REINHOLD ENVIRONMENTAL Ltd.

2017 APC & Wastewater Round Table & Expo Presentation

July 17 & 18, 2017 in Charlotte, NC / Hosted by Duke Energy

CARE AND FEEDING OF BIOREACTORS: O&M AND TROUBLESHOOTING

2017 APC & WASTEWATER/PCUG CONFERENCE

JULY 17 & 18, 2017

KEITH AMBROSE, DUKE ENERGY

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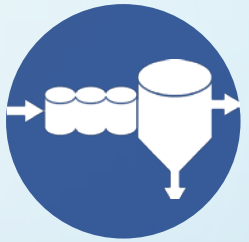
DIANE MARTINI, BURNS & MCDONNELL

AGENDA

HISTORY



Treatment Technologies

Care & Feeding

Troubleshooting

HISTORY

SELENIUM

A. ESSENTIAL MICRONUTRIENT

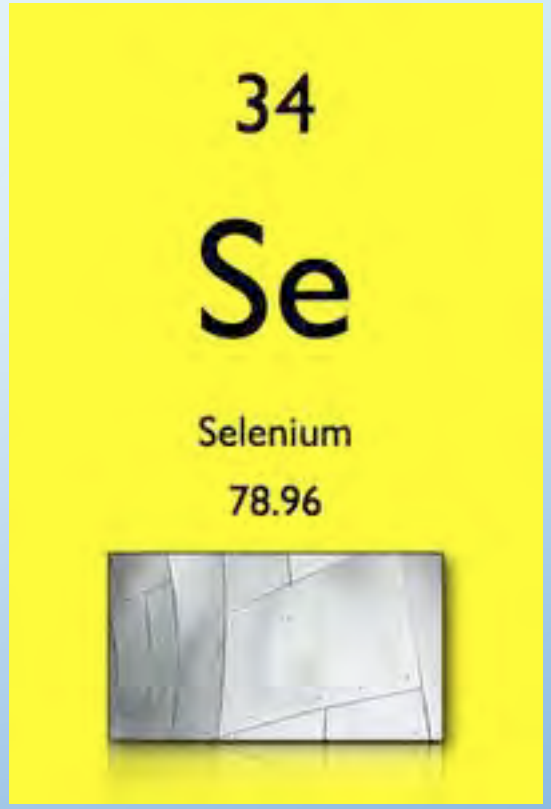
- RECOMMENDED DIETARY ALLOWANCE (RDA) 55 µG/DAY
  - ADULTS (> 14 YEARS)
- TOXIC PROPERTIES AS WELL
  - SELSUN BLUE - SELENIUM SULFIDE

B. WIDELY DISPERSED IN THE ENVIRONMENT

C. COMMON IN COAL

D. CAN BE TOXIC AND TERATOGENIC TO WILDLIFE

- IN SUFFICIENT CONCENTRATIONS



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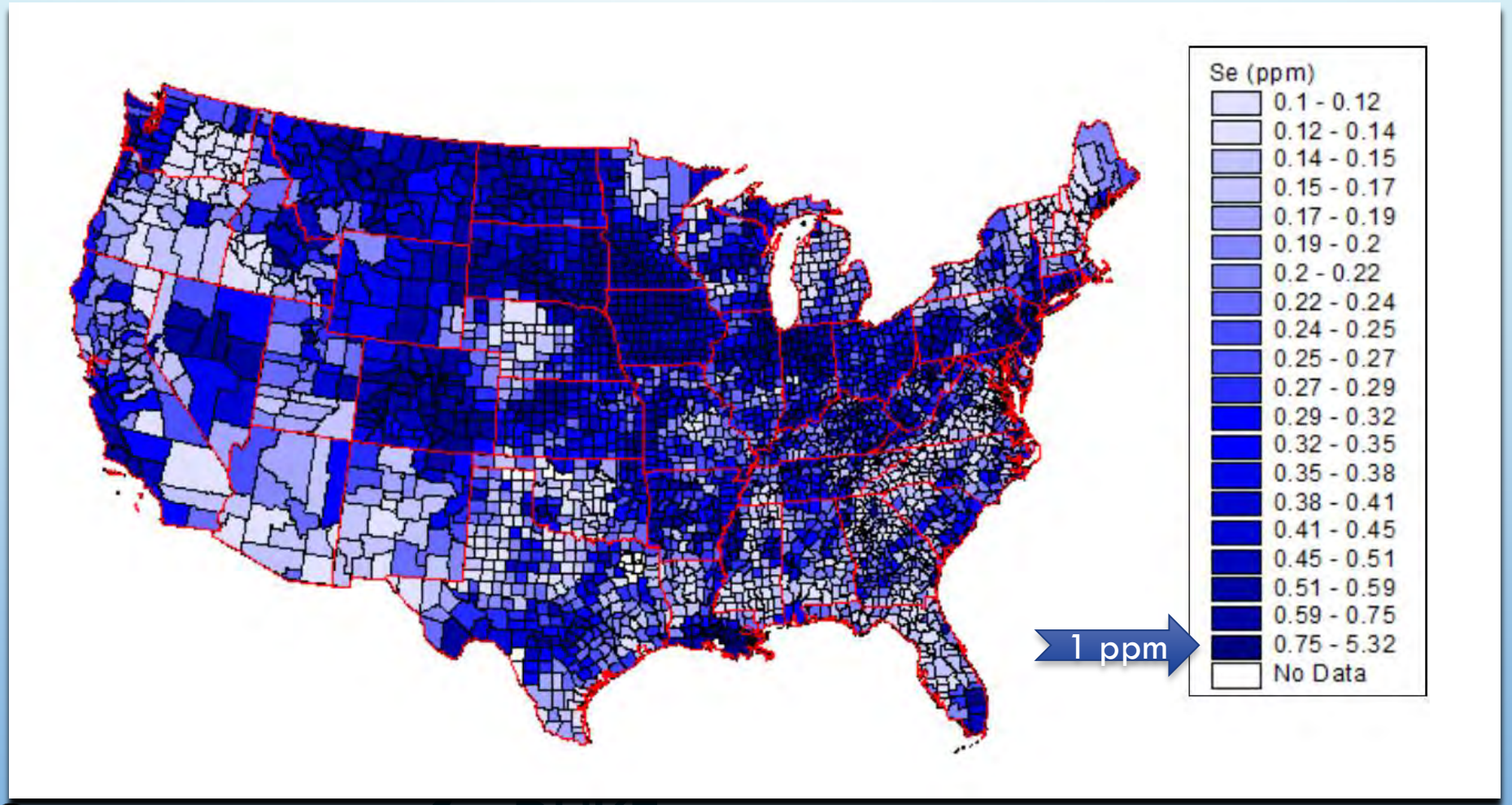
Source: US Patents 618344 B1, 7550087 B2

HISTORY

Selenium in Surface Soils & Sediments



Source: https://mrdata.usgs.gov/geochem/doc/averages/se/usa.html

HISTORY

KESTERSON RESERVOIR, CALIFORNIA

- 12 EVAPORATION PONDS FOR AG RUNOFF
- 1971 CONSTRUCTION
- DEAD AND DEFORMED BIRDS OBSERVED IN EARLY 80S
    1. "KESTERSON EFFECT"
    2. SELENIUM CONCENTRATIONS 85 – 440 PPB
- CLOSURE ORDERED IN 1986
- 1992 – PROPOSED BIOLOGICAL REMEDIATION FOR SELENIUM

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Photo Source: http://www.deltaflyfishers.com/Conservation/2012/conmay2012.html

HISTORY

AMBIENT WATER QUALITY CRITERIA (AWQC):

A. 1987 AWQC

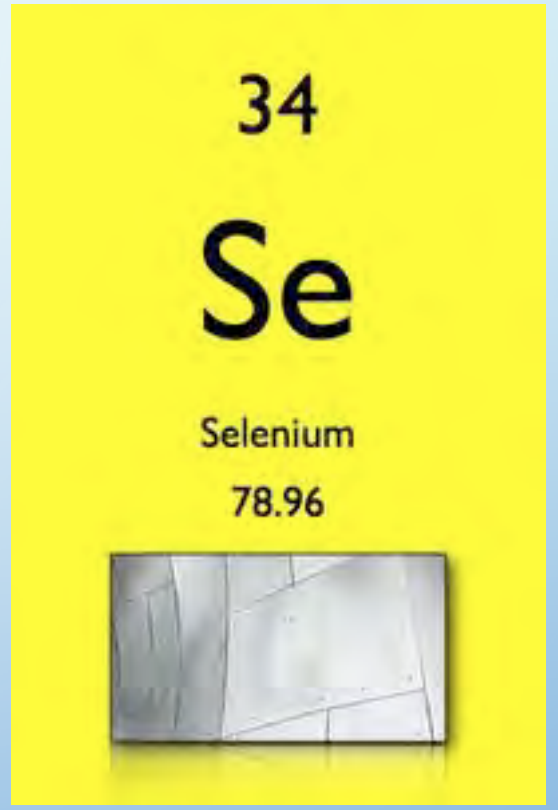
- 20 µG/L ACUTE AND 5 µG/L CHRONIC
- BASED ON NORTH CAROLINA DATA

B. 2016 AWQC

- 10 DIFFERENT CRITERIA - FISH TISSUE AND WATER COLUMN
- 1.5 µG/L IN LENTIC SYSTEMS (LAKES)
- 3.1 µG/L IN LOTIC SYSTEMS (STREAMS)

2016 STEAM ELECTRIC ELG

- 12 µG/L BAT AVERAGE
- 5 µG/L NSPS



Source: Aquatic Life AWQC for Selenium – Freshwater 2016

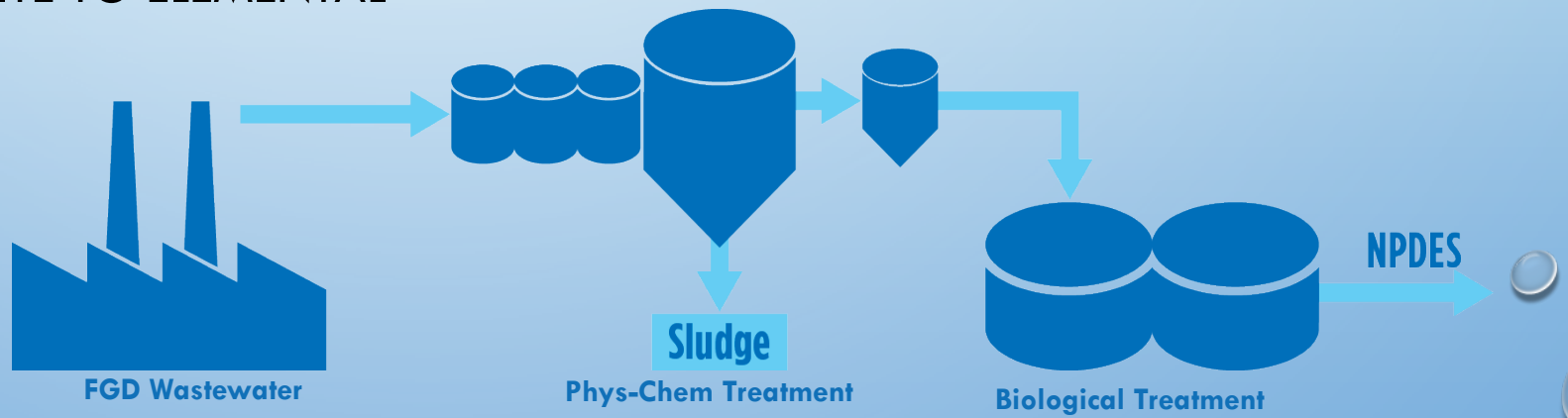
TREATMENT TECHNOLOGIES

A. **PRETREATMENT**
   - SOFTENING/OXIDATION/PRECIPITATION
   - CLARIFICATION/FILTRATION
   - NUTRIENT FEED/ORP ADJUSTMENT

B. **BACTERIA CONVERT:**
   - NITRATE TO $N_{2\ GAS}$
   - SELENATE OR SELENITE TO ELEMENTAL SE

NITRATE MUST BE REMOVED FIRST
   - ORP IS KEY
   - LOW ORP REDISSOLVES SOME METALS

EFFLUENT POLISHING
   - OXIDATION AND UF



BIOREACTOR BASICS

BIOREACTORS ARE VERY COMMON

- EVEN ANCIENT CULTURES MADE BEER
  - GREAT WAY TO PRESERVE FOODS
  - REAL REASON FOR AGRICULTURE????

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BIOREACTOR BASICS

TYPES:

A. SUSPENDED GROWTH

- GENERALLY AEROBIC
- SANITARY WASTEWATER
- NITROGEN REMOVAL

B. FIXED GROWTH

- MOST COMMON FOR SELENIUM SYSTEMS

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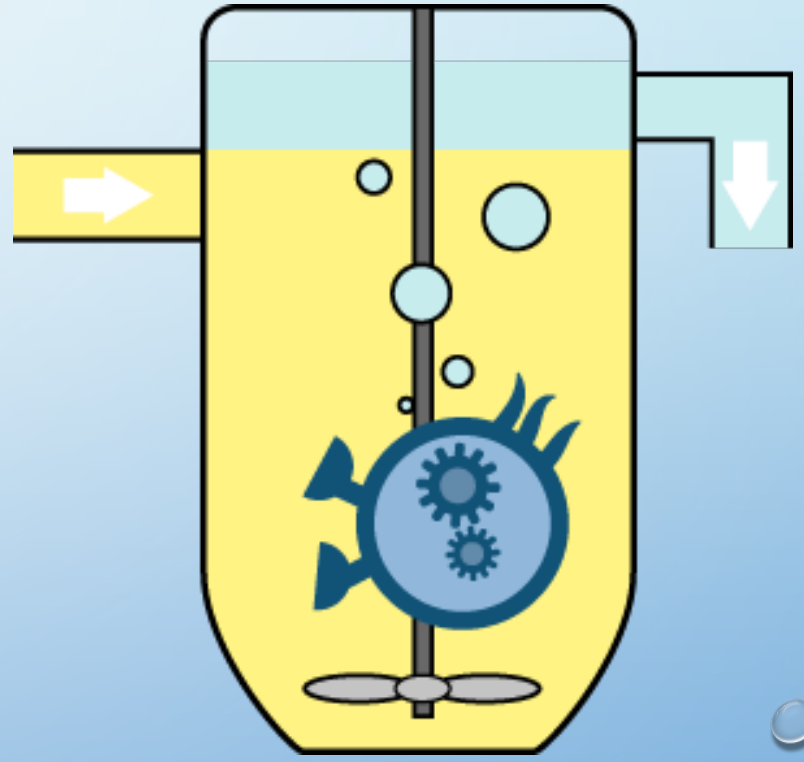
TREATMENT TECHNOLOGIES

A. FIXED BED BIOREACTOR

- DOWNFLOW (ABMET); UPFLOW (UOP)
- UPFLOW/DOWNFLOW (FRONTIER)
- FLUIDIZED BED BIOREACTOR (ENVIROGEN)
- MOVING BED BIOREACTOR (ANOX-KALDNES; LENA)



B. MEMBRANE BIOREACTOR (LENA; OTHERS)

- NITROGEN REMOVAL
- POLISHING

C. SUSPENDED GROWTH

- COD & NITROGEN REMOVAL

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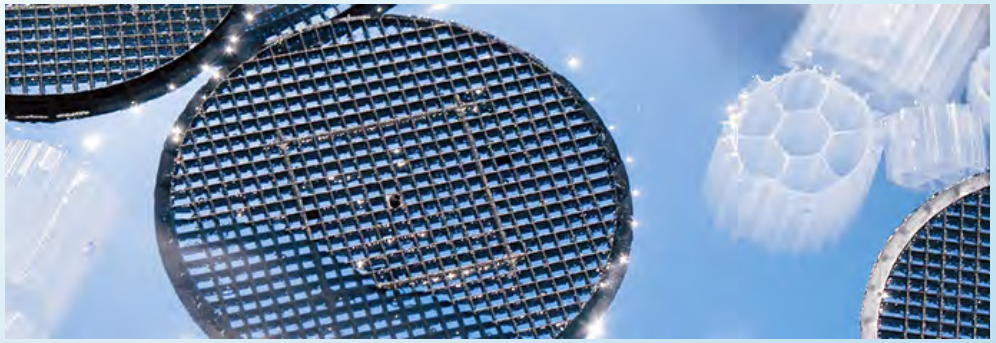
TREATMENT TECHNOLOGIES

MOVING BED BIOREACTOR (MBBR)

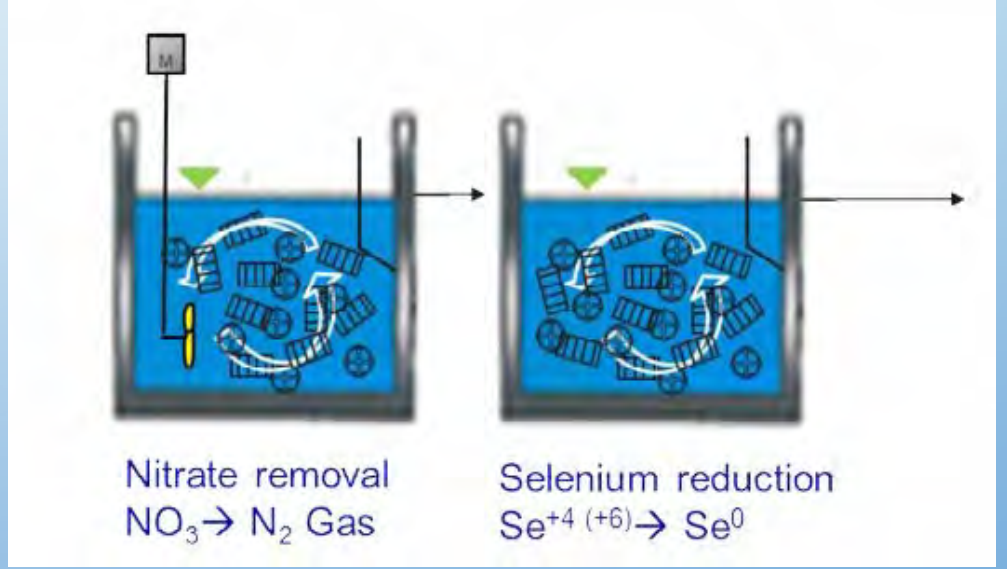
- ANAEROBIC/ANOXIC
- ACTIVE BIOFILM IS GROWN ON SMALL PLASTIC CARRIERS
- TARGETS: NITRATES AND SELENIUM



http://technomaps.veoliawatertechnologies.com/mbbr/en/

➢ **ADVANTAGES**:

- SMALL FOOTPRINT
- SINGLE PASS PROCESS
- SELF-REGULATING (LOAD RESPONSIVE)
- GOOD FOR SMALL SANITARY SYSTEMS



Source: http://www.doosanhydro.com/en/technology/lena_mbr.do

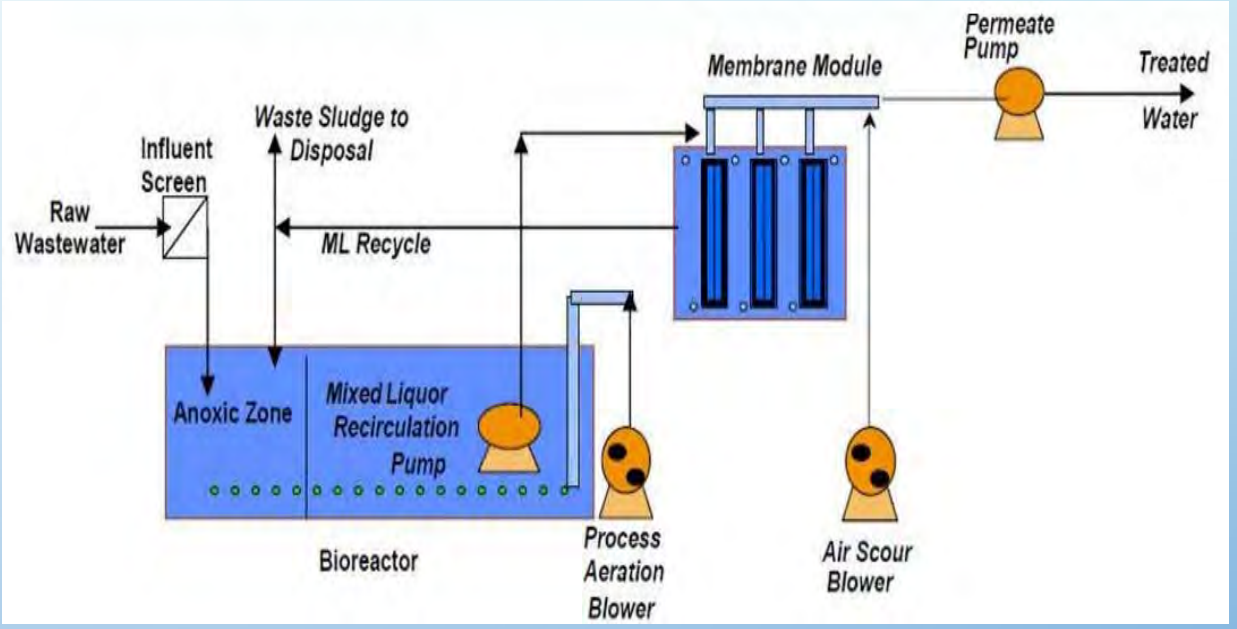
TREATMENT TECHNOLOGIES

MEMBRANE BIOREACTOR (MBR)

- ANOXIC
- BIOFILM IS SUSPENDED OR GROWN ON THE POLYMERIC OR CERAMIC MEMBRANE
- TARGETS: NITRATES, SELENIUM, AND SULFATE

➢ **ADVANTAGES:**

- HIGH LOADING RATE CAPABILITY
- HIGH EFFLUENT QUALITY
- REDUCED SLUDGE PRODUCTION



Source: http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/semi-centralised-wastewater-treatments/m

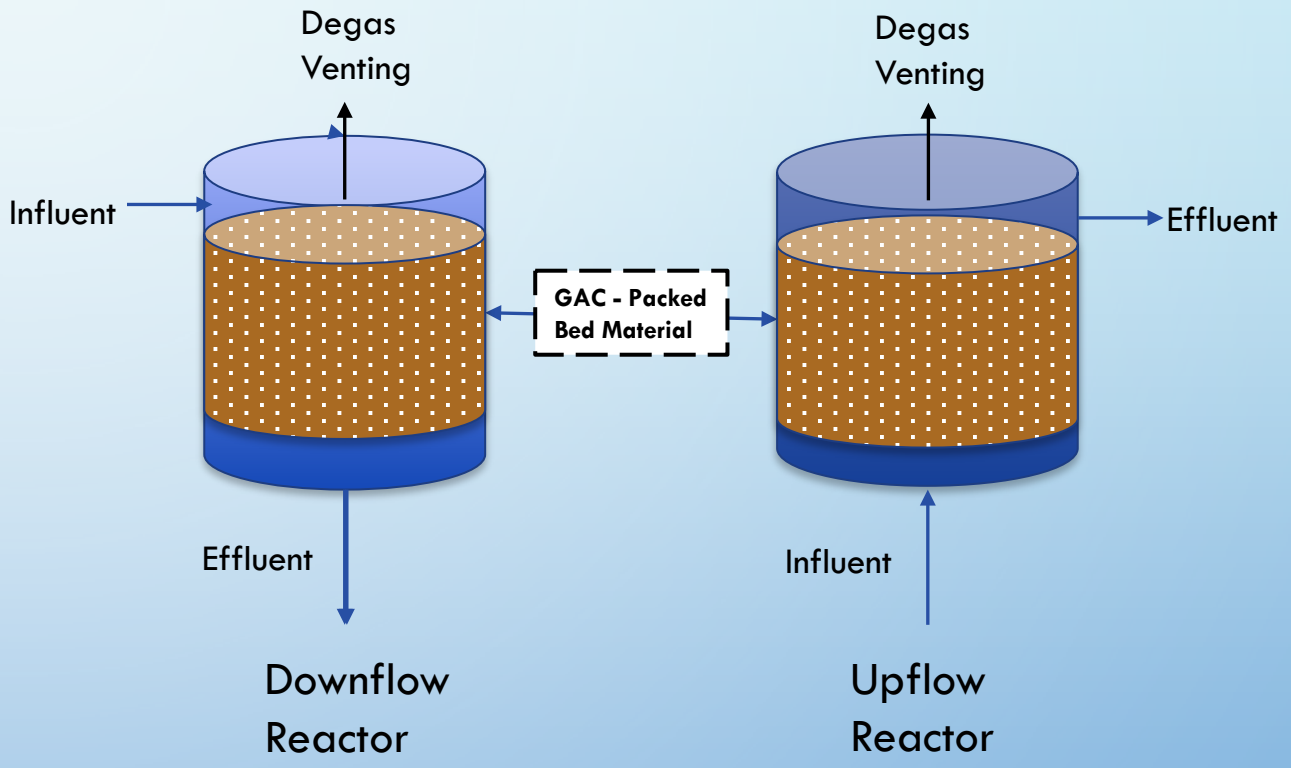
TREATMENT TECHNOLOGIES

FIXED OR PACKED BED BIOREACTOR

- ANOXIC
- BIOFILM IS GROWN ON A GAC SUBSTRATE MATERIAL
- TARGETS: NITRATES AND SELENIUM

➢ **ADVANTAGES:**

- SIMPLE DESIGN
- NO MOVING PARTS



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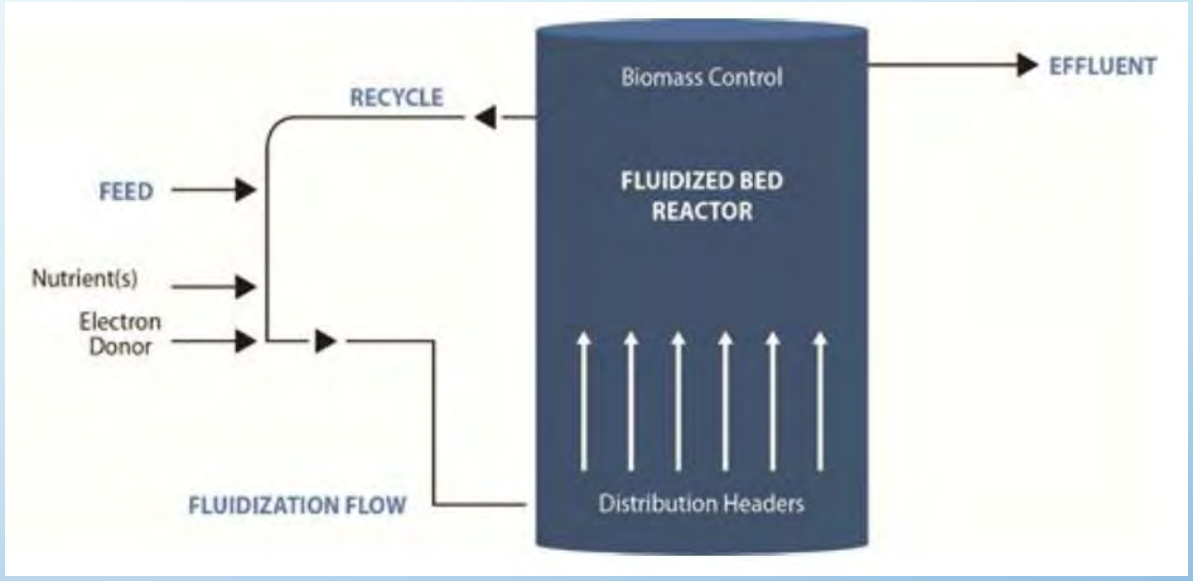
TREATMENT TECHNOLOGIES

FLUIDIZED BED BIOREACTOR

- ANOXIC
- BIOFILM IS GROWN ON A SAND OR ACTIVATED CARBON MEDIA
- TARGETS: NITRATES AND SELENIUM

➢ **ADVANTAGES:**

- LOWER HYDRAULIC RESIDENCE TIMES
- CONTINUOUS SYSTEM – NO BACKWASH REQUIRED
- UP FLOW – EXPANDED BED



http://www.envirogen.com/pages/technologies/bioreactors/

CARE AND FEEDING

OPERATING PRINCIPALS:

1. STARTUP
2. MONITORING
3. pH
4. TEMPERATURE
5. OXIDATION REDUCTION POTENTIAL (ORP)
6. DISSOLVED OXYGEN
7. VISUAL

STARTUP

- COMMISSION EQUIPMENT AND CONTROLS SYSTEM
- LOAD MEDIA
- SEED WITH BUGS
  - LOCAL SANITARY PLANT
  - PREVIOUS PLANT BIOREACTOR
  - OEM-PROVIDED CULTURES
- ACCLIMATION – 2 – 8 WEEKS

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CARE AND FEEDING

MONITORING

1. TARGET TO PROCESS REQUIREMENTS
2. REAL TIME DATA WHEREVER POSSIBLE
   - INSTRUMENTS
   - TEST KITS
   - TEST STRIPS
3. RECORD KEEPING
   - BENCH SHEETS, LOG BOOKS, DCS

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CARE AND FEEDING

pH: A FIGURE EXPRESSING THE ACIDITY OR ALKALINITY OF A SOLUTION ON A LOGARITHMIC SCALE ON WHICH 7 IS NEUTRAL, LOWER VALUES ARE MORE ACID, AND HIGHER VALUES MORE ALKALINE (LOG OF H^+ OR OH^- IONS)

- **TARGET RANGE**
  - NITRIFICATION (*NITROSOMONAS*): 7.8 – 8.0
  - DENITRIFICATION (*NITROBACTER*): 7.3 – 7.5
  - SELENIUM REMOVAL: 6.7 – 7.4
  - DIFFERENT OEMS MAY DIFFER ON THIS RANGE

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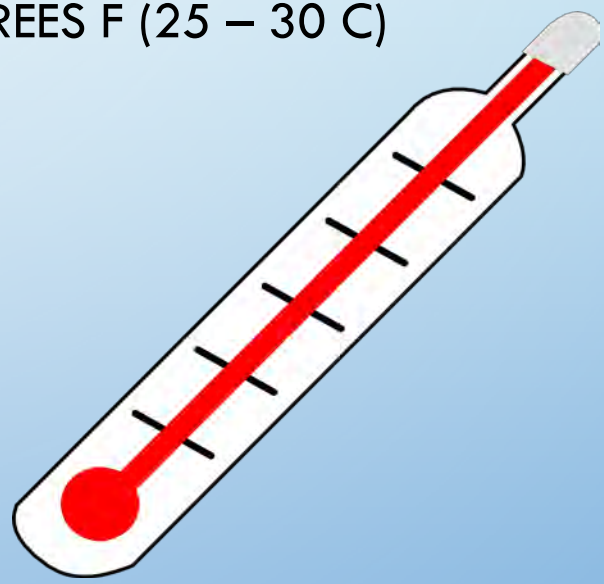
CARE AND FEEDING

TEMPERATURE

- SELENIUM REMOVAL GENERALLY WORKS BEST AROUND 90 - 95 DEGREES F (32 – 35 C)
  - SOME INTERESTING WORK DONE WITH THERMOPHILES AT 130 DEGREES F (55 C)
- NITRIFICATION AND DENITRIFICATION FROM 77 - 86 DEGREES F (25 – 30 C)
- FGD WASTEWATER CAN BE HOT: >110°F
  - HEAT KILLS
  - HEAT EXCHANGER OR OTHER MEANS OF REGULATING
- COLD ALSO IMPACTS
  - CHEMICAL REACTIONS SLOW IN COLD TEMPS
  - BACTERIA GO DORMANT



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CARE AND FEEDING

DISSOLVED OXYGEN: AMOUNT OF GASEOUS OXYGEN (O2) DISSOLVED IN THE WATER

- NOT FOR SELENIUM REMOVAL IN BIOREACTOR
- MAY NEED IN NITROGEN PROCESS IF AMMONIA IS COMING IN

NITRIFICATION: $2NH_4 + 5O_2 \rightarrow 2NO_3^- + 2H^+ + 2H_2O$

DENITRIFICATION: $NO_3^- \rightarrow NO_2 \rightarrow NO + N_2O \rightarrow N_2\,(g)$

ANAEROBIC AMMONIUM OXIDATION: $NH_4 + NO_2^- \rightarrow N_2 + 2H_2O$

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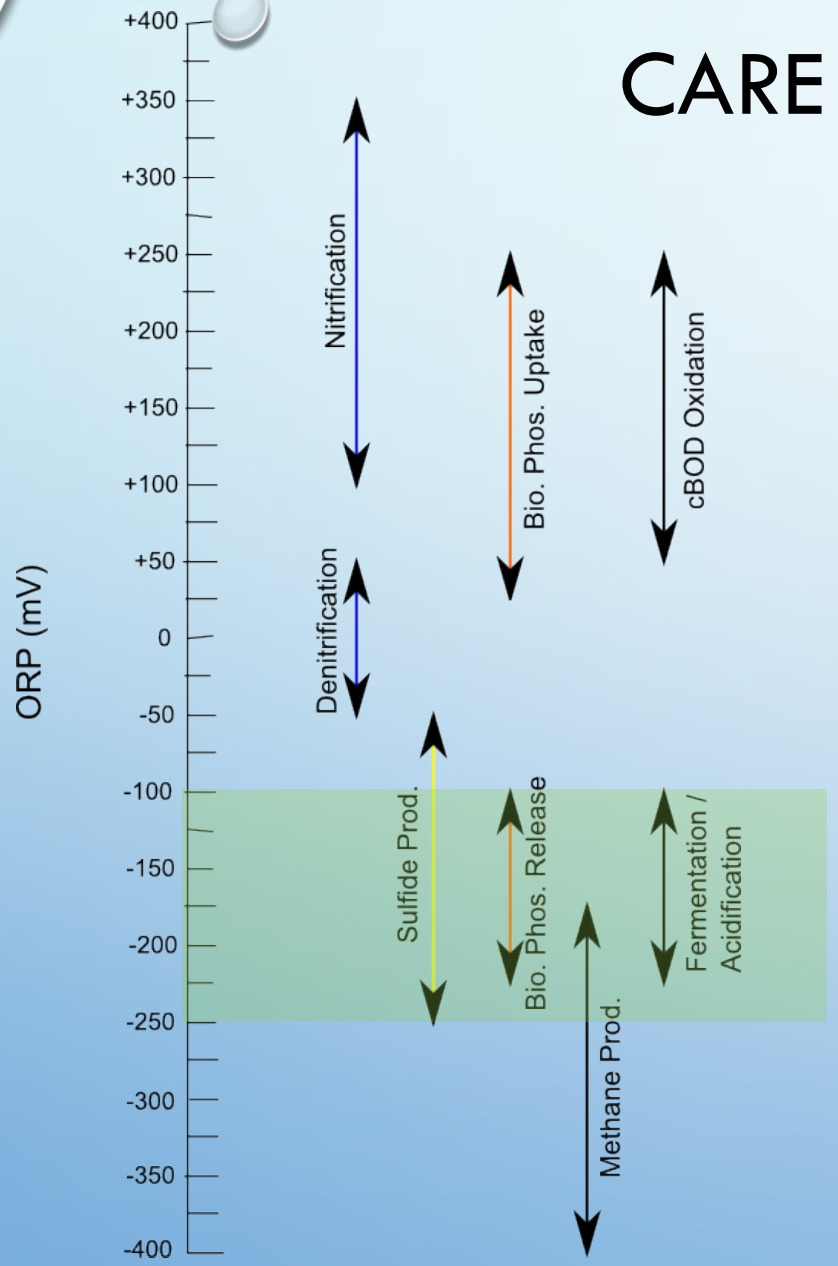
CARE AND FEEDING



OXIDATION REDUCTION POTENTIAL (ORP):

MEASURE OF A CHEMICAL SPECIES TO ACQUIRE ELECTRONS

- **NITRATE REDUCTION** (DENITRIFICATION) AT: 50 TO -50MV
- **SELENIUM REDUCTION** AT: -100 TO -250MV
- **SULFATE REDUCTION** INCREASES <-350MV
- MONITORING AT INLET, PROCESS, AND EFFLUENT

OPERATING PRINCIPALS - AEROBIC

- TYPICAL FOR SANITARY WASTEWATER
  - MAINTAIN DISSOLVED OXYGEN ABOVE 2 PPM
  - MAINTAIN COMPLETE MIXING
- CAN ACHIEVE NITRIFICATION AND DENITRIFICATION
  - AEROBIC CONVERSION OF NH_4 TO NO_2
    - 24 HOUR AERATION AND HYDRAULIC RETENTION TIME
  - ANOXIC CONVERSION OF NO_2 TO N_2
    - DENITRIFICATION IN SECONDARY CLARIFIER AND RETURN SLUDGE
    - FREQUENTLY 30 DAY SOLIDS RETENTION TIME
    - MAY NEED NUTRIENT SUPPLEMENTS FOR INDUSTRIAL WASTEWATER

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OPERATING PRINCIPALS – ANOXIC OR ANAEROBIC

- COMMON FOR HIGH STRENGTH WASTEWATERS
  - DEVELOPED BECAUSE OF PROBLEMS KEEPING UP WITH OXYGEN DEMAND
- OXYGEN IS LIMITED OR EXCLUDED
  - CLOSED TANKS
  - COMMON FOR SLUDGE DIGESTION OR BIOGAS PRODUCTION
  - CAN GENERATE METHANE, H_2S
- MECHANICAL MIXING RATHER THAN AERATION

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OPERATING PRINCIPALS – ANOXIC OR ANAEROBIC

- COMMON FOR HIGH STRENGTH WASTEWATERS
  - ANOXIC – DO <0.1 PPM
    - NO FREE OXYGEN, BUT CHEMICALLY BOUND IS AVAILABLE (NO3, OTHERS)
    - ORP 100 TO -100 MV
  - ANAEROBIC
    - NO FREE OXYGEN AND NO BOUND OXYGEN
    - ORP <-150 MV
  - PH 6.7 – 7.4 (ANAEROBIC DECOMP IS ACIDIC)
  - ALKALINITY (1.5 G $CACO_3$/L)
  - BIOGAS COMPOSITION
    - METHANE AND CO_2 DESIRED
    - H_2 AND CO INDICATE UPSET

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TROUBLESHOOTING

- ❑ IDENTIFY THE PROBLEM
- ❑ CAUSES
- ❑ PREDICTING
- ❑ RECOVERING/RESTART
- ❑ DOCUMENTING LESSONS LEARNED
- ❑ AVOIDING

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TROUBLESHOOTING

- IDENTIFY THE PROBLEM
  - FIRST, CHECK THE OBVIOUS
  - ARE BREAKERS ON, PUMPS WORKING, CHEM FEEDS WORKING?
  - CAN THE SYSTEM BE RESTARTED?
- WHAT JUST HAPPENED? (HISTORY)
  - POWER INTERRUPTIONS?
  - CHANGES UPSTREAM?
- COLLECT MORE INFORMATION IF NEEDED
  - PROCESS TESTS
- IMPLEMENT CORRECTIVE ACTION

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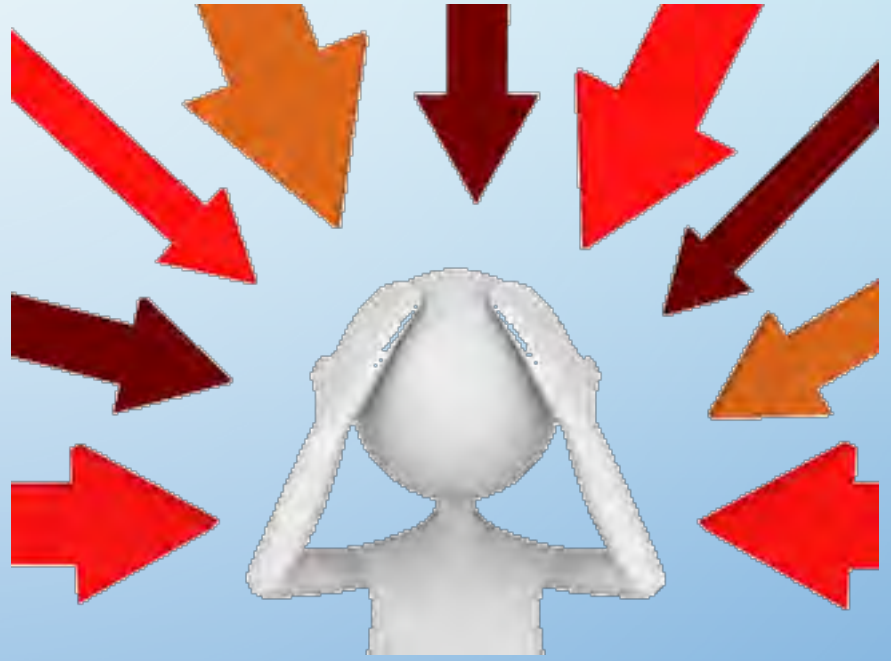
CAUSES

- POWER OR EQUIPMENT FAILURE IN TREATMENT PLANT
  - NUTRIENT FEED INTERRUPTION, PH ADJUSTMENT FAILURE, HEAT EXCHANGER PLUGGING, ORP DEVIATION
- CHANGE IN COAL
- FGD OPERATION CHANGES
  - PLANT STARTUP/CYCLING
  - SORBENT OR HALOGEN INJECTION
  - SCRUBBER ORP
  - SNCR AMMONIA SLIP
- NEW WASTE STREAM – OUTAGE WATERS



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PREDICTING

- STUDY SYSTEM TRENDS
  - TEMPERATURE CHANGES
  - PH TRENDS
  - ORP TRENDS
  - NUTRIENT MONITORING/INLET COD
- WATCH FGD SYSTEM TRENDS

RECOVERING/RESTART

- MICROBES ARE NOT INSTANTANEOUS
  - RECOVERY/RESTART DEPENDENT ON REASON AND DURATION
  - ENGINEERING DESIGN TAKE INTO CONSIDERATION
    - RETENTION TIME
    - NUMBER OF STAGES
- BUGS ARE RESILIENT
  - EVEN IF HAVE AN OOPS MOMENT, SOME TIME AND CARE WILL GET THE SYSTEM BACK RUNNING

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DOCUMENTING LESSONS LEARNED

- TAKE THE TIME TO WRITE IT DOWN
  - SYMPTOMS
  - INVESTIGATION ACTIVITIES
  - SAMPLE RESULTS
  - CHANGES TO OPERATIONS
  - REVISED SETTINGS
  - RESULTS OF CHANGES

- MAY BE REQUIRED BY NPDES PERMIT AS RESPONSE TO EXCURSION
- WILL HELP ADDRESS FUTURE ISSUES
- **IF YOU TELL EVERYBODY!!!!**

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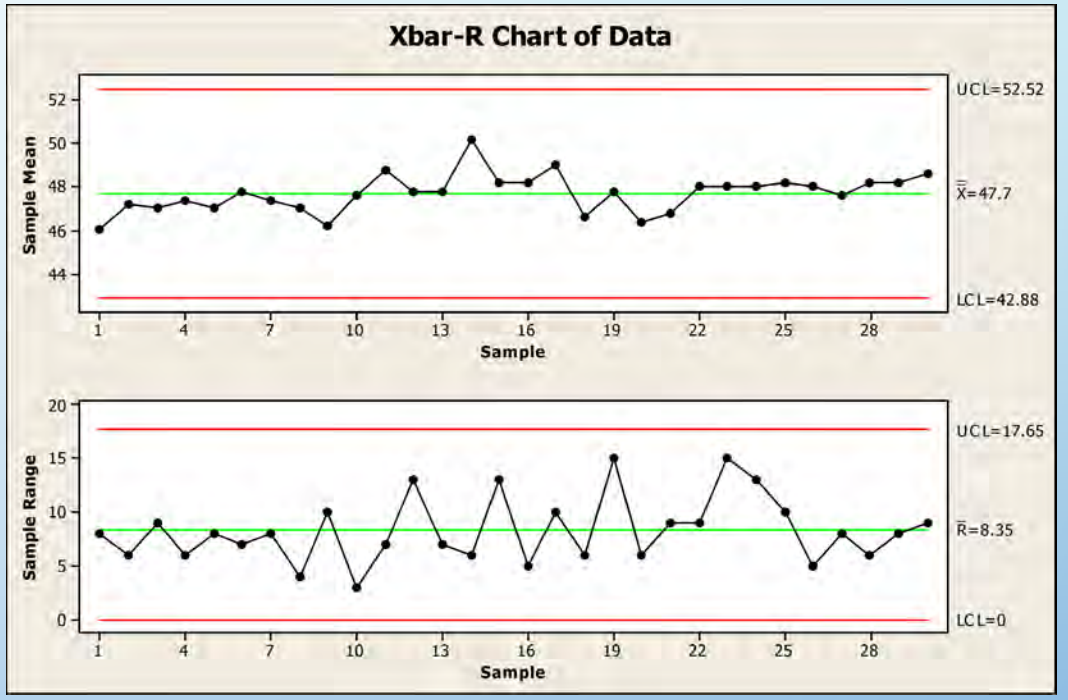
AVOIDING

- MONITOR CRITICAL PARAMETERS
- MAINTAIN CONTROL CHARTS
- TRACK TRENDS
  - PH, ALKALINITY, TEMPERATURE, ORP, NH_4, NO_3, PO_4 DIFFERENTIAL PRESSURE, OTHERS
- RECOGNIZE THE EARLY SIGNS OF AN UPSET
- CHECK SLUDGE/BIOMASS QUALITY PERIODICALLY
  - WHAT DOES NORMAL BIOMASS LOOK LIKE?
  - WHAT DOES "UPSET" BIOMASS LOOK LIKE?



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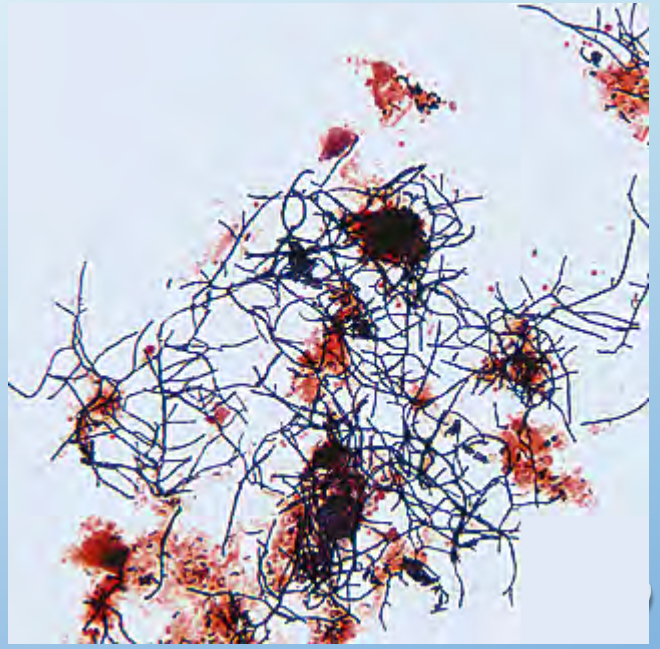
FILAMENTOUS GROWTH

- FILAMENTOUS BACTERIA CAN BE A PROBLEM FOR ANOXIC SYSTEMS
  - FREQUENTLY DUE TO LOW FOOD: MICROORGANISM RATIOS
  - WILL OUTCOMPETE DESIRABLE ORGANISMS AND CAUSE FOAMING
- TESTS:
- SLUDGE VOLUME INDEX/SETTLING VELOCITY
  - SAMPLE SLUDGE AND ALLOW TO SETTLE FOR 30 MINUTES
  - PUT 1 L SLUDGE INTO GRADUATED CYLINDER OR BEAKER
  - RECORD SLUDGE LEVEL EVERY MINUTE FOR FIRST 5 MINUTES, THEN EVERY 5 MINUTES THEREAFTER
  - IF SVI IS <100 ML – LIKELY NOT BULKING
- MICROSCOPIC EXAMINATION
  - MANY DIFFERENT FORMS



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NITRIFICATION TROUBLESHOOTING (AEROBIC)

- DROP IN REACTOR PH
  - POSSIBLE CAUSES:
    - NOT ENOUGH ALKALINITY, CHEMICAL FEED IMBALANCE, CHANGE IN FGD PH, INCREASE IN AMMONIA FEED RATE
  - ACTIONS:
    - CHECK PH, AMMONIA AND ALKALINITY IN INFLUENT AND EFFLUENT
      - ADD ALKALINITY TO RAISE PH IN REACTOR (TARGET 50 MG/L OR HIGHER)
      - IF INLET PH IS LOW, CHECK CHEMICAL FEED RATES, FGD OPERATIONS
      - IF INLET AMMONIA IS HIGH, CHECK AMMONIA SLIP AT SCR/SNCR

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NITRIFICATION TROUBLESHOOTING

- EFFLUENT AMMONIA IS TOO HIGH
  - POSSIBLE CAUSES:
    - NOT ENOUGH DO, TEMPERATURE PROBLEM, INCREASE IN AMMONIA FEED RATE, SRT TOO LOW
  - ACTIONS:
    - CHECK DO, INLET AMMONIA, TEMPERATURE, MLVSS
    - ADJUST AERATION RATE OR FEED RATE (INCREASE HRT) TARGET 2.0 PPM DO IN REACTOR
      - CAUTION IF USING AEROBIC NITRIFICATION BEFORE ANAEROBIC PROCESS, USE O2 SCAVENGER AT SELENIUM PROCESS
    - CHECK TEMPERATURE – ADJUST IF POSSIBLE
    - CHECK HISTORY (RECENT POWER FAILURE?)
    - CHECK SRT – DECREASE WASTING RATE
    - IF INLET AMMONIA IS HIGH, CHECK SCR/SNCR

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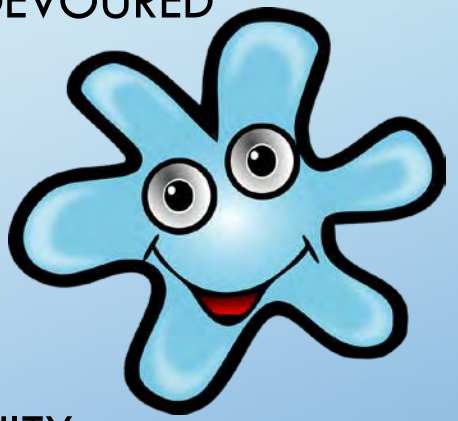
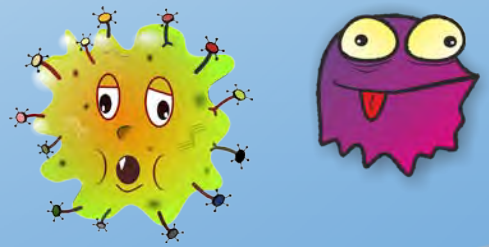
IN-FIELD EXPERIENCE

1. **BUGS LIKE TO TRAVEL:** BACKWASHES TO FRONT OF SYSTEM PROCESS CARRY MICROBES

2. **BUGS CAN BE PICKY EATERS:** EASIEST NUTRIENT SOURCE WILL BE DEVOURED FIRST PRIOR TO SELENIUM
   - DBA
   - OVERFEED NUTRIENT



3. **OXIDIZERS ARE A NO-NO:** BIOREACTOR IS A MICROBIAL COMMUNITY
   - ENVIRONMENTAL CONTROLS



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DENITRIFICATION TROUBLESHOOTING

- HIGH HEADLOSS ACROSS FILTER BED
  - POSSIBLE CAUSES:
    - EXCESSIVE SOLIDS, NITROGEN GAS BUILDUP
  - ACTIONS
    - CHECK LENGTH OF FILTER RUN
    - BACKWASH TO REMOVE SOLIDS (10 – 12 MIN)
    - BURP (1-2 MIN BACKWASH) TO REMOVE N2 GAS

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DENITRIFICATION TROUBLESHOOTING

- EFFLUENT NITRATE TOO HIGH
  - POSSIBLE CAUSES:
    - NOT ENOUGH NUTRIENT, PH OUT OF RANGE (<7 OR >7.5), TOO MUCH DO, NOT ENOUGH BIOMASS
  - ACTIONS
    - CHECK NUTRIENT FEED
    - CHECK ALKALINITY (<30), ADD ALKALINITY IF PH <7
    - CHECK DO (<0.5), ADJUST MIXING SPEED, ADD OXYGEN SCAVENGER

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DENITRIFICATION TROUBLESHOOTING

- EFFLUENT BOD/COD TOO HIGH
  - POSSIBLE CAUSES:
    - NUTRIENT OVERFEED
    - DBA
  - ACTIONS:
    - CHECK NUTRIENT FEED
    - MAINTAIN AT 3:1 (METHANOL:NITRATE)

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SUMMARY

- SELENIUM IS AN ESSENTIAL NUTRIENT
- BIOREACTORS ARE NOT NEW
  - MULTIPLE CONFIGURATIONS AVAILABLE
  - BUGS ARE EVERYWHERE
- O&M IS SIMILAR FOR CHEMICAL AND BIOCHEMICAL PROCESSES
- GOOD UNDERSTANDING AND MONITORING WILL RESOLVE MAJORITY OF UPSETS
- **PAY ATTENTION!!!!**

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QUESTIONS?

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THANK YOU!

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