and Practice. Somerset: John Wiley & Sons, Incorporated., at p. 127

⁶³ See Quality Assurance Code Definitions Table, [file title: WA-Quality-Assurance-Code-Definitions – file path: sample-code\common-data\water]

Fawad Kirmani, Marilyn E. Gartley, and Vedant Khandelwal
CSCE 590_Fall 2021_QuizTwo_Group Answers_FU_v.2

ValueQualifier Column Code	Meaning	Exclude: Yes or No	Notes:
A	Value reported is the mean of two or more determinations	Y	
AQ	Value reported is the mean of two or more determinations; Sample held beyond accepted holding time	Y	
B	Results based upon colony counts outside the acceptable range	Y	
BQ	Results based upon colony counts outside the acceptable range; Sample held beyond accepted holding time	Y	
J	Estimated Value questionable or not accurate	Y	
I#	Result value is between the laboratory method detection limit and the laboratory practical quantitation limit; see Project Managers Remarks	If we do not have these remarks, then exclude	the terms associated with Code I are being interpreted in a manner consistent with the following defined terms as used by the U.S. Environmental Protection Agency according to publications from the the Rocky Mountain Research Station, the U. S. Forest Service, and the U. S. Department of Agriculture. Tim Fegel, Charles Rhoades & Banning Starr, Summary of Method Detection Limit Testing for the Rocky Mountain Research Station Biogeochemistry Laboratory, published by the Rocky Mountain Research Station, U. S. Forest Service & U. S. Department of Agriculture (March 2020)
I>	Result value is between the laboratory method detection limit and the laboratory practical quantitation limit.	N	
IG	I: Result value is between the laboratory method detection limit and the laboratory practical quantitation limit and then G has three entries based on the Data Source: LAKECO_SWWQ: Greater than result value; SWFWMD_HYDRO-Site destroyed; PINELLAS, SEMCO_WRAD: Value reported is the maximum of two or more determinations	Y	Check the PINELLAS, SEMCO_WRAD G values
IJ	I code and L: Could not locate site	Y	
IQ	I and Q: sample held beyond accepted holding Time	Y	
IQ#	(based on above)	Y	
JI	J: Estimated value questionable or not accurate	Y	
JQ	J: Estimated value questionable or not accurate	Y	
JQI	J: Estimated value questionable or not accurate	Y	
JT	J: Estimated value questionable or not accurate	Y	
K	K: Actual value is known to be less than the value given	Y	
KQ	K: Actual value is known to be less than the value given; Q: sample held beyond accepted holding Time	Y	
	**Had to just start doing single codes to be applied to all codes containing the specified letter as long as the letter is not used in a combined delineated Value Code		
L	L: Actual value is known to be greater than the value given	Y	Exclude all entries with L
P	P with PINELLAS: Bacteria were present in a sample; P with SEMCO_WRAD: Too numerous to count; P with SJRWMD_WQ: Presumptive evidence of presence of material; P with SWFWMD_HYDRO: Gage Missing	Y	
Q	Q: Sample held beyond accepted holding time	Y	
S	S: Secchi disk visible to bottom of waterbody. The value reported is the depth of the waterbody at the location of the Secchi disk measurement	N	
T	T: Value reported is less than the laboratory method detection limit	Y	
U	U: Material was analyzed for but not detected	N	
V	V: Analyte was detected in both the sample and the associated method blank	Unsure	
W	W: Value observed is less than lowest value reportable under T code. This code is used when a positive value is not observed or calculated for a result, i.e., the test instrument or calculation is not capable of producing negative values.	Y	
X	X: Indicates, when reporting results from a Stream Condition Index Analysis (LT 7200 and FS 7420), that insufficient individuals were present in the sample to achieve a minimum of 280 organisms for identification (the method calls for two aliquots of 140-160 organisms), suggesting either extreme environmental stress or a sampling error.	Should be analyzed individually when present	
Y	Y: Analysis form unpreserved or improperly preserved sample	Y	
Z	Z: Too many colonies were present - the numeric value represents the filtration volume.	Unsure	
<	Less than result value	Unsure	
>	Field blank analyte value was high (> 2 x MDL)	Unsure	