WASTEWATER 101

Part 5
How is water quality monitored?

NWBE

Wastewater Surveillance Program
Water Environment Federation

nwbe.org
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DISCLAIMER

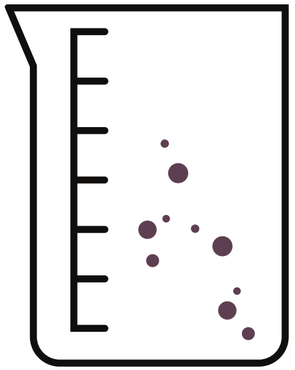
Development and production of this material was made possible through funding from the US Centers for Disease Control and Prevention (CDC) to the Water Environment Federation (WEF) under Cooperative Agreement CK20-2003 (Improving Clinical and Public Health Outcomes through National Partnerships to Prevent and Control Emerging and Re-Emerging Infectious Disease Threats). This material is solely the responsibility of WEF and does not necessarily represent the official position of CDC.

WASTEWATER SAMPLE TYPES

MATRIX

Liquid

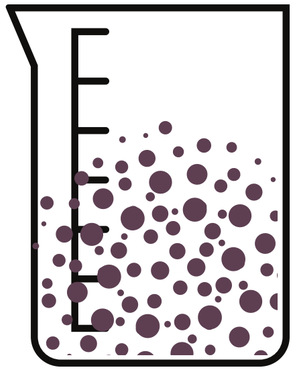
< 0.01 to 0.5% solids



Examples: raw influent, primary effluent, mixed liquor suspended solids, secondary effluent, final effluent

Sludge

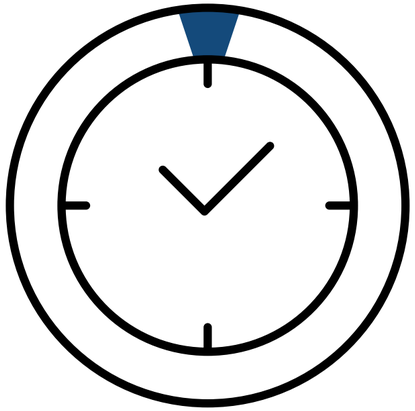
~1 to 8% solids



Examples: septage, primary sludge, waste activated sludge, thickened sludge

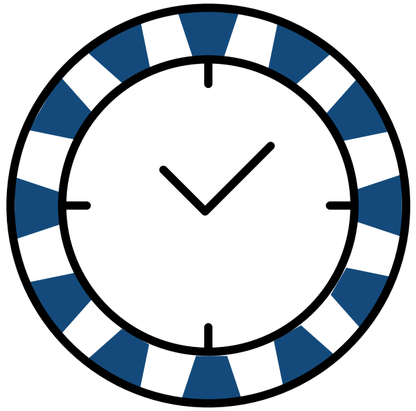
METHOD

Grab



Commonly used for:
sludge and certain liquid analyses
(pH, temp, nitrate/nitrite)

Composite



Commonly used for:
raw influent and
final effluent

GRAB

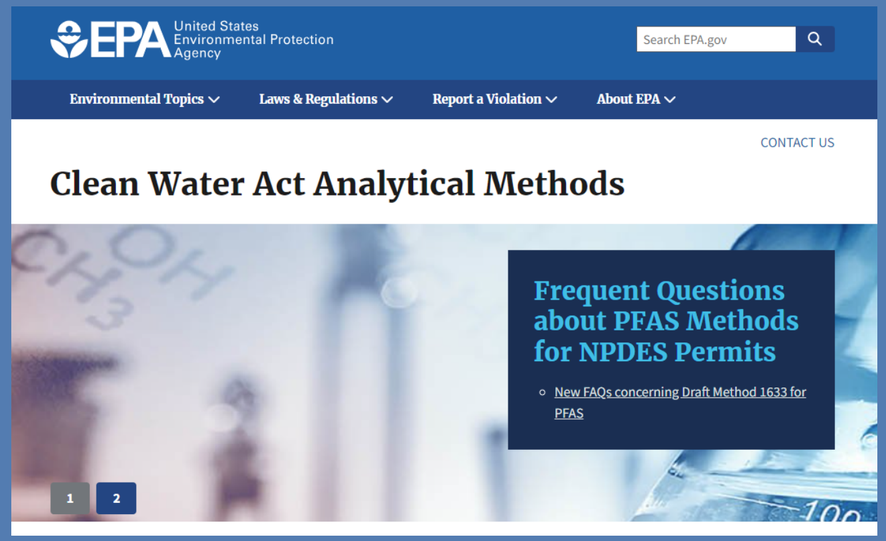
All photos from A. Mehrotra collection unless otherwise noted

COMPOSITE

All photos from A. Mehrotra collection unless otherwise noted

METHODS REFERENCES

“EPA METHODS”



epa.gov/cwa-methods

“STANDARD METHODS”

American Public Health Association, American Water Works Association, Water Environment Federation. Lipps WC, Braun-Howland EB, Baxter TE, eds. **Standard Methods for the Examination of Water and Wastewater. 24th ed.** Washington DC: APHA Press; 2023.

standardmethods.org

CATEGORIES OF ANALYTES

- Physical & aggregate properties
- Metals
- Inorganic nonmetallic constituents
- Aggregate organic constituents
- Individual organic compounds
- Radioactivity
- Toxicity
- Microbiological examination
- Biological examination

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PHYSICAL AND AGGREGATE PROPERTIES

Appearance
Color
Turbidity
Odor
Taste
Flavor profile analysis
Acidity
Alkalinity
Calcium carbonate saturation
Hardness
Oxidant demand/requirements
Conductivity
Salinity
Floatables
Solids
Temperature
Particle counting and size distribution
Asbestos
Oxidation-reduction potential
Tests on sludges
Anaerobic sludge digester gas
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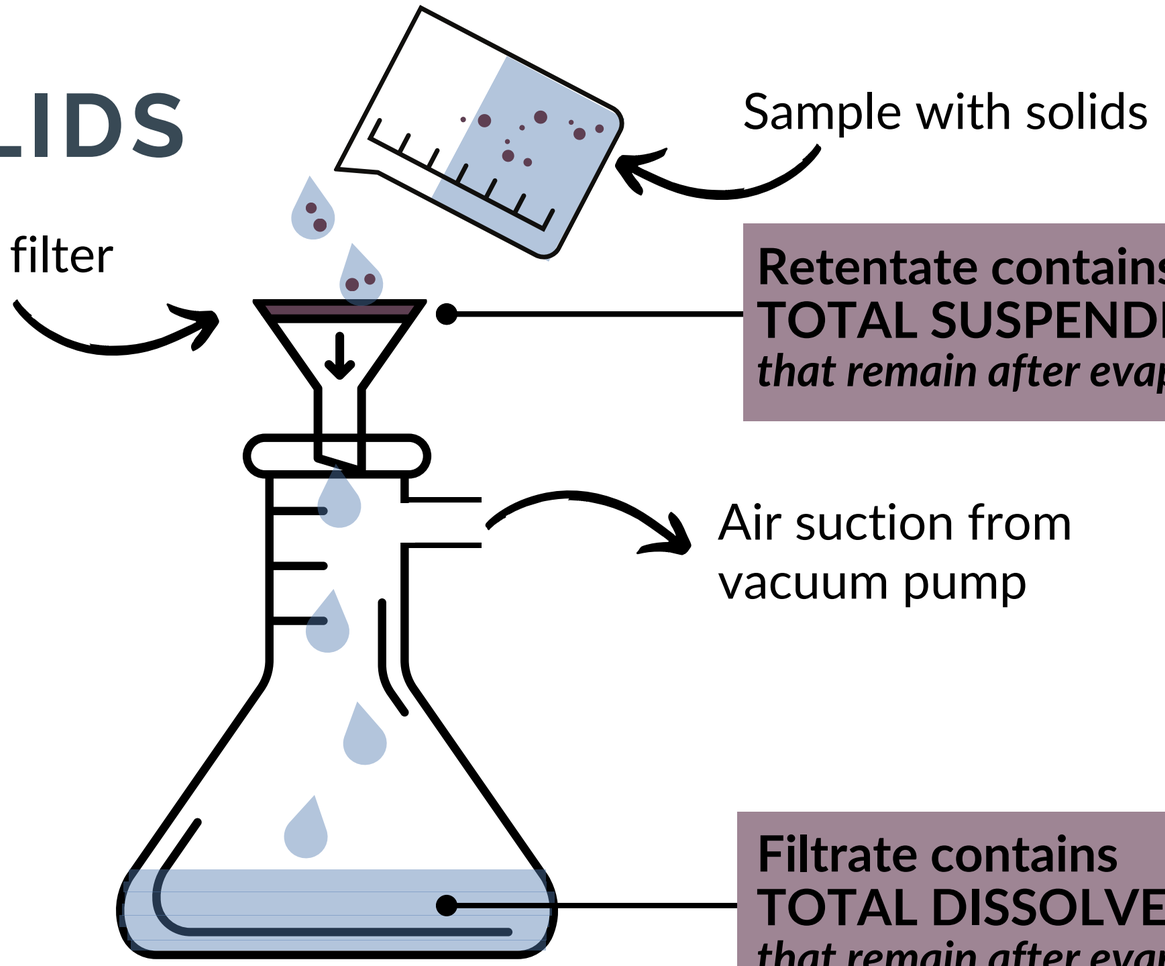
TSS: TOTAL SUSPENDED SOLIDS



Glass fiber filter pore size ranges from ~1.0 to 1.5 µm depending on manufacturer

Typical raw influent TSS: ~100 to 400 mg/L

SOLIDS & WASTEWATER SURVEILLANCE

Particles from enveloped and non-enveloped viruses appear to preferentially partition to solids in raw wastewater

- **Mercier *et al.*, 2022, *Nature Scientific Reports***: 88.1 ± 10.6% of the endogenous influenza A viral signal was partitioned to the solids fraction in samples from 1 Ontario treatment plant
- **Roldan-Hernandez & Boehm, 2023, *Environmental Science & Technology***: Endogenous RNA concentrations of SARS-CoV-2, RSV, rhinovirus, F^+coliphage were 1,000 to 10,000 times higher in solids fraction than in liquid fraction in samples from 6 California treatment plants

Centrifuge at 10,000 x *g* for 45 min; decant; centrifuge at 10,000 x g for 10 min
→ pellet = solids fraction

Centrifuge at 24,500 x *g* for 20 min; decant
→ pellet = solids fraction

INORGANIC NONMETALLIC CONSTITUENTS

Anions by ion chromatography
Inorganic nonmetals by flow injection analysis
Inorganic anions by capillary electrophoresis
Boron
Bromide
Carbon dioxide
Cyanide
Chlorine (residual)
Chloride
Chlorine dioxide
Fluoride
pH
Hydrogen peroxide (residual; proposed)
Iodine/iodide/iodate
Nitrogen (ammonia, nitrite, nitrate, organic, total)
Oxygen
Peracetic acid (residual; proposed)
Phosphorus (soluble reactive, total)
Potassium permanganate
Silica
Sulfide/sulfite/sulfate

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Chloride
Chlorine dioxide
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Iodine/iodide/iodate
Nitrogen (ammonia, nitrite, nitrate, organic, total)
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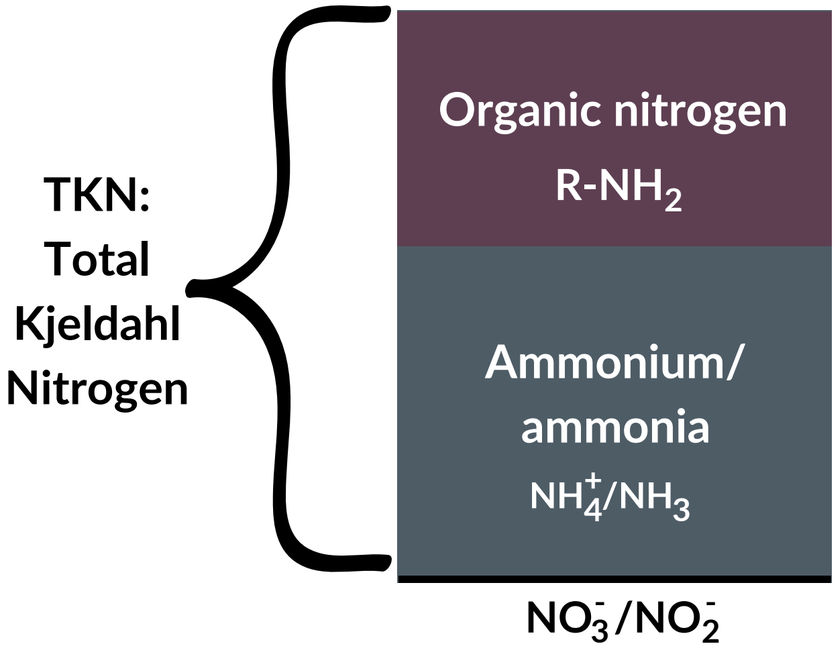
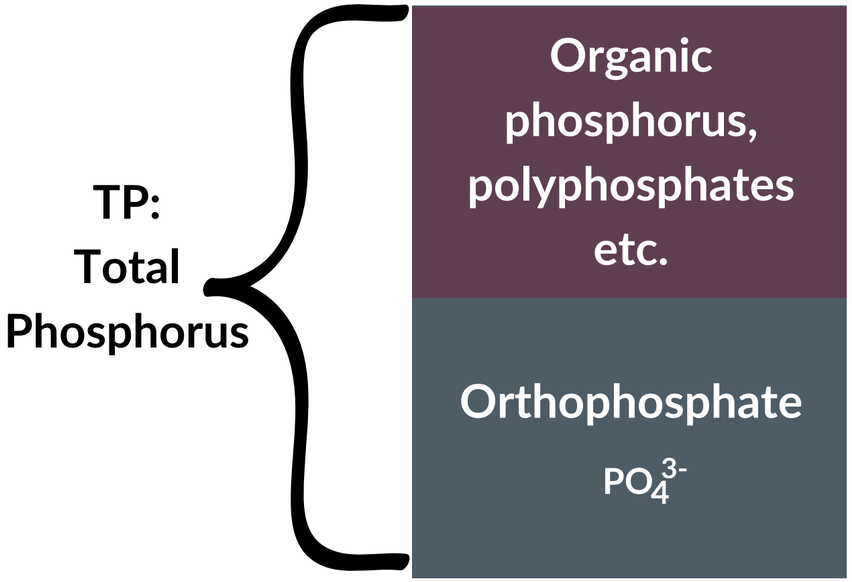
NITROGEN & PHOSPHORUS

Nitrogen



TKN is usually ~30 to 70 mg/L (as N) in raw influent, and 60 to 70% is ammonium

Phosphorus



TP is usually ~4 to 12 mg/L (as P) in raw influent, and about 50% is orthophosphate

AGGREGATE ORGANIC CONSTITUENTS

Biochemical oxygen demand (BOD)
Chemical oxygen demand (COD)
Total organic carbon
Dissolved organic halogen
Aquatic humic substances
Oil and grease
Phenols
Surfactants
Tannin and lignin
Organic and volatile acids
Formation of trihalomethanes and other disinfection byproducts
UV-absorbing organic constituents

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OXYGEN DEPLETION

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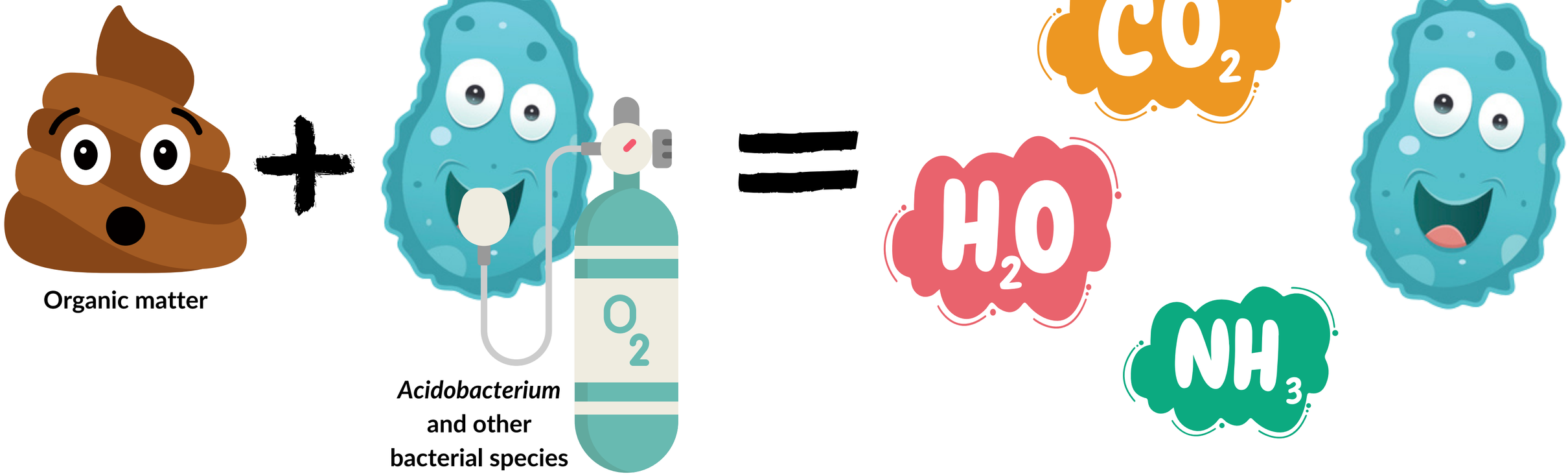
OXYGEN DEMAND

Measure of the amount of biodegradable organic matter in wastewater in [mass]/[volume]



Organic matter

Acidobacterium and other bacterial species

BOD VS. COD

BOD

- Biochemical oxygen demand
- Bioassay
- Measure of oxygen uptake by microorganisms
- Typically performed for 5 days
- Usually ~100 to 350 mg/L in raw influent

COD

- Chemical oxygen demand
- Chemical analysis
- Measure of oxygen needed to chemically oxidize organic matter
- Can be completed in a few hours
- Usually ~350 to 550 mg/L in raw influent

Most NPDES permits are written around BOD_5

CONVENTIONAL PARAMETERS CONSIDERED FOR NORMALIZATION OF SARS-COV-2 RNA CONCENTRATIONS IN WASTEWATER

- For influent samples from 2 WWTPs in Kansas, normalization with **ammonium** and **BOD** did not improve correlations with 21-day cumulative case counts (Hutchison *et al.*, 2022, *FEMS Microbes*)
- For samples from 9 collection system sites in Michigan, normalization with **TKN** resulted in strong correlations with cumulative COVID cases during the 10-month study period, whereas normalization with **BOD** or **TSS** did not (Li *et al.*, 2022, *Science of the Total Environment*)
- For influent samples from 12 WWTPs in Alberta, normalization with **ammonium**, **TKN** and **TP** improved correlations with 7-day average COVID case counts, whereas normalization with **BOD** and **TSS** weakened the association, but the difference between normalized and unnormalized associations was not statistically significant (Maal-Bared *et al.*, 2023. *Science of the Total Environment*)
- For samples from 394 sites in England, normalization with **ammonium** or **phosphate** improved correlation with three indicators of COVID prevalence (Sweetapple *et al.*, 2023, *Journal of Water and Health*)

CONVENTIONAL PARAMETERS CONSIDERED FOR NORMAZLIATION OF SARS-COV-2 RNA CONCENTRATIONS IN WASTEWATER

In other words,

the evidence suggests that:

X Normalizing with **BOD** or **TSS** likely does *not* improve correlations between wastewater SARS-CoV-2 RNA concentrations and COVID case data

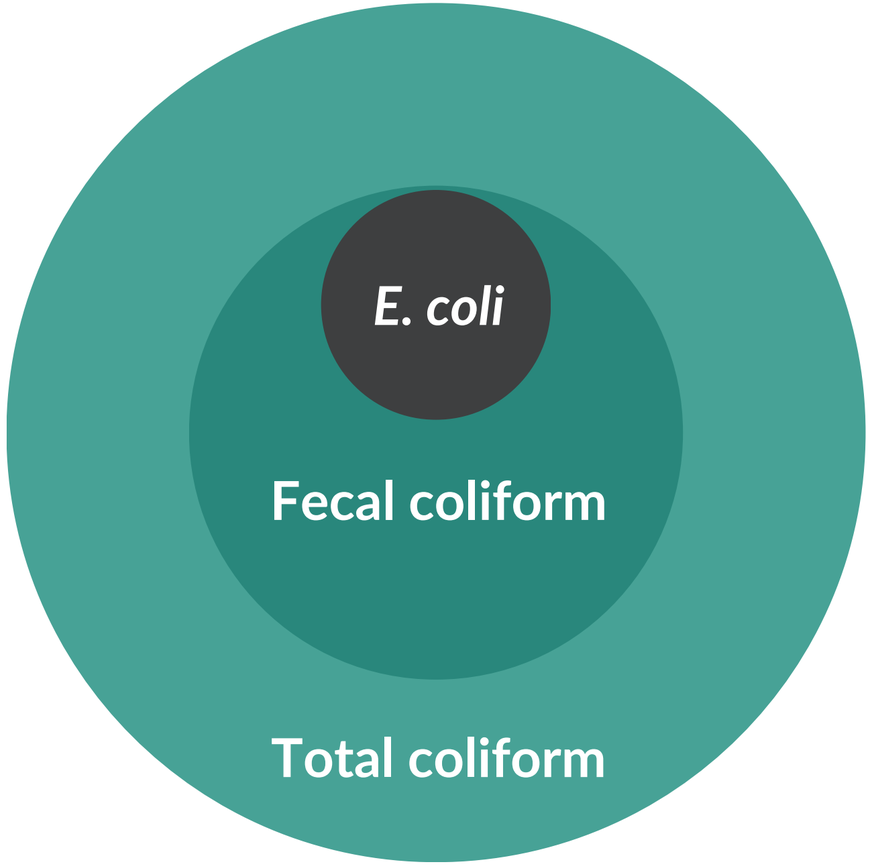
? But normalizing with **ammonium**, **TKN**, **phosphate**, or **TP** *may* help improve correlations between wastewater SARS-CoV-2 RNA concentrations and COVID case data

MICROBIOLOGICAL EXAMINATION

Heterotrophic plate count
Direct total microbial count
Biodegradable organic matter
Aerobic endospores
Multiple tube fermentation (coliform)
Membrane filter technique (coliform)
Enzyme substrate coliform test
Detection of coliphages
Differentiation of coliform bacteria
Fecal enterococci
Iron and sulfur bacteria
Detection of actinomycetes

Aeromonas
Campylobacter
Diarrheagenic *Escherichia coli*
Legionella
Leptospira
Mycobacterium
Salmonella
Vibrio
Yersina enterocolitica
Detection of enteric viruses
Detection of Fungi
Detection of protozoa

A NOTE ON FECAL INDICATOR BACTERIA (FIB)



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TERMINOLOGY

GRAB SAMPLE

Aliquot of wastewater collected at a single point in time

COMPOSITE SAMPLE

A wastewater sample comprised of blended discrete aliquots taken at a regular interval over a specified period of time

TSS

Total suspended solids: quantity of solids retained on a glass-fiber filter and remaining after evaporation of water, usually expressed in mg/L

TERMINOLOGY

TKN

Total Kjeldahl nitrogen: measure of both free ammonia and organic nitrogen compounds, usually expressed in mg N/L

TP

Total phosphorus: measure of all phosphorus compounds, including orthophosphate and organic phosphorus, usually expressed in mg P/L

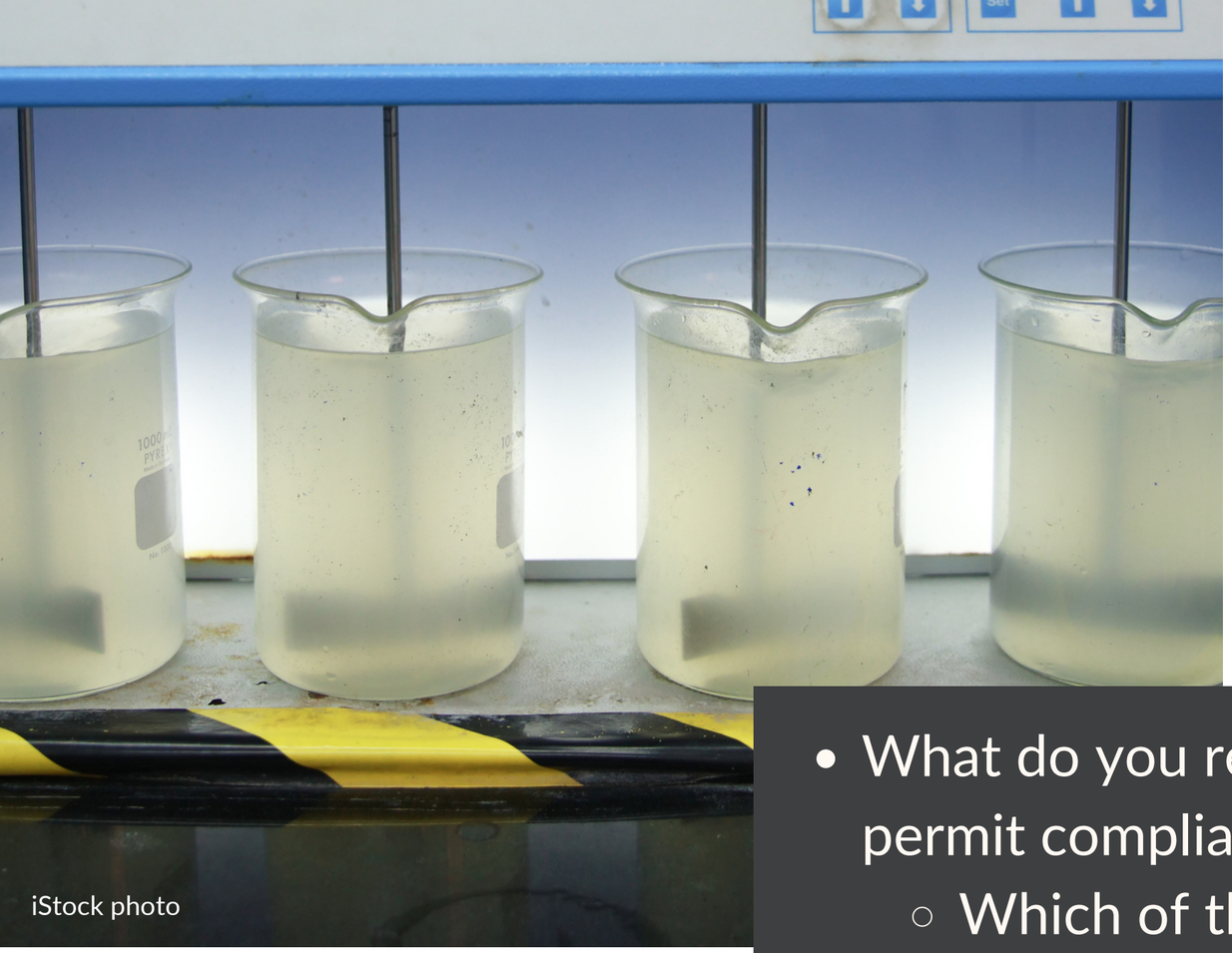
TERMINOLOGY

BOD

Biochemical oxygen demand: measure of the biodegradable organic matter via bioassay; usually expressed in mg/L of BOD_5

COD

Chemical oxygen demand: measure of the biodegradable organic matter via chemical oxidation; usually expressed in mg/L COD



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WHAT TO ASK YOUR UTILITY PARTNERS

- What do you regularly test for in your raw influent, either for permit compliance or for process control?
  - Which of these are measured on grab samples and which are measured on composite samples?
  - How frequently do you analyze for each?
  - Which type of glass-fiber filter is used for your TSS measurements?
  - How easy is it for you to share your raw influent data with your health department and lab partners?

WATER QUALITY MONITORING RESOURCES

Third Century of Biochemical Oxygen Demand on accesswater.org

Clean Water Act methods summary at epa.gov/cwa-methods

Standard Methods for the Examination of Water & Wastewater at standardmethods.org

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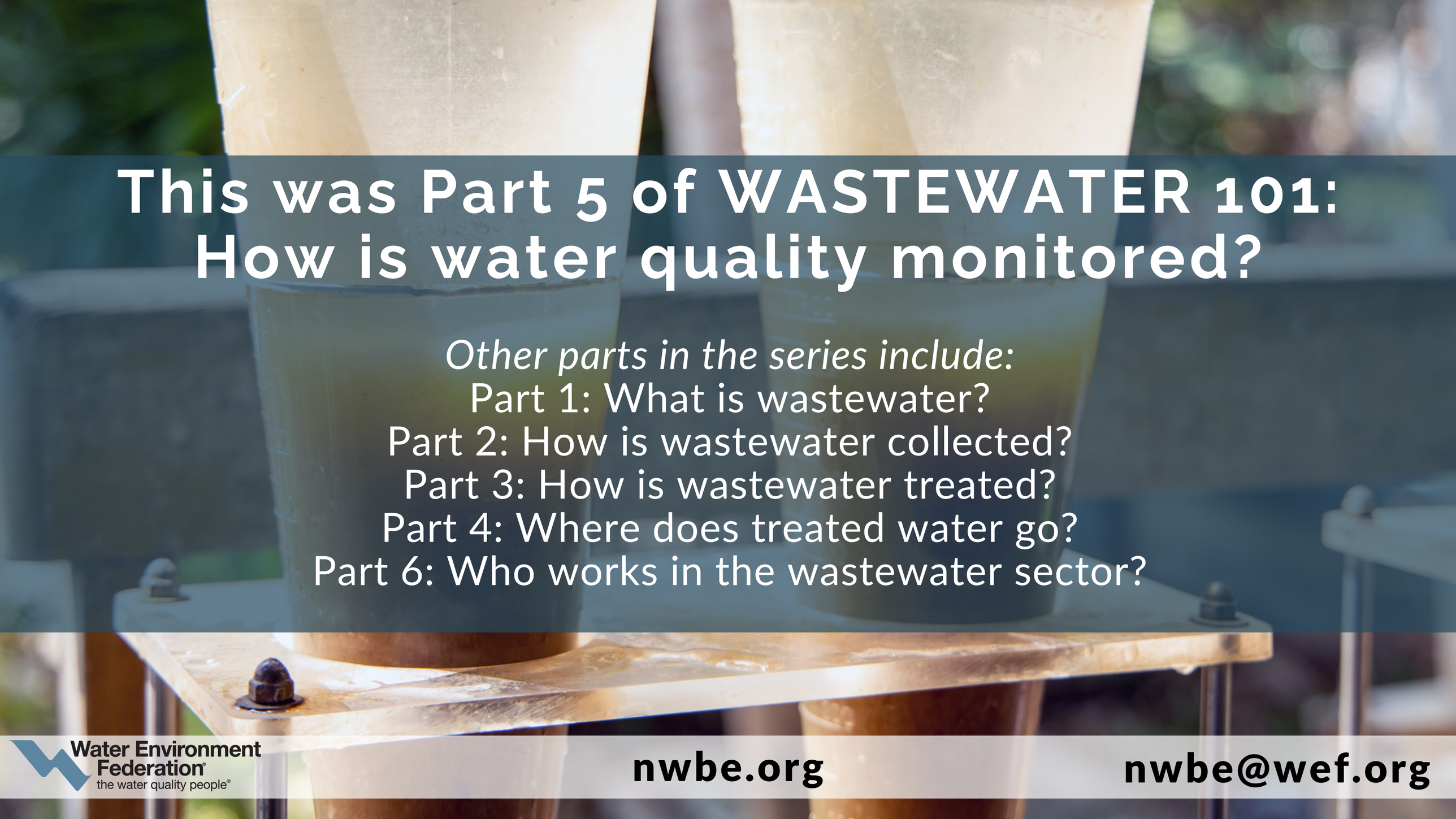

This was Part 5 of WASTEWATER 101: How is water quality monitored?

Other parts in the series include:

Part 1: What is wastewater?
Part 2: How is wastewater collected?
Part 3: How is wastewater treated?
Part 4: Where does treated water go?
Part 6: Who works in the wastewater sector?

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