1

Starting Soon: Biochemical Reactors (BCR) for Treating Mining Influenced Water (MIW)

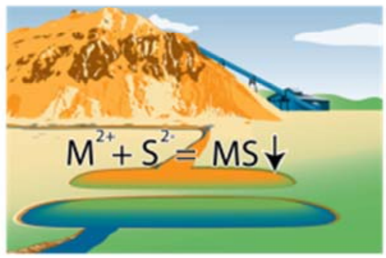
- Biochemical Reactors (BCR) for Treating Mining Influenced Water (MIW) at http://www.itrcweb.org/bcr-1/
- Download PowerPoint file
  - Clu-in training page at http://www.clu-in.org/conf/itrc/bcr/
  - Under "Download Training Materials"
- Download flowcharts for reference during the training class
  - http://www.cluin.org/conf/itrc/BCR/ITRC-BCRforMIW-DecisionFlow.pdf
- Using Adobe Connect
  - Related Links (on right)
    - Select name of link
    - Click "Browse To"
  - Full Screen button near top of page

No associated notes.

2

Welcome – Thanks for joining this ITRC Training Class

Biochemical Reactors (BCR) for Treating Mining Influenced Water (MIW)



Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)
Hosted by: US EPA Clean Up Information Network (www.cluin.org)

Mining influenced water (MIW) includes aqueous wastes generated by ore extraction and processing, as well as mine drainage and tailings runoff. MIW handling, storage, and disposal is a major environmental problem in mining districts throughout the U.S and around the world. Biochemical reactors (BCRs) are engineered treatment systems that use an organic substrate to drive microbial and chemical reactions to reduce concentrations of metals, acidity, and sulfate in MIWs. The ITRC Biochemical Reactors for Mining-Influenced Water technology guidance (BCR-1, 2013) and this associated Internet-based training provide an in-depth examination of BCRs; a decision framework to assess the applicability of BCRs; details on testing, designing, constructing and monitoring BCRs; and real world BCR case studies with diverse site conditions and chemical mixtures. At the end of this training, you should be able to complete the following activities:

Describe a BCR and how it works
Identify when a BCR is applicable to a site
Use the ITRC guidance for decision making by applying the decision framework
Improve site decision making through understanding of BCR advantages, limitations, reasonable expectations, regulatory and other challenges
Navigate the ITRC Biochemical Reactors for Mining-Influenced Water technology guidance (BCR-1, 2013)

For reference during the training class, participants should have a copy of Figure 2-1, decision flow process for determining the applicability of a biochemical reactor. It is also available as a 1-page PDF at http://www.cluin.org/conf/itrc/BCR/ITRC-BCRforMIW-DecisionFlow.pdf.

Participants should also be familiar with the ITRC technology and regulatory guidance for Mining-Waste Treatment Technology Selection (MW-1, 2010) and associated Internet-based training that helps regulators, consultants, industry, and stakeholders in selecting an applicable technology, or suite of technologies, which can be used to remediate mining sites.

ITRC (Interstate Technology and Regulatory Council) www.itrcweb.org
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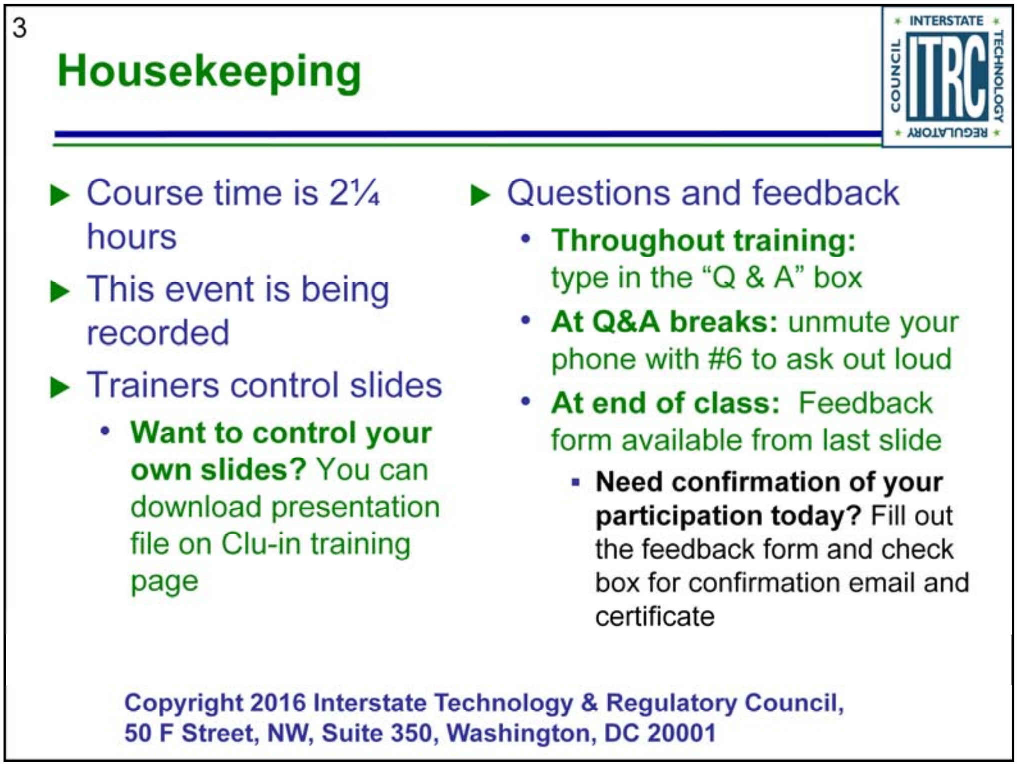
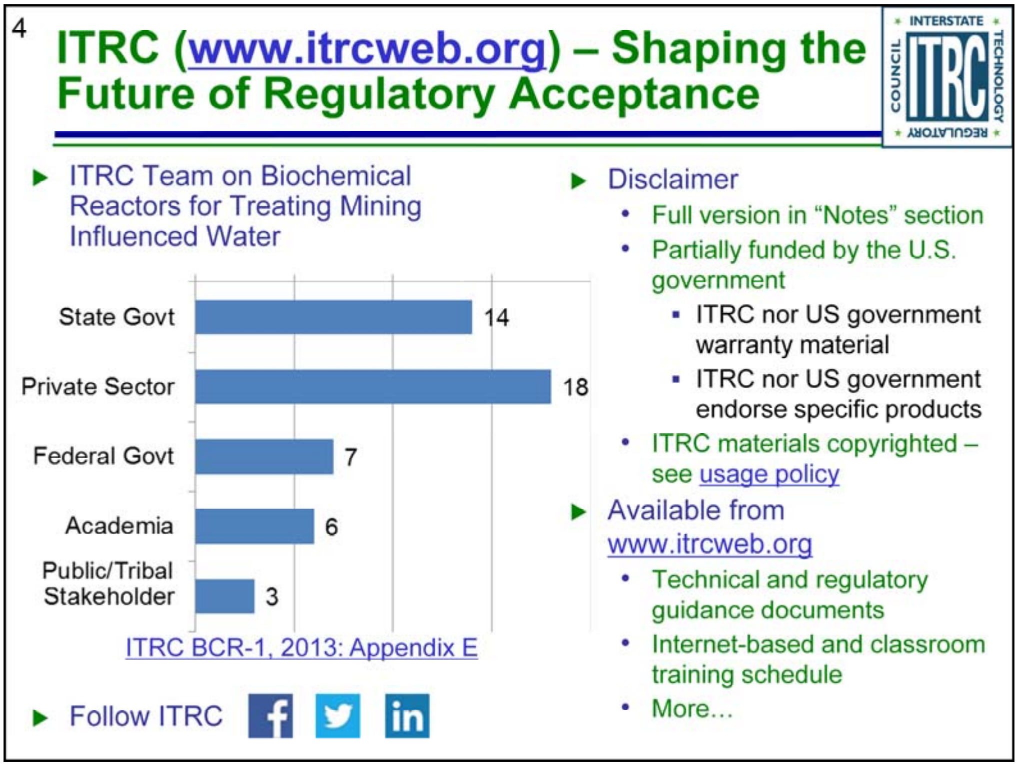


Although I'm sure that some of you are familiar with these rules from previous CLU-IN events, let's run through them quickly for our new participants.

We have started the seminar with all phone lines muted to prevent background noise. Please keep your phone lines muted during the seminar to minimize disruption and background noise. During the question and answer break, press #6 to unmute your lines to ask a question (note: *6 to mute again). Also, please do NOT put this call on hold as this may bring unwanted background music over the lines and interrupt the seminar.

Use the "Q&A" box to ask questions, make comments, or report technical problems any time. For questions and comments provided out loud, please hold until the designated Q&A breaks.

Everyone – please complete the feedback form before you leave the training website. Link to feedback form is available on last slide.



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For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the “contacts” section at www.itrcweb.org. Also, click on “membership” to learn how you can become a member of an ITRC Technical Team.

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Cherri Baysinger is the Administrator for the Section of Epidemiology for Public Health Practices with the Missouri Department of Health and Senior Services in Jefferson City, MO. She has worked for the state of Missouri since 1991, dividing her time between the Missouri Department of Health and Senior Services and the Department of Natural Resources. Regardless of which agency she was working for, Cherri has spent most of her career working on mining waste sites. Since 2007, she has overseen environmental health activities occurring throughout the state, including around Missouri's current and historic lead mining sites. In previous positions, she has worked on the Superfund project management side and prepared risk assessments for mining sites and other hazardous waste sites. Cherri is a regular guest lecturer in undergraduate and graduate level environmental health courses, covering topics such as risk assessment, hazardous waste, air and water quality. In her spare time, Cherri enjoys swimming, canoeing and dancing with her husband, Tom, and spending time with her three adorable, yet loud, granddaughters. Cherri has been a co-team leader for ITRC's Mining Waste Team since 2005. Cherri earned a bachelor's degree in Biology and a master's degree in Forestry, Fisheries and Wildlife from the University of Missouri-Columbia in 1982 and 1989, respectively.

Paul Eger is a volunteer with Minnesota Department of Natural Resources. He specializes in passive treatment of mining influenced water, waste management, reclamation and regulatory issues. Prior to 2011, he was a principal engineer with the Minnesota Department of Natural Resources, Division of Lands and Minerals, where for over 30 years he worked with environmental issues related to mining. He was a pioneer in the use of wetlands to remove trace metals from mine drainage, and much of his work focused on the development of successful passive treatment systems to control mine drainage problems. He has also been a leader in the development of cost-effective and environmentally safe reclamation using waste products, such as municipal solid waste compost, paper processing waste, and dredge material from Lake Superior. He served as an expert witness on water quality issues and at reclamation rules hearings and served on the Department's hazardous waste team, where he was responsible for the clean up of abandoned dump sites. Paul has been involved with ITRC for 10 years; initially as a member and instructor for the Constructed Treatment Wetlands team and later as a co-team leader and training instructor for the ITRC Mitigation Wetlands and Mining Waste teams. He earned a bachelor's degree in chemical engineering from the University of Rochester in Rochester, NY. Paul is a registered professional engineer.

Eduardo Gasca, P.E. is a Senior Environmental Engineer with Burns & McDonnell Engineering Co., Inc. in Chicago, IL. He has over 23 years of experience as an environmental consultant supporting industrial wastewater and environmental remediation programs including: Clean Water Act, RCRA, State Voluntary Cleanup, CERCLA and DOD BRAC programs. He has been involved in the characterization, design and implementation of remediation systems at multiple industrial sites. Eduardo has been an active member with the Biochemical Reactors for Mining-Influenced Water in ITRC since 2011. Eduardo earned a bachelor degree in Chemical Engineering in 1985 from the Universidad de Guanajuato, Mexico; and a master's degree in 1989 in Environmental Engineering from the Illinois Institute of Technology in Chicago, IL. Eduardo is a licensed Professional Engineer in the State of Illinois.

Christine Brown is a Hazardous Substances Engineer at the California Department of Toxic Substances Control (DTSC) in Cypress, California. She started working for the DTSC in 1993. Christine reviews Workplans and reports on remedial technologies. She has participated in ITRC teams on Attenuation Processes for Metals and Radionuclides, Environmental Molecular Diagnostics, Biochemical Reactors for Mining-Influenced Water, and DNAPL Site Characterization. She earned a bachelor's degree in biochemistry from University of California, Davis in Davis California and a master's degree in chemical engineering from Ohio State University in Columbus, Ohio.

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Today's Learning Objectives

- At the end of this training, you will be able to…..
  - Describe a Biochemical Reactors (BCR) and how it works
  - Identify when a BCR is applicable to a site
  - Navigate the ITRC guidance
  - Use the ITRC guidance as a framework for decision making (apply decision tree)

Improve site decision making through understanding of BCR advantages, limitations, reasonable expectations, regulatory and other challenges

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Training Outline

- BCR basics
- Determining applicability
- Designing and implementing a BCR
- Challenges and solutions
- Summary

ITRC BCR-1, 2013: Section 1

No associated notes.

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Mining-Influenced Water: Challenges

- Mining-Influenced Water (MIW) can create:
  - Negative environmental impacts
  - Downstream impacts
  - Community impacts
  - Liability for mine owners
- Remote mine sites can compound the challenge

Mining influenced water entering a stream. Note the color changes.

Mining influenced water, because of the metal content and pH, can create some very negative environmental effects. Those effects can range from decreasing biodiversity to completely killing aquatic life within the receiving water body. Those effects may continue for many miles downstream, as was the case with the stream shown on this photo. There is no aquatic life in the stream from the point where MIW enters the creek, shown in the upper left hand corner of the photo, for 32 miles downstream. Because there is no aquatic life, the stream is not used for fishing. Because of the contamination, the stream cannot be used for other recreational activities. This results in a net loss for the community as well as for the ecosystem. Along with the community and environmental losses come liability for the mine owner.

While some mining areas are located in populated areas, others are in very remote locations. Remedial activities in populated areas are difficult, but carrying out these activities in remote locations is doubly difficult.

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One Possible Solution….

- Biochemical Reactor (BCR)

Coal Pit Run BCR, PA

The 2010 ITRC Mine Waste Technology Selection Guidance and decision tree would suggest the use of a Biochemical Reactor in situations where mining-influenced water has created an ecological or human health issue AND

•the source is in remote locations

•there is a lack of infrastructure, such as power

•locations are difficult to access for the implementation of traditional treatment alternatives

An overview of the biochemical reactor technology was provided in the Treatment Technology Selection Guidance. The guidance that we are discussing today will provide quite a bit more information on functionality and applicability of biochemical reactors.

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What is a Biochemical Reactor (BCR)?

- ***…engineered treatment system that uses an organic substrate to drive microbial and chemical reactions to reduce concentration of metals, acidity, and sulfate in MIW.***

Penn Hill #2 BCR, PA

The team took time evaluating the MW-1 Guidance outline on Biochemical Reactors at the onset of developing our more detailed guidance on this technology. At the onset, we asked ourselves how we would define a BCR and resolved to make use of the definition provided on this slide. Thereafter we proceeded to investigate the use of BCRs to address MIW.

Although we are focusing on using BCRs to treat MIW, the technology can be used in other situations where an oxidation reaction can be used to reduce metals, sulfides, or nitrates. Those situations include food production, waste water treatment, fermentation and several other industries where metals, sulfates and metalloids are common contaminants. BCRs can be used individually or as part of a treatment train.

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Traditional Treatment Approach vs. Biochemical Reactor (BCR)

Iron Mountain Mine, Shasta County, CA
Traditional Lime Treatment Plant & Sludge Disposal Unit
Photo Courtesy of Douglas Bacon

Golinsky Mine, Shasta County, CA
Biochemical Reactor
Photo Courtesy of Douglas Bacon

When presented with a remote location, relatively small footprint, no utility or infrastructure options, an alternative technology in comparison to traditional technology may be appropriate.

BCRs can effectively treat mining influenced water when presented with a relatively inaccessible site and small footprint to locate the treatment unit upon, as is represented by the Golinsky Mine in Shasta County, California.

Comparison:

The traditional lime treatment plant at the Iron Mountain Mine in Shasta County, California has a large footprint and requires an even larger disposal unit for the sludge produced by the plant. The Richmond Mine of the Iron Mountain copper deposit contains some of the most acidic mine waters ever reported, with pH measured as low as -3.6. Combined metals (including copper, cadmium and zinc) concentrations have been measured as high as 200 g/L and sulfate concentrations have been measured as high as 760 g/L. As a result of EPA decisions, a capture control system was constructed to address the containment of most of the mine drainage flows. This system directs captured mine drainage into a reservoir, Slickrock Creek Retention Reservoir, constructed on-site. The mine drainage is then metered from the reservoir to a lime treatment plant.

Depicted in the upper left photo are the lime slacking plant, sludge thickener and sludge drying pads of the lime treatment plant. In the middle of the photo is the site's lime sludge thickener (rust colored water). The thickener has a diameter of approximately 290 Feet, covering approximately 66,019 square feet or 1.52 acres. The lime slacking plant covers approximately 28,380 square feet (0.65 acres). Four drying ponds located to the east of (and topographically lower than) the sludge thickener (small water body visible along the left margin of the photo) cover approximately 1,010,940 square feet (23.21 acres) and are used to dry the lime treatment sludge prior to its disposal in the pit repository (two are in use at any given time). Once dried, the sludge is hauled (approximately 6.79 miles west) up the mountain, to the historic open pit mine. The open pit at Iron Mountain currently has over a 100 feet (relative to depth) of sludge disposed within its boundaries. The open pit has a capacity to receive another 1.0 million cubic yards, and capacity is slated to be reached in 2030. At full capacity, the surface area of the pit will cover approximately 712,044 square feet (16.35 acres).

The Golinsky Mine BCR is approximately 13,700 square feet (0.32 acres) in dimension. The mine portals (3) are located approximately 1.5 miles up-gradient (west) of the only relatively flat location at the 20 acre mine site to construct the BCR on, the historic lime quarry. A pipeline was constructed to collect and convey the mine drainage to the BCR. The BCR was designed to manage approximately 38 L/min. The mine drainage has a pH ranging from 2.5 to 4 (containing metals including iron, aluminum, copper, cadmium and manganese). The BCR functions as a downward vertical flow BCR, with treated water being discharged to the underlying local soils via a buried flow dispersion structure. Treated water infiltrates to the alluvial-bedrock interface and then flows along the interface or through fractures in the bedrock, eventually discharging into Shasta Lake as a non-point source discharge. Metals precipitate out of solution, depositing into the bottom of the BCR. The BCR began operations in 2010.

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BCRs can be used:

- Various mining sites
  - Metals
  - Coal
- Remote sites
  - Limited Infrastructure
  - Extreme conditions
- Variable water qualities
  - pH
  - Sulfate
  - Metals and metalloids

Penn Hill #2, PA

Mammoth Mine, CA

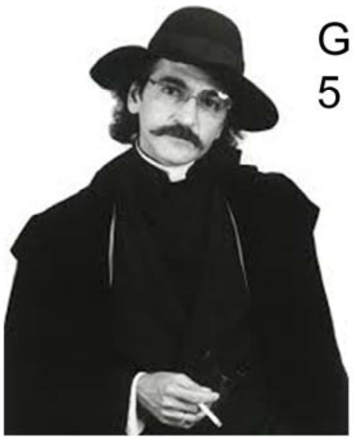
MIW be formed in both hard rock and coal mining areas. The Penn BCR shown in the upper photo is an example of MIW in a former coal mining area, while Mammoth Mine was a hardrock gold mine located in Northern California.

While some mining areas are located in populated areas or near towns or cities, many are located in remote areas. While the mines were operating, there were ways to access the area, however, once mining ceased, access was generally not maintained. That means that many areas with MIW may be difficult to access, they may be in areas without access to water, power or other infrastructure. These sites may also be in areas where seasonal access is an issue (snow in winter or extreme heat in summer).

BCRs can handle a variety of water qualities.

In terms of pH, BCRs can treat water which is acidic, basic or circumneutral. BCRs can reduce concentrations of sulfate, metals (Fe, Cu, etc.) and metalloids (As).

How does a BCR work?



Guido Sarducci's
5 Minute University

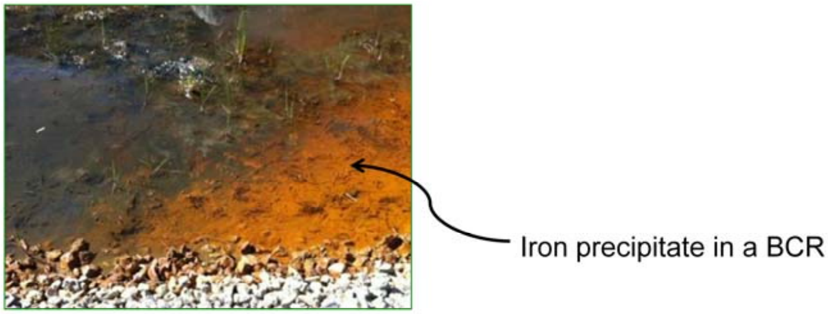
Intro to BCRs

No associated notes.

14

What Does a BCR Do?

- Precipitate metals and metalloids
- Produce circumneutral waters



Golinsky BCR, Lake Shasta, CA

Basically, the BCR uses microbes and an organic substrate to precipitate metals and metalloids. Then, the pH is adjusted to produce circumneutral water.

The photo here shows reddish iron precipitate at the interface of the substrate and free water in the Golinsky BCR in Lake Shasta, CA.

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How Does a BCR Do That?

- Sulfate reducing bacteria
  - Common bacteria
  - Present in soil
  - High concentrations in manure
- Remove sulfate by reducing it to sulfide
- Need oxygen free environment, sulfate, and an electron donor
  - Usually organic compound

Photo of sulfate reducing bacteria

The microbes that are used in a BCR are sulfate reducing bacteria. They are extremely common – you can find them in soil just about anywhere. However, manure is a fabulous source of sulfate reducing bacteria. And, manure is pretty easy to come by, no matter where you live.

Sulfate reducing bacteria remove sulfates by reducing them to sulfides, which then precipitate out of the water column.

In order for this reaction to occur, you need to create the anaerobic environment that sulfate reducing bacteria prefer. IN a BCR, the anaerobic environment is created by the degradation of the organic substrate.

Once you have the bacterial and the correct environment, all you need is sulfate (generally from the mining influenced water) and an electron donor, which is usually an organic compound.

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Chemistry 101

- Sulfate reacts with organic carbon
  - Produce hydrogen sulfide and bicarbonate
  - Hydrogen sulfide reacts with metals
  - Produce metal sulfide and hydrogen

$$SO_4^{-2} + 2\ CH_2O \ = \ H_2S + 2\ HCO^{-}_3$$

$$H_2S + M^{+2} \ = \ MS\ (solid) + 2H^{+}$$

- Limestone is often necessary
  - Increase the alkalinity
  - Consume hydrogen
  - Thus raise the pH

$$2H^{+} + 2HCO_3^{-1} \ = \ 2\ H_2CO_3$$

$$2H^{+} + CaCO_3(solid) \ = \ Ca^{+2} + 2HCO_3^{-1}$$

- If there is not enough M^{+2}
  - H_2S will be lost as a gas

In a bit more detail, sulfate in the mining influenced water reacts with organic carbon in the substrate to produce hydrogen sulfide and bicarbonate. The hydrogen sulfide reacts with metals to form a metal sulfide and hydrogen ions. Metal sulfides tend to be highly insoluble and precipitate out.

If you have more sulfate reduction than metals, the sulfate reduction proceeds in excess producing additional alkalinity. Alkalinity is also generated due to the reaction of the acid with the limestone that has been incorporated in to the media.

If there are not enough metals, hydrogen sulfide can be lost as a gas. In addition to a stinky nuisance, this can be a health and safety issue.

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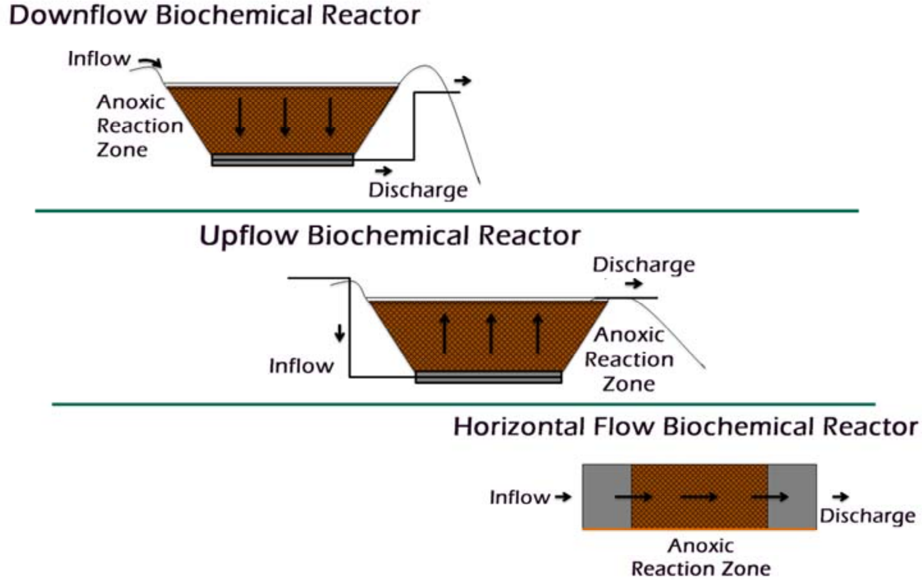
System Configurations



There are several general designs for bioreactors which can be used, based on your site characteristics. However, all reactors have a mechanism for MIW to enter and be distributed through the system, an anoxic reaction zone where water, microbes and substrate react to precipitate metals and metalloids, reduce sulfides and increase pH, then a way for water to leave the system.

The reactor can be designed so that:

-water enters the system from the top, moves down through the reaction zone, then exits through the bottom of the reactor;

- water enters the system from the bottom, moves upwards through the reaction zone and exits through the top of the reactor; or

- water enters, moves through and exits the reactor horizontally.

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Advantages

- Low energy requirements
- May be low maintenance if designed properly
- Can be used in remote situations
- Removes metals
- Flexible and versatile
- Treats wide variety of MIW
- Will improve ecological function of receiving stream

Low energy requirements

doesn't need a lot of outside power,

water moved through the system using gravity flow

May be low maintenance – not NO maintenance - if designed properly

Capital costs may seem significant, but O&M costs will be lower

Can be used in remote situations

Once the system is in , it doesn't need a lot of infrastructure to support it

Remove metals

Technology works for MIW as well as other situations where you want to remove metal contamination.

Flexible and versatile

May be used alone or in conjunction w/other treatments

Treats wide variety of MIW (acidic, neutral, etc.)

Will improve ecological function of receiving stream

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Cautions

- BCRs may not consistently meet strict water quality standards
- BCRs are not *walk away* systems
- Monitoring is required
- Maintenance may be needed periodically

Monitoring and maintenance are discussed in more detail later in the training and in the web-based guidance.

Ask Not What a BCR Can Do For You…

…Ask what this guidance can explain for your site

My fellow environment professionals… Ask not what a BCR can do for you, Ask what this guidance can explain for your site!

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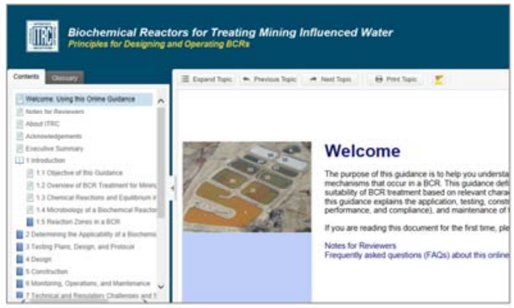
What This Guidance Can Do For <u>YOU</u>:

- Assess the suitability of using a BCR
- Support
  - Planning
  - Testing
  - Monitoring
  - Operating
  - Maintaining



www.itrcweb.org/bcr

- Provides examples of real world application of BCRs

ITRC MW-1 (Treatment Technology Selection Guidance) assists a user in choosing treatment technologies which may be useful in remediating a mine waste site. We are assuming for the purposes of this guidance that you have already determined that a BCR may be an appropriate technology for your particular site.

The BCR guidance is intended to provide further clarification on the suitability of a BCR for your site, by providing more detail on the design and operational aspects of a BCR. By gaining an understanding of the physical, chemical, and biological mechanisms of a BCR (and how such should be tested and monitored), the application of a BCR at a particular site can be assessed. This guidance explains (in more detail) the application, testing, construction, operation, monitoring (including operational, performance, and compliance), and maintenance of these treatment units. Such information is provided in detail to facilitate the site specific designing of BCR treatment units per the conditions at your site.

Please keep in mind that BCRs are only one type of treatment technology. They are often used in conjunction with other pre-and post treatment technologies. Those additional treatment technologies are mentioned in various parts of this guidance, but are not the focus of this guidance. For more information on additional treatment technologies, consider reviewing MW-1.

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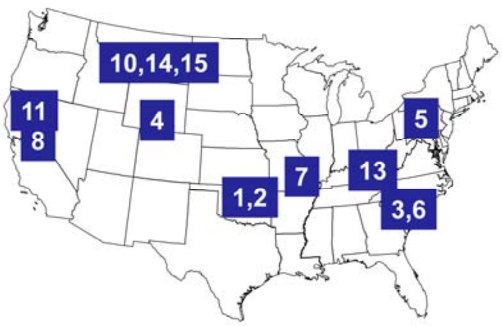
BCR Case Studies

1. Beaver Creek, OK
2. Mayer Ranch, OK
3. Haile Mine, SC
4. Ferris Haggerty, WY
5. Fran Coal Mine, PA
6. Brewer Mine, SC
7. West Fork, MO
8. Leviathan, CA
9. Wheal Jane, UK
10. Peerless Jenny, MT
11. Golinsky Mine, CA
12. Dankritz Mine, Germany
13. Copper Basin Mine, TN
14. Lady Leith Mine, MT
15. Luttrell, MT



Not on map:
9 Cornwall, England
12 Sachsen, Germany

ITRC BCR-1, 2013: Appendix B

The guidance provides further information on the application, design, testing, operation and monitoring of BCR treatment units, through the provision of case study write-ups, which are provided in Appendix B of the web-based guidance.

Case studies are another tool from which users of the BCR-1 guidance can gain information on the real world application of BCRs. The information contained in the case studies can facilitate an understanding of site specific parameters which have (in part) caused for BCR design modifications. As noted earlier on, BCRs are not a "cookie cutter" technology and the case studies exemplify why.

The team collected and presents in the guidance 14 case studies, collected from the contiguous United States and from Europe (2). The case studies exemplify the use of BCRs to address MIW from both hard-rock and coal mining sites.

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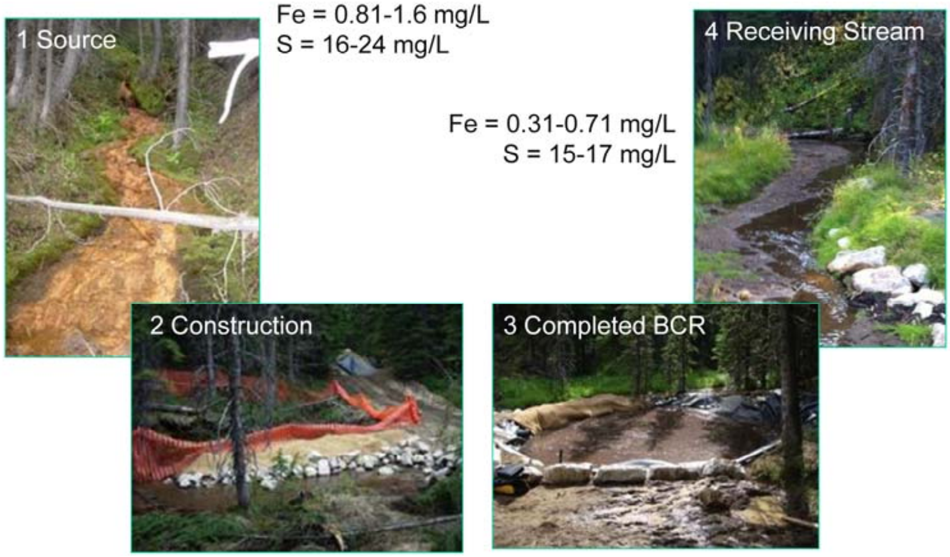
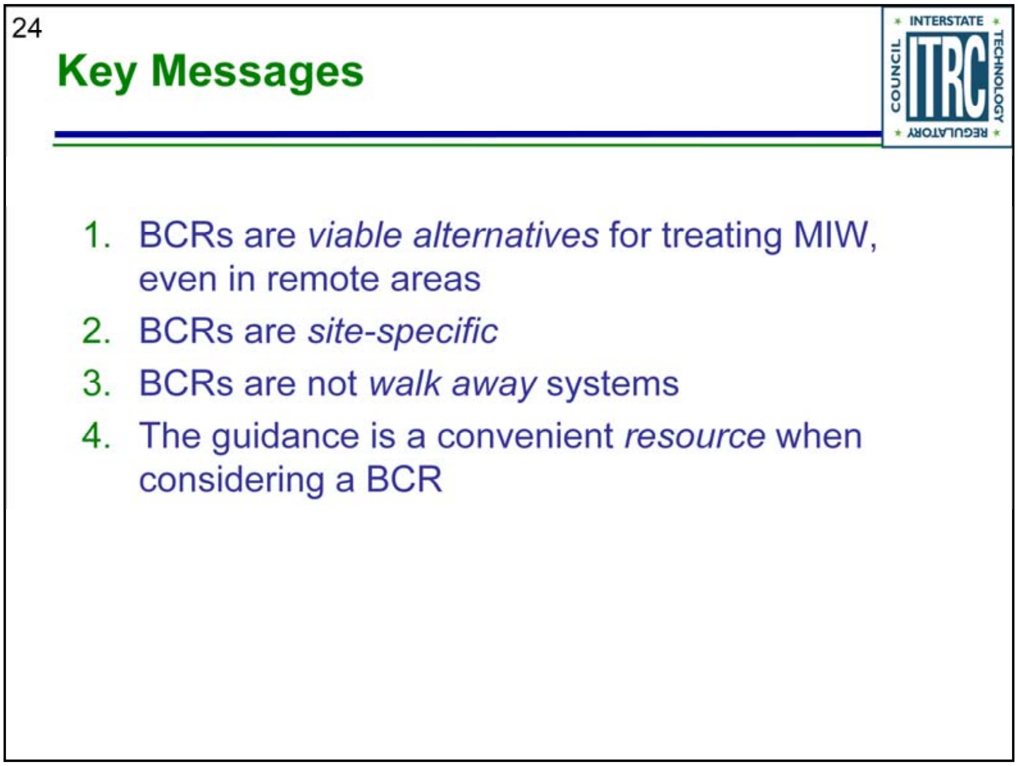
Lady Leith BCR, Jefferson Co, MT



ITRC BCR-1, 2013: Appendix B14

These four photos show the Lady Leith Mine. The site is located in a very remote part of Deerlodge National Forest in Jefferson County, MT. The BCR was designed to remove iron and zinc from mine influenced water (MIW) collected from the Lady Leith Mine; it consists of a single sulfate reducing bioreactor (SRBR) fed from the bottom. The photos show, moving counter clockwise, the source of MIW, water exiting the partially collapsed adit for the Lady Leith Mine (note the orange-red color), the BCR during the construction phase (BCR is in side the orange construction fence); the completed BCR and the receiving stream (note the lack of orange/red color).

Influent concentrations of iron and sulfur range from 0.81-1.6 mg/L and 16-24 mg/L, respectively. After treatment in the BCR, the iron and sulfur concentrations were reduced by approximately half in the effluent (iron, 0.31-0.71 mg/L and sulfur, 15-17 mg/L).



Before we move into the next section of today’s training, lets revisit some key concepts which this training has and will emphasize.

1.BCRs are a viable alternative for treating MIW, even in remote areas

2.BCRs are *site-specific*, as noted this technology is not a “cookie cutter” technology site specific parameters and treatment standards have to drive the design for BCRs to be successful.

3.BCRs are not *walk away* systems, they require maintenance and monitoring to ensure the biological functions and chemical reactions are sustainable.

4.This guidance is a convenient resource when considering the use of a BCR, for new and experienced site personnel, regulators and interested stakeholders.

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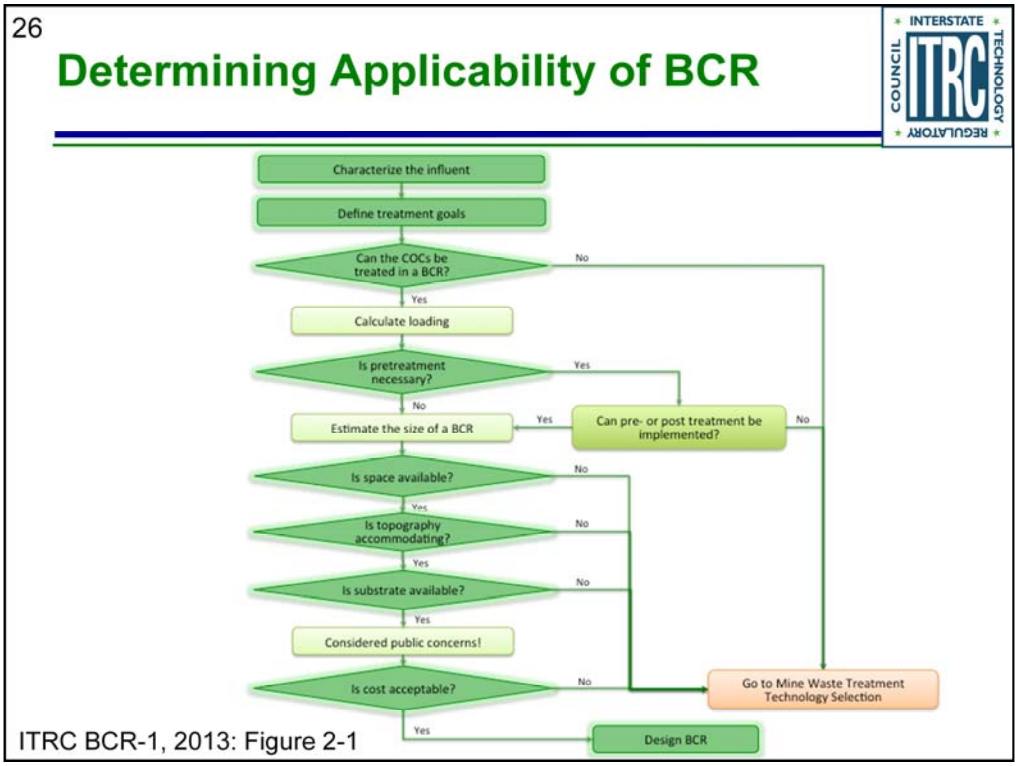
Training Outline

- BCR basics
- Determining applicability
  - Decision tree and BCR selection
- Designing and implementing a BCR
- Challenges and solutions
- Summary

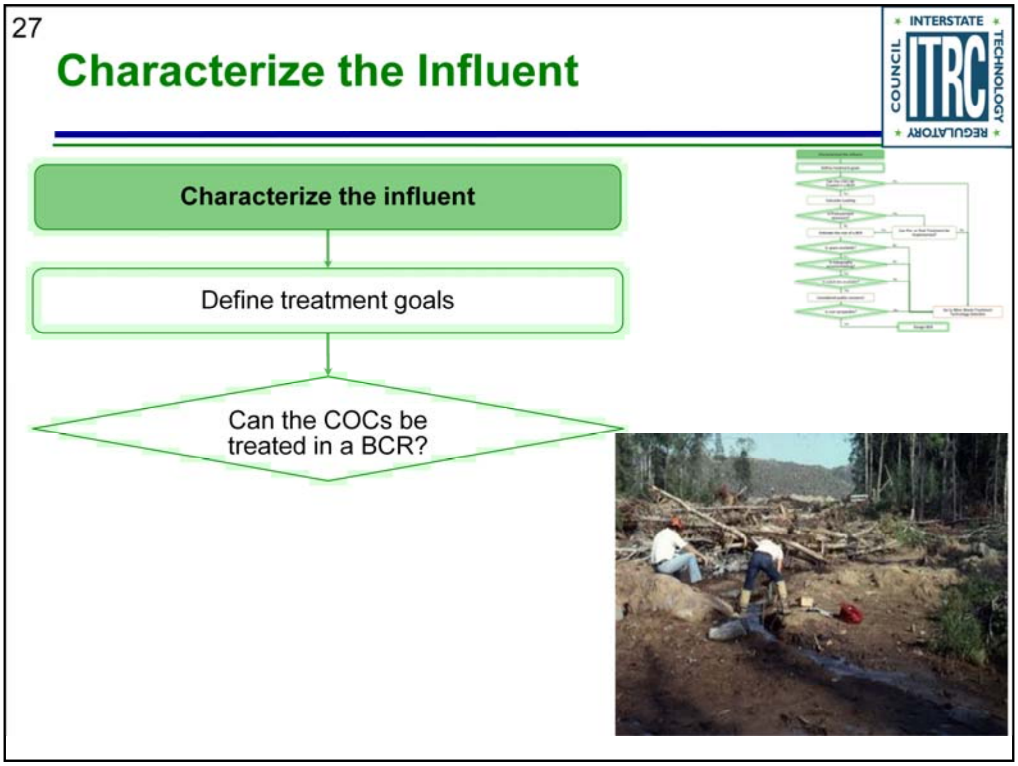
ITRC BCR-1, 2013: Section 3

No associated notes.

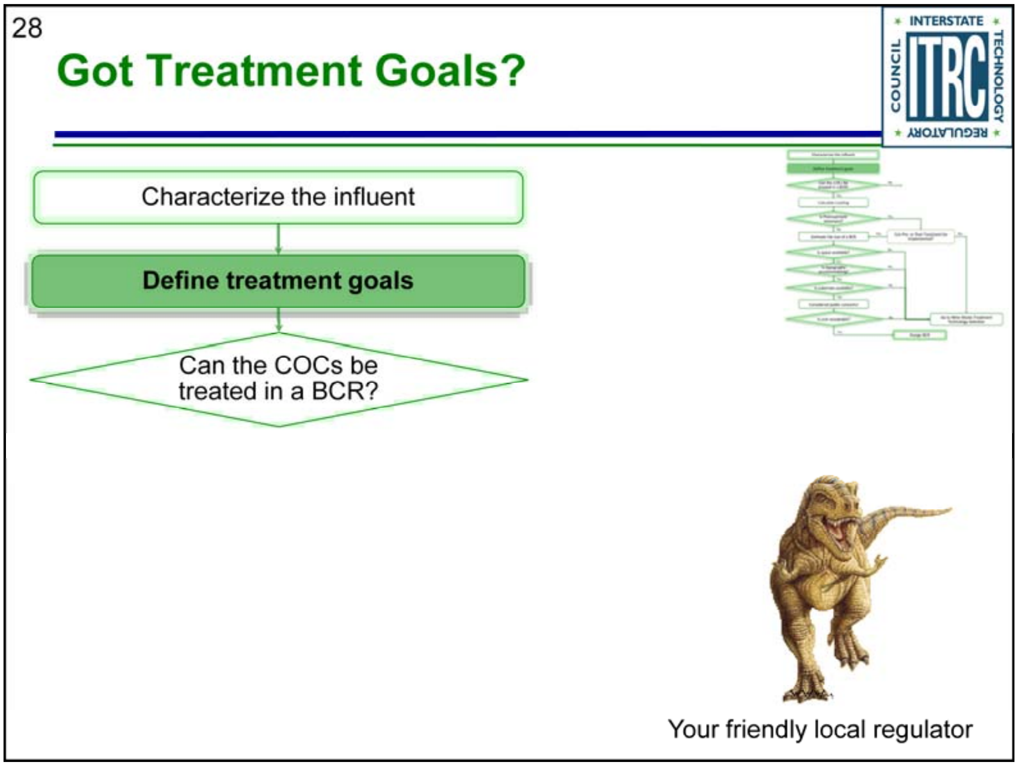


Intro slide, document includes decision tree to help determine if a BCR is right for your site, next few slides we'll walk thru tree and discuss.

Explain how they can use the decision tree to migrate through the guidance and remind them that they should have downloaded a copy of the decision tree prior to the training.



Characterization includes both flow and quality, average and extreme, ideally have a minimum of 1 year



Talk to regulatory agency, critical that have clear understanding of what limits are

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Can the BCR Treat Your Water?

Characterize the influent

Define treatment goals

Can the COCs be treated in a BCR?

Need to make sure the contaminants are removed in an anaerobic environment, next slide provides that info

Is My Water BCR-Worthy

Periodic Table of Treatable Elements

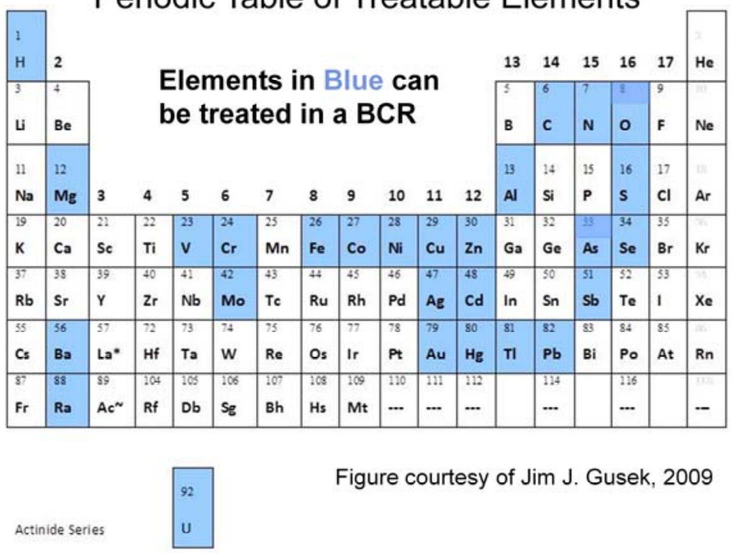
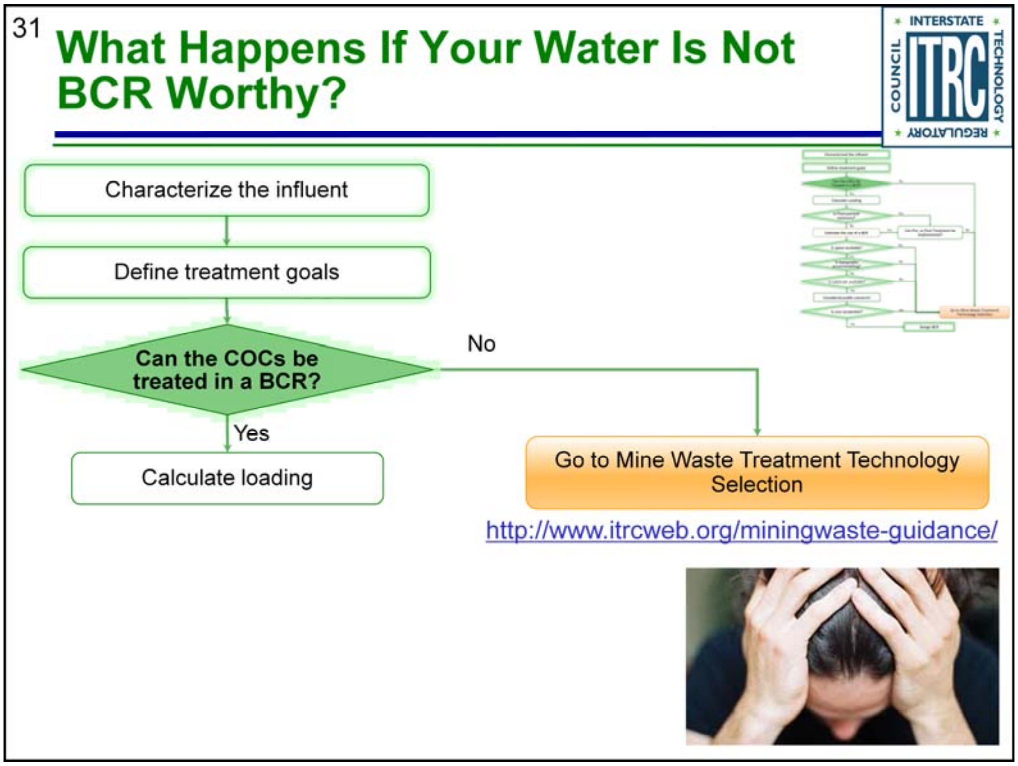
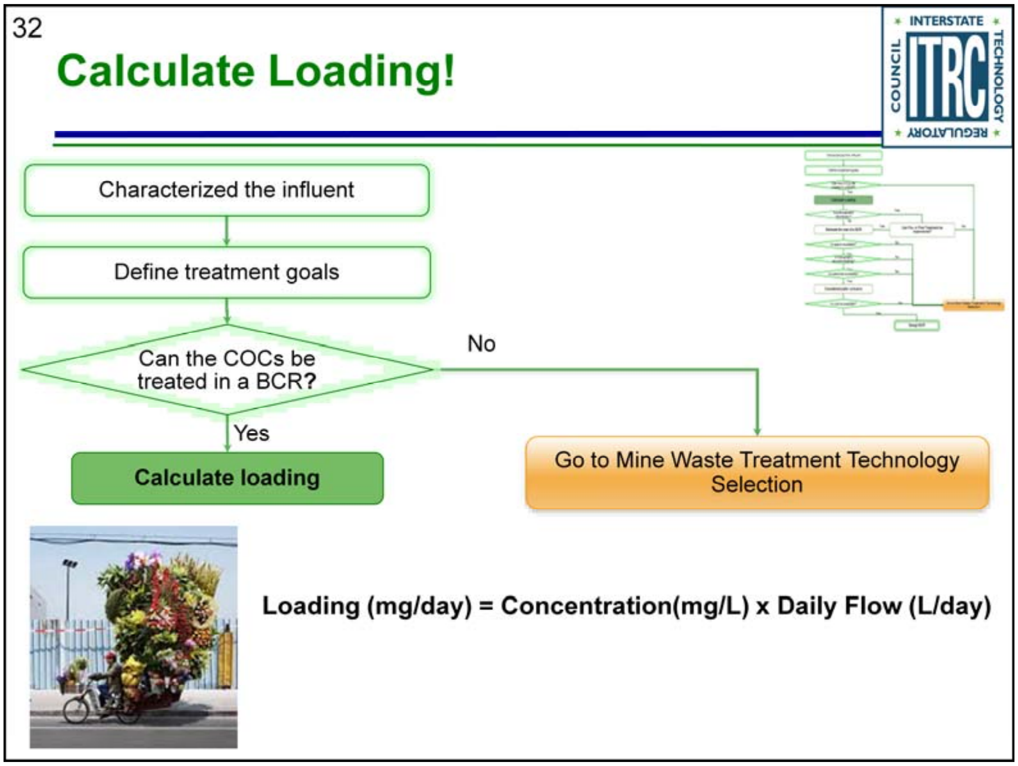


Figure courtesy of Jim J. Gusek, 2009

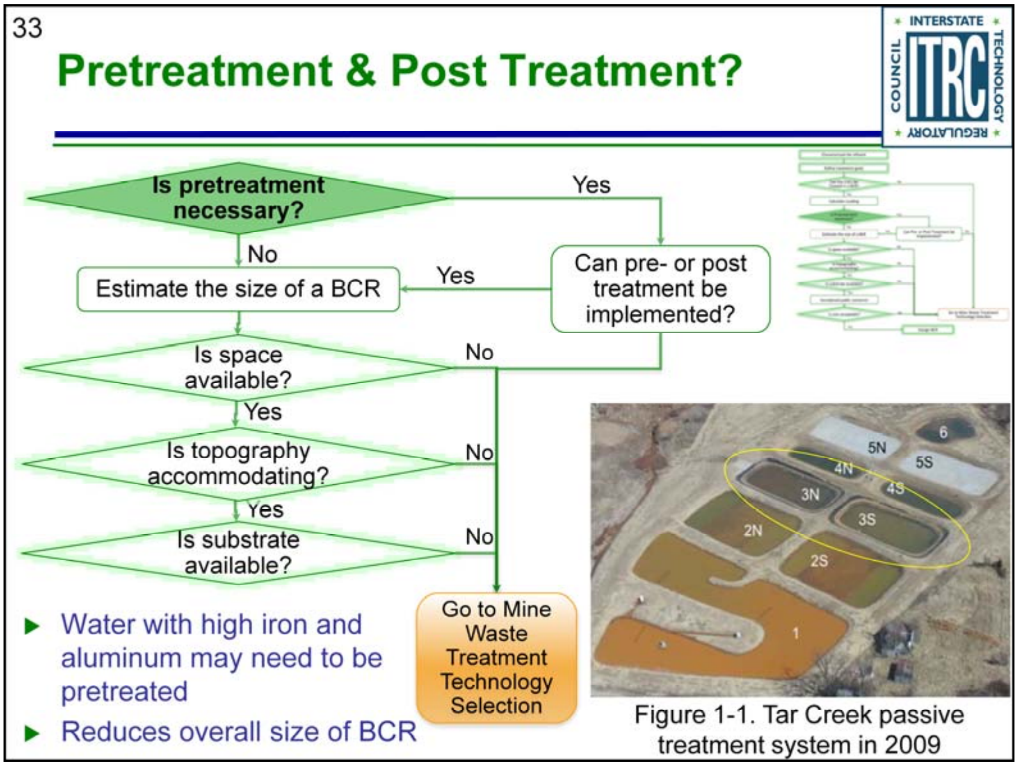
Adapted from Jim Gusek, Periodic table of passive treatment,



Our first document provides assistance if the contaminants are not treatable in a BCR



The design is based on the total mass coming into the system, i.e., the load



Factors that influence pretreatment

Land availability

topography

Infrastructure

Climate

Substrate availability

Cost

BCRs can treat low pH with high Fe and Al but can require very large systems. It is often more cost effective to do pretreatment.; either passively as shown in the photo which is the Maier Ranch treatment system in OK, or semi-passively, with a pH adjustment unit , like an Aqua Fix

Mayer Ranch

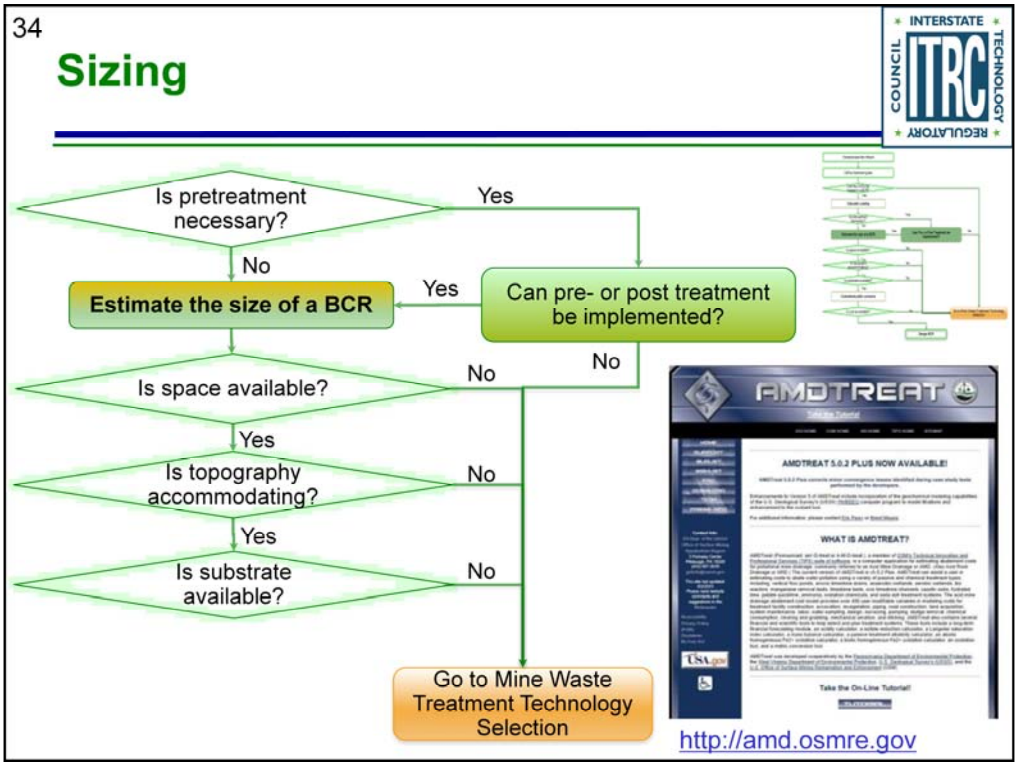
1 is iron oxidation and settling

2 is surface flow wetland

3 is BCR

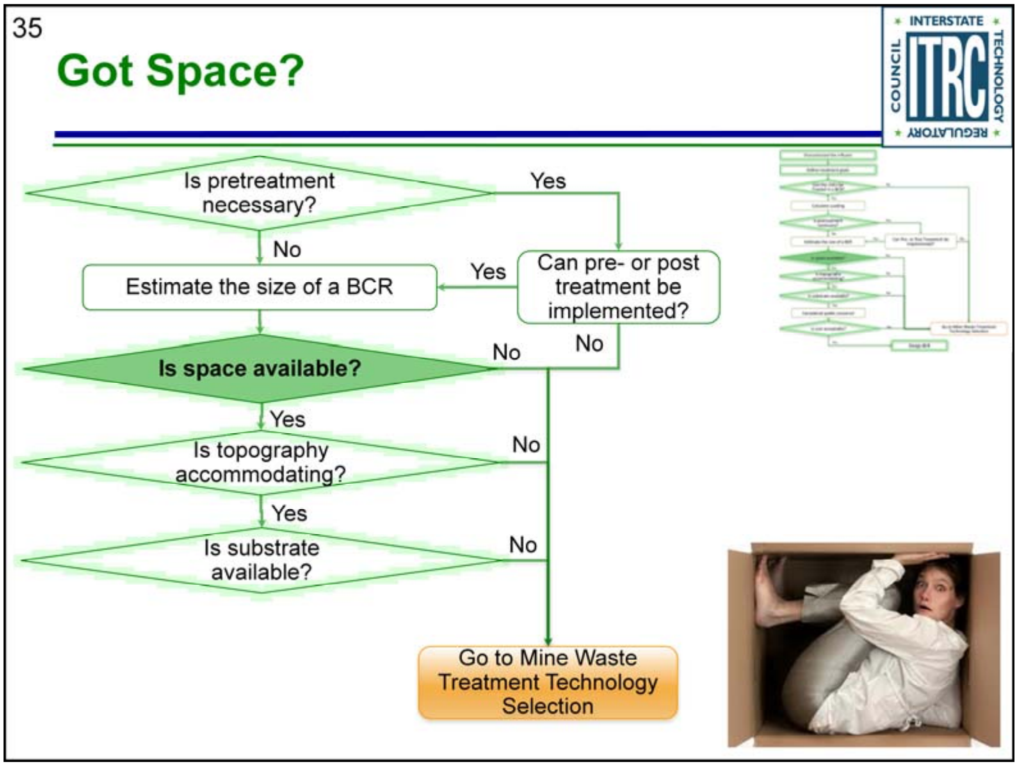
4 is aeration

5 is limestone bed

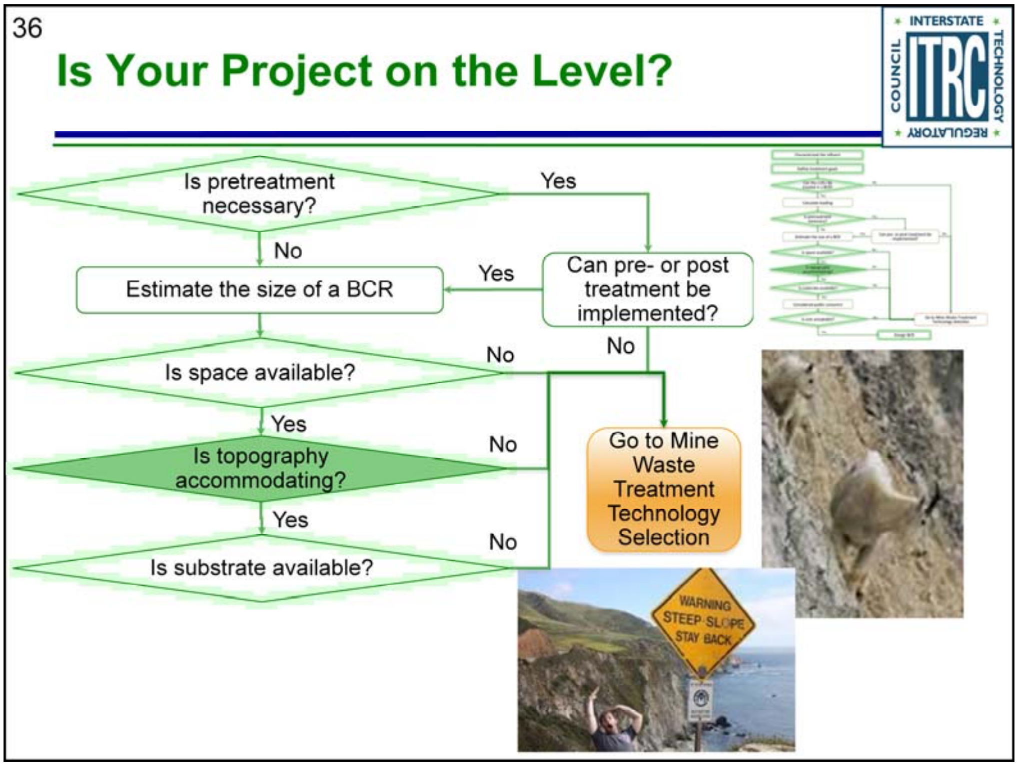


We will address in more detail later in training, and there is a detailed discussion in the guidance

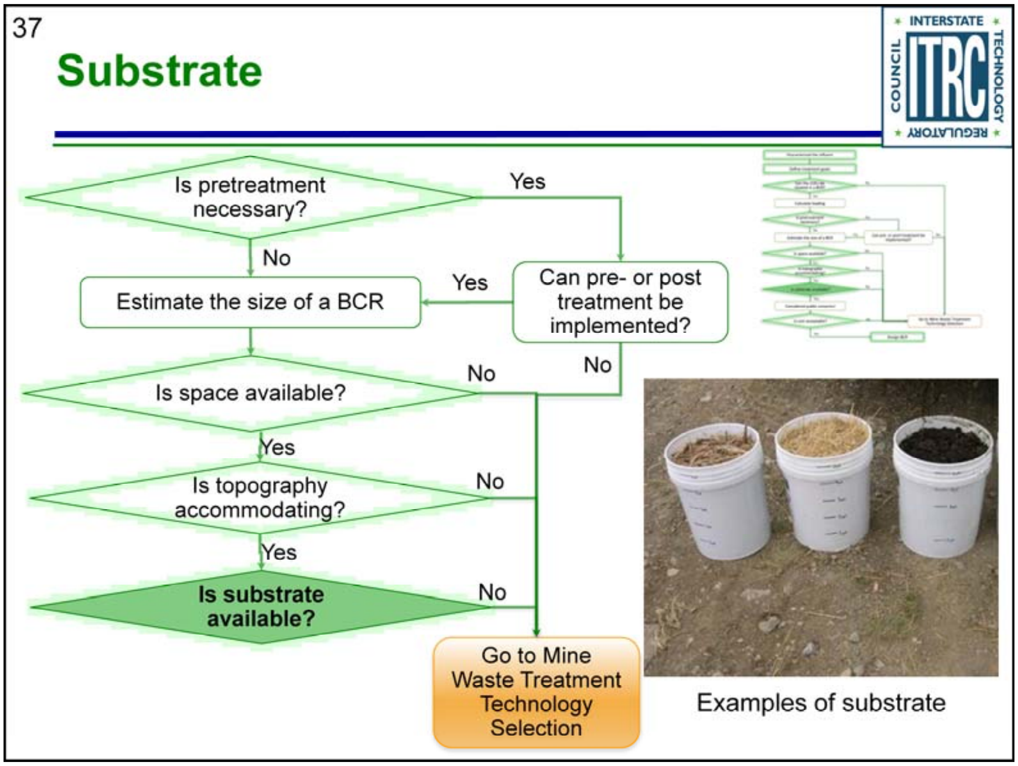
AMD treat is free software developed by OSM which allows user to estimate size and preliminary cost



The BCR must fit on the site, or water needs to be piped to an area where space is available, in general, passive systems have a much larger footprint than an active treatment plant



Many abandoned sites particularly in west are in steep terrain, at the Golinsky site, water was piped about a mile to a level spot so the BCR could be built



This is usually not an issue, since the goal is to use locally available materials to minimize shipment costs; don't need a "designer" substrate

For example in eastern coal fields, mushroom compost is often used, but not generally available in west

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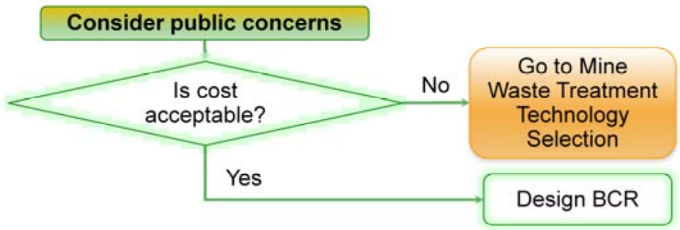
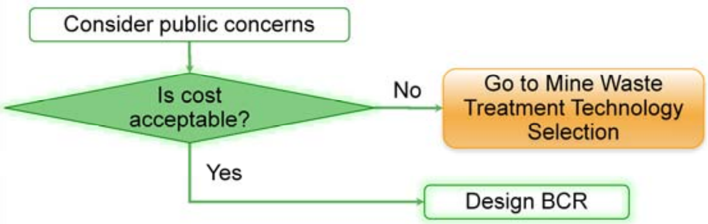
How Close to a BCR Would You Live?



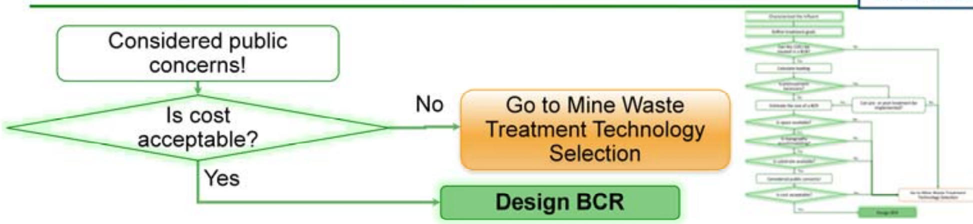
Although to those of us who work in passive system, the smell of H2S shows the system is working, you don’t want to live next to it. In areas where residences are close by the smell could be a major roadblock. The smell is particularly bad at startup.

Cot



It’s always a bottom line question.

Design



Coal Pit Run BCR, PA

The next section we'll discuss design in more detail.

Training Outline

- BCR basics
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- Summary

ITRC BCR-1, 2013: Section 3

You've used the decision tree and decided that your water can be treated in a BCR ;the site can accommodate it and costs appear within your budget. Now it's really time to have some fun- let the testing and design phases begin!

Treatability Testing

- What is needed for treatability testing?
  - Site MIW
  - Substrates

Hay

Wood Chips

Limestone

Want to use actual site water, not simulated.

Substrates –locally available and priced within budget and provides one of the characteristics on the next slide

Substrate Selection

- Characteristics of an effective substrate:
  - Source of long-term carbon source
    - Electron donor (food/energy source)
  - Source of short-term carbon source
    - Electron donor (food/energy source)
  - Source of microbial inoculum
  - Source of alkalinity
  - Good permeability
  - Microbial attachment sites
  - Locally available

reference table in guidance

Other factors affecting substrate selection

Availability

Cost

Chemical composition of substrate (leaching?)

Substrates

Function	Material
Long term carbon	Wood chips, sawdust, walnut shells, mushroom compost, other composts, chitin products, rice hulls
Short term carbon	Manure, hay, straw, chitin products, yard waste, brewery waste, beet pulp, dairy whey, acetic acid, ethanol
Microbial inoculum	Ruminant manure, other BCRs, POTW sludge, sludge pond or slime dams at mining sites, or septic system products
Alkalinity	Limestone, seashells, fly ash, cement kiln dust
Permeability	Sand, gravel, wood chips, nut shells, crushed rock,
Microbial attachment	Provided by all materials; in liquid reactors provided by rock matrix

Almost all BCR substrates are now mixtures, to provide all these functions

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Proof of Principle

- Lab test
  - Screening
  - Can I treat my water in an anaerobic environment?
  - What substrate is best?

-was widely used in early days of BCR development

For common contaminants and typical substrates generally not used

Would use if suspect MIW might be toxic, waste substrate that has not been tested before, or for a parameter that has not been tested or very limited data is available, e.g., antimony

proof of principle

Photos of bottles in lab (Jim)

Particularly important if think have toxicity testing or new water, new contaminants (e.g. Antimony)

Consider Modification to chapter 3 title – i.e. Treatability Study Design and Testing Protocols

-The phase of testing depends on the client, history of the site, funding available, client's previous use of technology, stakeholder preference, similarity to other sites, etc…..

-Discuss definitions of phases – perhaps modify definitions.

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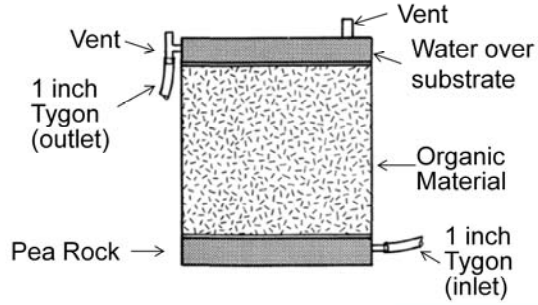
Testing

- Field test
  - 55 gallon barrels (typical)
  - Evaluate media
  - Residence time
  - Loading
  - Pre-and-post treatment if applicable
  - Other parameters



Drum BCR field test

-Duration 3-6 months

Laboratory or field study

Determine estimates of percent metal removal, sulfate reduction rate, hydraulic retention time

Test pre-and-post treatment if applicable

Identify potential secondary contaminant releases

Identify substrate selection

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Pilot Test

- Field test
- Adequate data to design full scale system
  - 1-10 gpm (typical)
  - Lined cell
  - Operating conditions and performance over time
  - Other parameters

Field Test

-minimum of 1 year, provides performance under field conditions, evaluate seasonality and long term variation in treatment

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ITRC BCR-1, 2013: Section 4

Now what do we do with all the data we just collected in our testing phase

Design

Prior

Proper Planning

Prevents Poor Performance

Politically correct version of the 7 Ps: Planning is critical

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Design Inputs

- Detailed design inputs
- Characterization
  - MIW flow and quality
    - Average and extremes
  - Site
    - Workable area available
    - Detailed site map
    - Climate
      - Average
      - Extremes
  - Treatment goals
  - Pre-and post-treatment?

Consider how flow and chemistry of site may change; are there other site activities occurring that can reduce or increase load

Effect of climate change- more intense precipitation, extended drought?

Influent Chemistry Issues

- iron
- suspended solids
- aluminum
- mercury – potential methylation
- potential inhibitory constituents
  - low pH – inhibitory to bacterial growth
  - High oxygen – Need to get to a reduced condition
  - High nitrate – need to reduce nitrate before can reduce sulfate (nitrate is preferred over to sulfate)
  - High metals – potential toxicity

Performance Data

- Seasonal variability
- Loading range
- Residence time
- Substrate mixture
  - Thickness
  - Degradation rate
  - Metal removal efficiency

No associated notes.

What Size BCR Do I Need?

- Balance the amount of sulfate reduction with the input contaminant load
  - Total amount of sulfate reduction = volumetric rate of sulfate reduction (mmoles/m^3/day) x volume of reactor (m^3)
  - Contaminant load = sum of all contaminants in input water (mmoles/day)
    - Metals (Me^{+2}, Me^{+3} ;+ H^+)= total acidity

Goal is to have a perfect balance between the total amount of sulfate reduction and the total acidity (metals + acid) load

This gives the perfect system which is not achievable in a passive system.

The rate has been determined by your testing, now the size is determined by the total contaminant load that needs treatment

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BCR Size Calculations

- Compute total acidity load (metals + acid)
  - Use flow and concentrations from characterization

Total acidity load = Σ *m*mole divalent metals (M^{+2}) in input + 1.5 Σ *m*mole Al^{+3}, Fe^{+3} + 0.5 (1000×10^{-pH})

- Volumetric sulfate reduction rate
  - Determined from testing data

$$\text{Volume of reactor}(m^3) = \frac{\text{total acidity rate } (m\text{mole/day})}{\text{Sulfate reduction rate } (m\text{mole}/m^3/\text{day})}$$

These equations assume that the system will be in perfect balance; try to estimate long term sulfate reduction rate from long term pilot to insure long term treatment

This means likely will have initial excess of sulfate reduction and resulting H2S emissions

Also generally want to insure that can treat specific high flow and high concentration which also gives a larger BCR than needed to treat low flows

Can sometimes use overflow to feed a second BCR in highflow, or blend BCR effluent with untreated high flow to provide some treatment

Design Adjustments

- Does it fit?
  - Adjust design if necessary
  - Volume = area x depth
    - Maximum depth ~ 6 ft
  - Bugs on booze?
    - Supply carbon source as liquid
    - Ethanol, molasses

Photo is pilot in northern MN, tank contains ethanol, horizontal subsurface flow

Liquid substrate is used directly by sulfate reducers so reaction rate is much higher, in lab tests for the site shown in the photo, rates of 1000 – 3000 mmoles/m3/day were achieved or about 3-10 times the rule of thumb rate of 300 for solid based systems. This would mean that a liquid fed BCR for that site could be 3 to 10 times smaller than a solid substrate

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Got Flexibility?

- Provide flexibility
  - Parallel treatment trains

Parallel systems: Photo courtesy of Paul Eger

Parallel systems can be used to more efficiently treat high flows and at some point the substrate will need to be replaced. If done during a low flow period, maintenance or replacement can be done on one cell while the other cell continues to treat the flow

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Need More?

- Appendix C. BCR Calculation Examples
- AMDTreat (http://amd.osmre.gov/)

Here's where you can find more detail and more equations!

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The Big Question – How Long Will It Last?

- Typical estimate 10 - 20 years
- Initial estimates
  - Carbon consumption
  - Limestone consumption

This is always a big question. We now have systems that are approaching 10 years of operation. Many of older systems when technology was new failed within 3 years or less. As we began to understand them, the design changed and they are working better and longer.

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Questions & Answers

Follow ITRC

Penn Hills Lower BCR, PA

Penn Hills BCR upper effluent, PA

Outfall from Penn Hills BCR

No associated notes.

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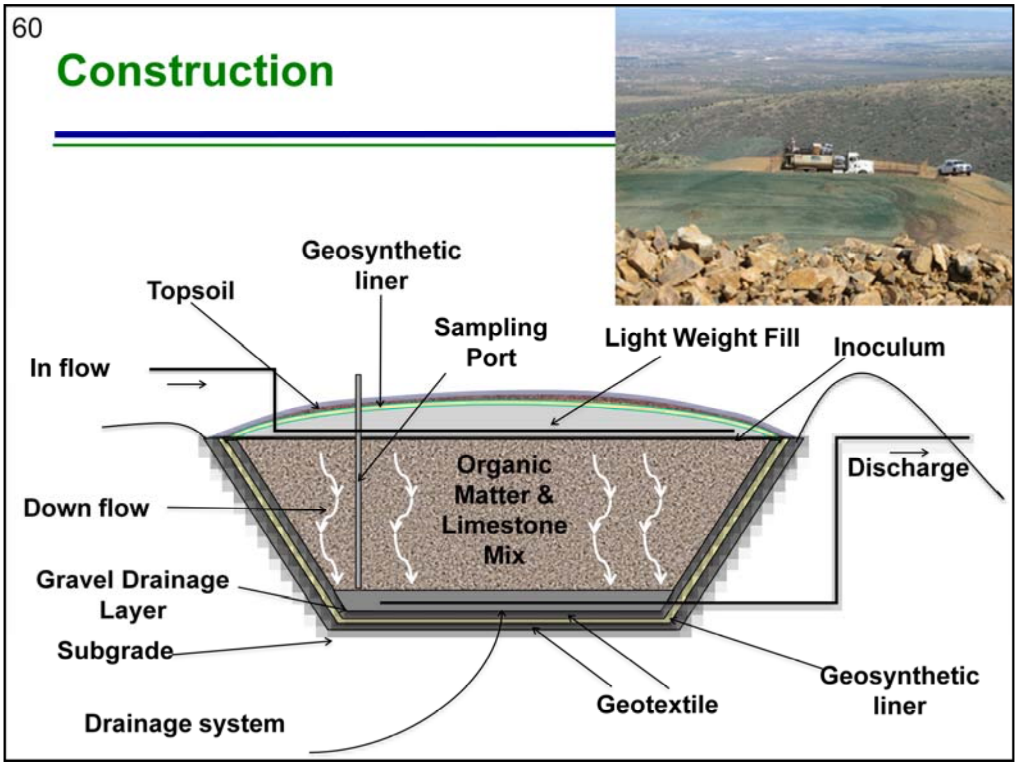
ITRC BCR-1, 2013: Section 5

No associated notes.



Cross section, schematic

Final view of BCR

Will walk thru each component

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Sub-grade Preparation

Good subgrade is critical, most systems are now built with synthetic liners, these require a well prepared and smooth bedding, subgrade generally must be approved by installer

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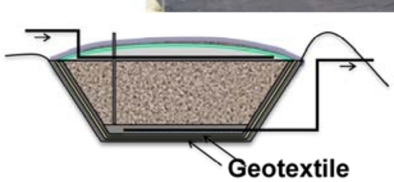
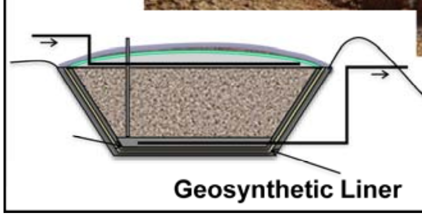
Placing Geotextile Underliner



Geotextile is often placed over subgrade, although not technically needed if you have a sand layer or a soil without any rocks > 3/8”:

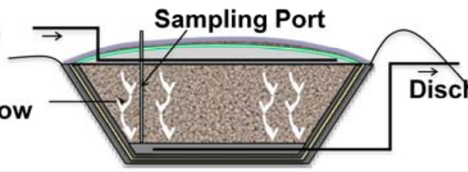
LLDPE Liner Installation



For small systems liner can be installed in one piece (100 x 100) for larger systems Liner is installed as individual sheets and seamed in field, a good construction QA program is critical to insure proper installation and prevention of leakage

After the liner is installed a geotextile is placed over it

BCR piping Installation



Piping is generally PVC, drainage pipe is perforated, can buy preslotted or slot or drill in field

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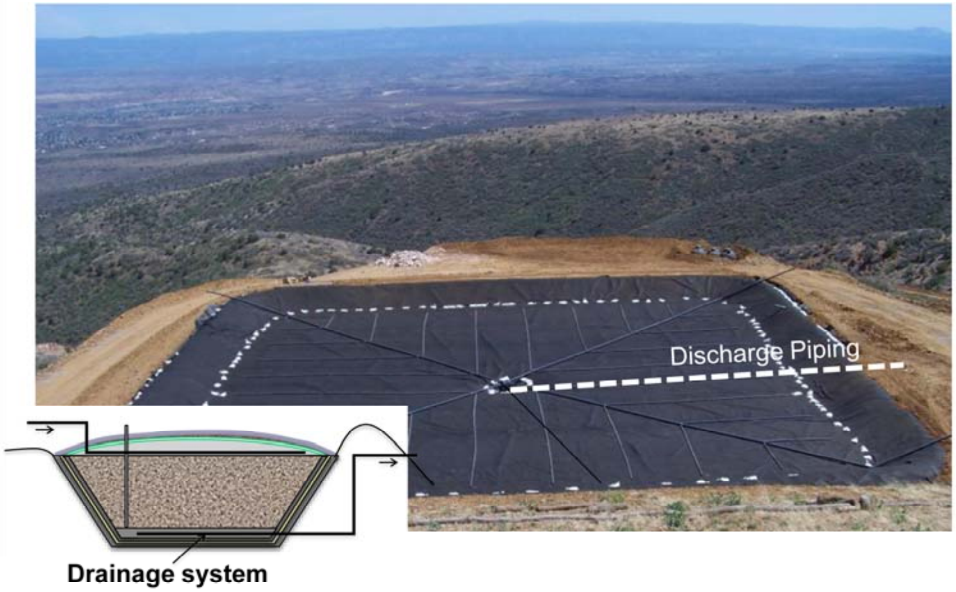
Drainage Collection Piping



Overall view of system, designed to try and get even flow through substrate

Gravel Placement

Gravel Drainage Layer

Various ways to install gravel, want to avoid having equipment directly on liner so use methods that can place gravel from dike

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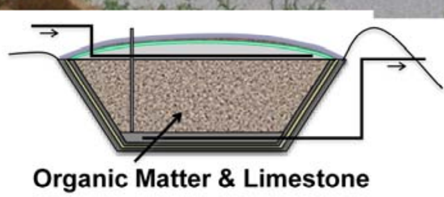
Mixing Organic Substrate

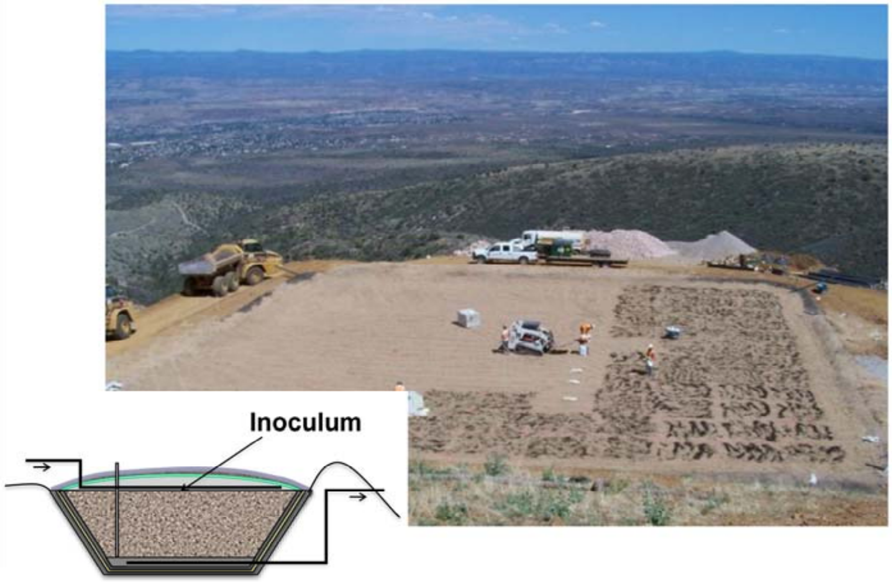
Variety of ways to mix, need to have on site overview to insure complete mixing

Substrate Placement



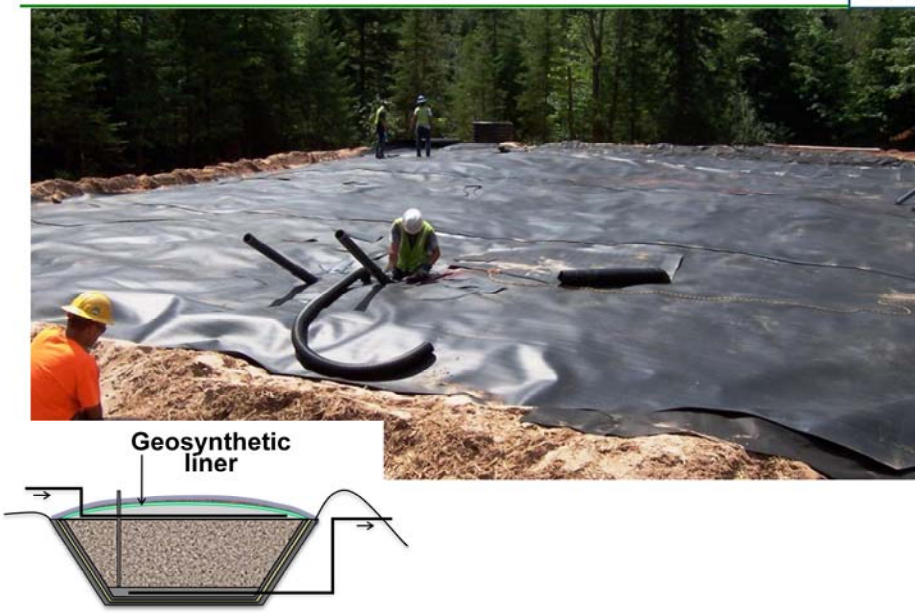
Place with low pressure equipment , make sure there is always a layer of substrate under the equipment to protect piping and liner

Manure Inoculum Placement & Mixing



Early systems had large % of manure, over time found not needed; add small amount of manure to top of BCR

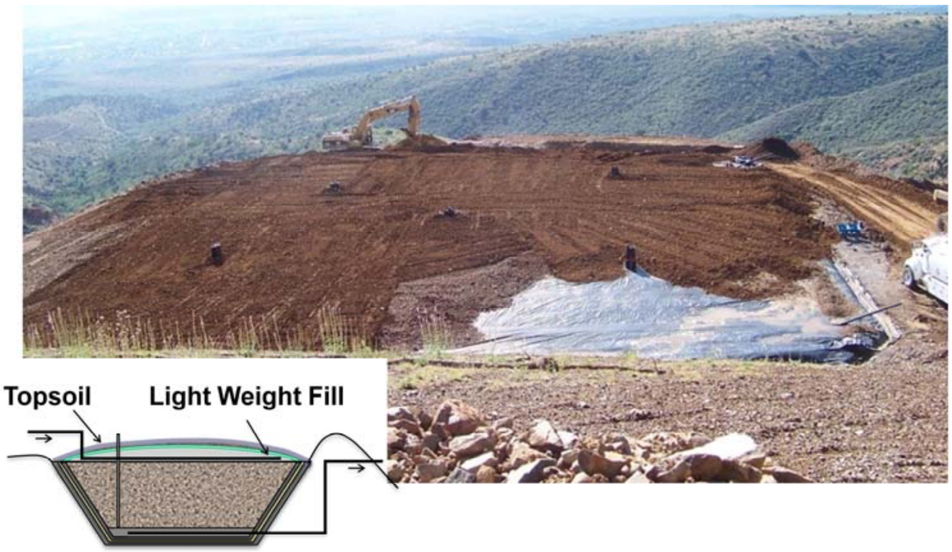
Cover Installation



In cold climates need to insulate BCR for winter operation

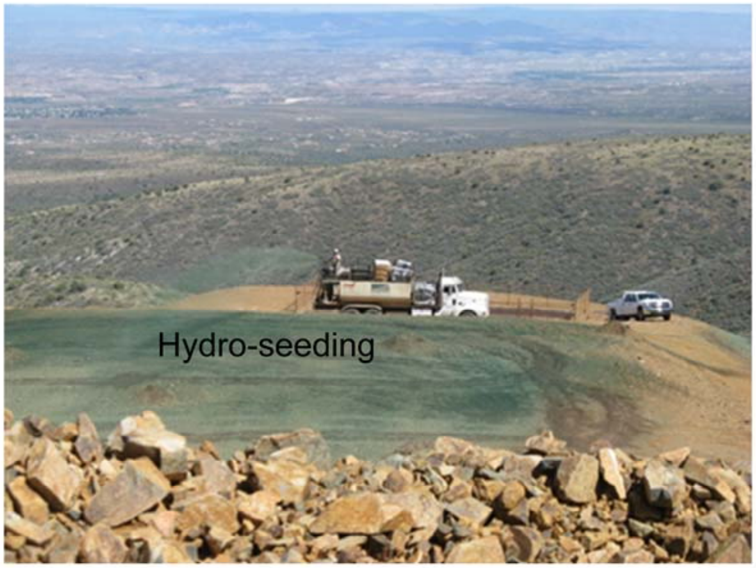
After inoculum added, the inlet piping is placed and then a light weight fill, such as wood chips is placed over the piping to insulate, a geomembrane cover is placed to isolate and protect the BCR

Topsoil



Topsoil, or growing media is placed over the cover to provide a growth layer and get the correct cover depth for frost protection, at a site in the upper Midwest, frost depth was 5 ft, so used 3 ft wood chips and 2 feet of soil

Cover Seeding



BCR is hydroseeded to establish vegetation

Does It Have To Be So Complex?

- Goals
  - Best Management Practices or National Pollution Discharge Elimination System
- Size
- Setting

Large systems that must meet strict numeric limits for their discharge, need to be carefully designed and constructed. At remote sites, with smaller flows and a goal of simply improving water quality the systems can be built by local contractors and watershed groups. At these sites the BCR may be considered a BMP, best management practice. It still needs to be designed and built properly but would not need the level of detailed design drawings etc. that are needed for a large site

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ITRC BCR-1, 2013: Section 6

Moving on to the Monitoring, Operation and Maintenance.

This part of the presentation discusses the monitoring, operation and maintenance that BCRs normally have. Specifically, we will be presenting the what, when, where and why we monitor, operate and maintain the BCRs.

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Monitoring, Operation, Maintenance

- BCRs designed for
  - Minimum operation & low maintenance
  - Low energy/passive
- Monitoring Conducted periodically for;
  - Physical conditions
  - Performance evaluations
  - Compliance requirements

Because they are often in remote locations and passive treatment systems, BCRs are inherently designed to have minimum operational efforts and low maintenance needs with periodic monitoring conducted for performance evaluations and compliance requirements.

Three main types of monitoring to consider are as follows:

1.Monitoring the physical condition of the system,

2. Operational performance monitoring of system flow rates and water chemistry conditions,

3. Monitoring water chemistry for regulatory compliance.

As presented in the BCR construction section, BCRs should be constructed with monitoring ports or locations that allow for the evaluation of the BCR operation performance.

Effluent monitoring is also performed to demonstrate that the BCR effluent meets effluent quality compliance criteria.

Monitoring devices can include piezometers, monitoring wells, influent and effluent structures and sampling ports, and outfall effluent monitoring stream stations. Although not as common, automated monitoring equipment can be used and include open channel flow measuring devices as well as automatic samplers that can be programed to collect samples and perform analysis.

Most of the monitoring performed at BCRs is to ensure that the design criteria such as design flow, water chemistry and expected treated effluent water quality are met; and that the organic substrate consumption takes place as designed.

Monitoring: When and Where

- When?
  - For performance evaluations
    - At Initial BCR Startup (low flow or recirculated flow)
    - During full flow operation
  - For compliance
- Where?
  - At influent
  - In the BCR
  - At the effluent
  - At other pre- or post treatment units
  - At compliance points

Eh and pH field instruments

So, when is monitoring of BCRs necessary?

There are two specific phases of the life of the BCR that monitoring is necessary. First during the initial startup of the BCR and then during normal full-flow operation.

During BCR start-up, the BCRs can be monitored more frequently to determine that the system is functioning as designed and to ensure the sulfate reducing bacteria and biomass growth in the BCR system are acclimated.

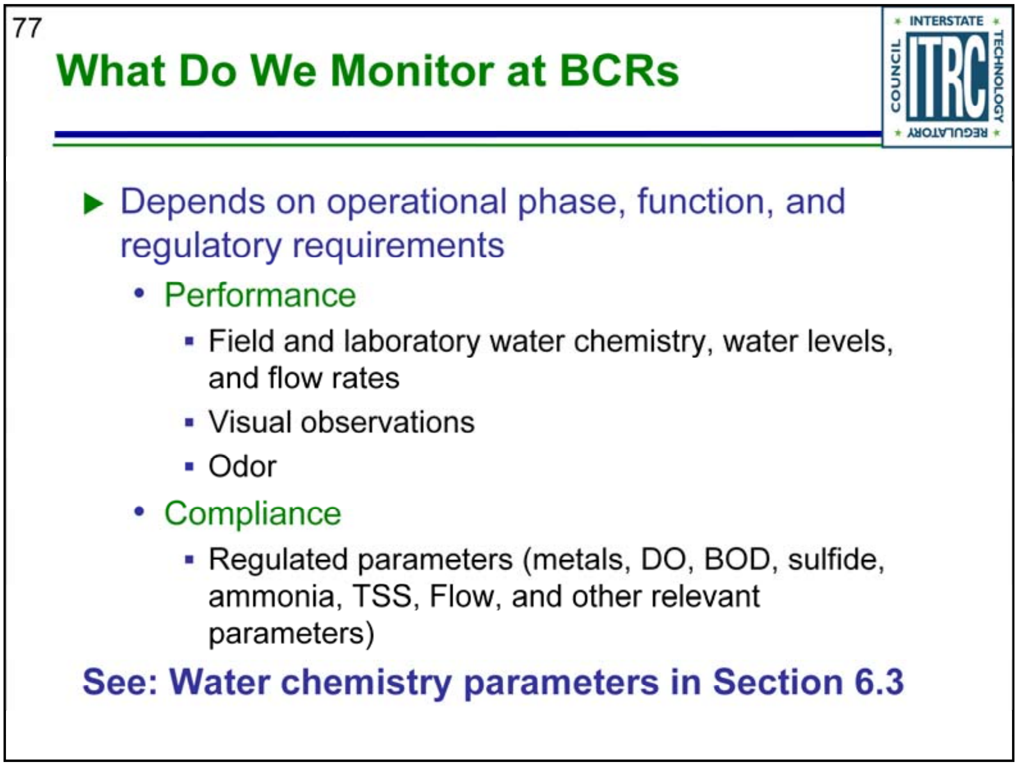
During Normal Operation BCRs are monitored for performance and for compliance purposes.

At minimum seasonal monitoring efforts (once to twice a year) are implemented.

Where are BCRs monitored?

At influent of the BCR, in the BCR itself, and at the effluent of the BCR.

Additional locations where monitoring is necessary include: locations at Pre- or Post Treatment Units and at designated Compliance Points



What do we monitor at BCRs?

Well, the answer depends on the specific operational phase that the BCR is under, as well as the regulatory requirements for monitoring.   There are two main types of monitoring: Performance monitoring and monitoring for compliance.

To monitor the performance of the BCRs one measures parameters that can be read in the field such as pH, Temp, ORP, DO, flow, and using field kits (e.g., HACH kits for alkalinity and sulfide).

Performance can also be assessed by visual observations and laboratory analysis of parameters such as metals, sulfate, sulfide, and alkalinity. Visual observations include assessment of water levels within each treatment component, sludge accumulation, and integrity of infrastructure such as liners, berms, and piping.

In addition, monitoring for hydrogen sulfide (rotten egg smell) can be a good indicator that sulfide reduction is occurring. It is also an important health and safety factor, generally levels at an open air facility will not reach toxic concentrations but low lying areas or manholes could accumulate this toxic gas.

Odor monitoring is also important in areas that have nearby residents, even a small amount of hydrogen sulfide odor may be unacceptable to neighbors

Compliance monitoring includes not only parameters that can be readily measured in the field, but also laboratory parameters such as metals, BOD, TSS, ammonia, and sulfide. The parameters to be analyzed by the laboratory will be dependent on the regulatory compliance requirements of each site.

These parameters should be measured as often as possible, in the influent to the reactor unit, sampling ports within the reactor unit, if available; and the effluent of the BCR.

The specific water chemistry parameters are discussed further in Section 6.3.

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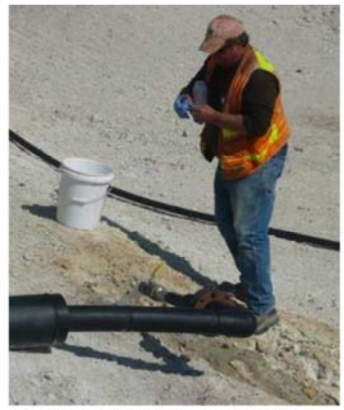
BCR Performance Monitoring

- Can be frequent and seasonal
- Mostly manual (can include lab analysis)
  - Influent
    - Flow and water chemistry
  - Bioreactor
    - Physical parameters
    - Substrate consumption
    - Chemical conditions at various depths
  - System effluent & other pre- and post-treatment units
    - Flow and water chemistry



Collecting effluent samples from the Luttrell BCR, MT

Under the Operational Performance Monitoring of a BCR system, there are common parameters that need to be monitored in the field and for laboratory analysis.

Influent to the BCR – these include the flow rate as well as water Chemistry

At the BCR, we monitor for the physical conditions of the system , which can include BCR substrate consumption and the chemistry at various locations and depths of the BCR.

We also monitor the flow and water chemistry of the BCR effluent. Monitoring at pre-and post treatment units can also be conducted but may not be as frequent as the influent and effluent of the overall treatment system

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Field Parameters

- Common Field parameters
  - Flow rate
  - Temperature, pH, ORP, DO
  - Visual observations
  - Hydrogen sulfide presence
- Optional field parameters
  - Iron speciation
  - Acidity & alkalinity
  - Sulfide and sulfate
  - Conductivity

Sampling influent flow at Penn Hills BCR, PA

This slide lists both common and optional field parameters. For common field parameters, …

Flow rate is used to track system loading, monitors if treatment flow differs from designed treatment flow, and recording of any overflow or treatment by pass events.

Temperature is used to track changes in the system seasonally. For example, very cold temperature at the influent and inside the BCR can cause low microbial activity (and potentially less efficient sulfate reduction), and can cause less efficient settling of solids

pH is used to determine that the desired treatment pH is achieved. Common treatment pH compliance requirements are between 5.5 and 8.5.

Oxidation Reduction Potential (ORP) is used to track changes in how oxidizing or reducing the water conditions are through the biochemical reactor unit. Low (negative) ORP generally less than -200 to -250 mV can indicate reducing conditions suitable for sulfate reduction. Higher or positive ORP inside the BCR substrate or BCR effluent can indicate that sulfate-reducing bacteria activity is limited and sulfate reduction is not occurring sufficiently to remove metals. Increases in ORP can also be indicative of physical issues such as system overloading, higher levels of oxygen are entering the system than anticipated, plugging, or short circuiting.

Dissolved Oxygen (DO) is used to indicate the level of oxygen in the system. Oxygen-depleted conditions (below 2 mg/L as measured by probes or chemical test kits) in the BCR are required for successful sulfate reduction. High DO within the BCR or BCR effluent can indicate the same potential issues noted with increased ORP.

Visual observations of influent, effluent, and water levels assess the physical condition of the system. BCR effluent color, such as the presence of black precipitate can indicate the presence of metal sulfides (e.g., iron sulfide) and therefore is a good indicator that sulfate reduction is occurring. White or pink precipitates, which are elemental sulfur forms, may also be observed and indicate that sulfate reduction is occurring.

One must also monitor for the presence of Hydrogen Sulfide gas which at low concentrations has a characteristic smell of rotten eggs. The presence of some hydrogen sulfide gas can be a good indicator that sulfide reduction is occurring

In addition to those parameters considered common for monitoring BCRs performance, there are a number of parameters that are considered Optional. These are parameters that provide supplemental information on the BCR system, provide real-time data, or can be used as a substitute for a common field parameter.

Iron speciation can be measured with a field test kit. Iron speciation identifies whether reduced (Fe^{2+}) or oxidized (Fe^{3+}) iron predominates in the system and can be used to determine the redox condition. Reduced iron is indicative of a well functioning system.

Acidity can be measured in the field using test kits, and can track in the field what the acidity loading reduction is between influent to effluent.

Alkalinity can also be measured in the field using test kits, and tracks changes that are due either to alkalinity production from sulfate reduction or alkalinity addition from chemical or physical substrate.

Sulfide in the BCR effluent is indicative of excess sulfide being generated and discharged from the system. This sulfide is not being precipitated with metals within the BCR, but may be present in the effluent as unstable precipitates (suspended solids) in the effluent. Excess sulfide can be another indicator that sufficient sulfate reduction is occurring.

Sulfate tracks the rate and level of sulfate reduction in the biochemical reactor. Good sulfate reduction can be an indicator of healthy sulfate reducing bacteria and can be used to determine if enough sulfide, stoichiometrically, is produced to precipitate the load of metals in the influent source water.

Conductivity is measured to evaluate significant changes in TDS that be indicative of overloading or substrate leaching, however, this parameter is generally not considered critical.

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Laboratory Parameters

- Metals
- Sulfate
- Sulfide
- Alkalinity
- BOD/COD
- TDS/TSS
- Ammonia
- Nitrate/nitrite
- Phosphorous
- Substrate use

This slide covers common commercial Laboratory parameters.

(Note - Some of the following can be measured in the field using appropriate test kits.)

Metals can include aluminum, arsenic, cadmium, copper, chromium, lead, iron, manganese, selenium, and zinc or other metals that may be present and regulated at the site. Metals are measured in the influent and effluent to determine removal efficiencies and to determine regulatory compliance. High levels of iron and aluminum can increase clogging potential and are often monitored closely. Often only dissolved metals are measured unless total metals are regulated at the site.

Sulfate, sulfide, and alkalinity were described in the previous slide. It is generally preferred to analyze these parameters using an analytical laboratory to obtain more accurate data. Field kits can be used to evaluate real-time checks as desired. In addition, these parameters may be regulated to protect receiving water bodies.

Biological oxygen demand (BOD) is used as an indicator of the readily available organic carbon concentration in the system water. This parameter is used to ensure sufficient food source and may also be regulated in the system effluent to protect receiving water bodies.

Chemical oxygen demand (COD) tracks the oxygen demand from chemical oxidants. COD may also be regulated in the system effluent to protect receiving water bodies.

Total dissolved solids (TDS) and Total suspended solids (TSS) may be regulated to protect receiving water body. TDS and TSS are not intended to be treated by biochemical reactors but some removal may occur.

Ammonia, Nitrate/Nitrite, and Phosphorous are all also potentially regulated. These parameters may be present in BCR effluent water, especially when manure materials are utilized as substrates.

Monitoring of substrate use - If appropriate sampling access points are installed during construction, pre-placed packets or cores of the substrate can be accessed to determine how much unreacted solid substrate remains in the system. Cores or packets can be observed visually and laboratory assessment can also be done by calculating loss on ignition and comparing that to measurements from the original substrate.

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Compliance Monitoring

- May be subject to multiple regulatory programs
  - Clean Water Act,
  - Surface Mining Control and Reclamation Act
  - NPDES
  - CERCLA / RCRA
  - State and County
- Required frequency
- Required parameters
  - Site Specific
  - Metals, BOD, TSS, ammonia, nitrate/nitrite, P, sulfide

Effluent pH and Eh Testing

Generally it is assumed that biochemical reactor systems will discharge effluent to surface water rather than groundwater. Surface water discharges to streams, wetlands and oceans are typically regulated by the Clean Water Act of 1972 (CWA) or State or tribe equivalent. In most cases active mine sites must comply with provisions of the Surface Mining Control and Reclamation Act (SMCRA) for coal mining and hard rock mining and secure permits for discharges to surface waters under the National Pollutant Discharge Elimination System (NPDES).

Abandoned mine sites fall under other regulatory purviews including CERCLA, RCRA, SMCRA, brownfields, state, local, or tribal programs.

Frequency of compliance monitoring also can vary based on location, goals of treatment, and variability of influent flows or concentrations. The intended purpose of the system and the location of the system often dictate the required monitoring frequency. Remote mountainous locations may only allow infrequent site visits, particularly in snowy climates. It is anticipated that these sites also have more flexibility in the discharge water quality criteria as site visits may be limited to only spring through fall seasons.

Required compliance monitoring parameters will vary based on the regulatory framework. The previous slide discussed several parameters that may be potentially regulated to protect receiving water bodies

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Sample Collection

- Sample collection methods
  - Follow site-specific plan and procedures
  - Manual and automatic sampling
  - Field measurement instruments
    - Portable meters
    - Permanent meters
  - Field chemistry kits (HACH, etc.)
  - Sample type - grab, composite, incremental

Penn Hills influent flow test

Sample collection procedures should always follow site-specific plans, if applicable, or best practices to maintain sample quality and meet compliance requirements. In some instances, site-specific sampling and analysis plans and data quality assurance plans are necessary to validate field and laboratory data.

Consistent field protocols including flow monitoring and samples collections should be implemented.

Sampling protocols that outline the planning, execution and documentation of sampling and field events are strongly encouraged, especially those activities that are instituted for demonstrating compliance with applicable local, state or federal requirements.

Prescribed methods for manual sampling should be followed as well as published methods provided by manufacturers of field meters, chemistry kits, and other equipment.

Sample types can also be grab, composite, or incremental depending on site requirements and goals.

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Sample Analysis

- Chemicals analysis
  - Field parameters, methods and purpose **(Table 6-2)**
  - Laboratory parameters, methods and purpose **(Table 6-3)**
- Samples packaging and transportation
  - Custody procedures
  - Samples preservation **(Table 6-4)**
  - Samples transportation
- Samples analysis QA/QC
  - Duplicates, spikes

Automatic wastewater sampler

ITRC BCR-1, 2013 :Figure 6-2.

Sample analysis protocols will also be site/project specific.

Summary tables showing the specific field (see Table 6-2) and laboratory parameters (table 6-3) as well as samples management, including preservation (see Table 6-4), packing and transportation and quality assurance/quality control are presented in the guidance.

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Flow Measuring Devices

- Flume
- V-Notch weir
- Marsh-McBirney
- Bucket and stop watch

There are numerous devices and methods utilized for flow measurement. Details of some flow measuring methods are included in one of the guidance appendices. A few examples include flumes, V-notch weirs, Marsh McBirney flow meters, and using bucket/cup and stopwatch to measure flow in streams

In in this slide we have an example of a triangular V-notch weir (on the right) and a trapezoidal flume (on the top). These devices are used to measure the flow over the weir (or flume) by using a standard ruler just upstream of the V notch or a water level sensor and converting the water head into a flow using standard hydraulic flow calculation formulas.

This slide also shows an example of measurement of stream flow using a Marsh McBirney flow meter. Measurements of depth and velocity are collected systematically across the stream channel and then converted to a volumetric flow rate by averaging methods.

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Operations

- BCR will run by itself
- Periodic Inspection of physical conditions
  - Visual inspection of system
  - Flow rates & water level in units, piezometers, gauges and standpipes
  - System integrity (berms, liners, piping)
  - Site access
  - Identify potential short-circuiting of water
  - Drop inlets/outlets, pipes, & weirs
  - If used, check electrical & mechanical equipment (e.g., pumps)

Figure 4-4. Sampling pipe/piezometer

Generally, a passively designed BCR can run by itself, but may require onsite O&M seasonally, such as opening and closing valves or modification to other flow control structures.

Periodic inspection of the physical condition of the treatment system should be conducted. Monitoring the physical condition of the system generally includes visual inspection of the overall system and surroundings, including the various components of the system, including pre- and post- treatment units.

One must look for changes from normal operations and track changes that may occur slowly over time in order to identify and mitigate minor problems before they cause major system upsets. Regular inspection should include monitoring flow through the system, system integrity, site access, potential short-circuiting, flow control structures or valves, and electrical and mechanical equipment if applicable.

It is important to maintain flow through the biochemical reactor units and identify if preferential flow or clogging is causing areas to dry out or become stagnant. Either of these situations will impact treatment performance because of the loss of treatment area. The following should be included in monitoring system flow:

-Monitor hydraulic head with piezometers, gauges or standpipes or other designed feature at the influent and effluent to treatment units.

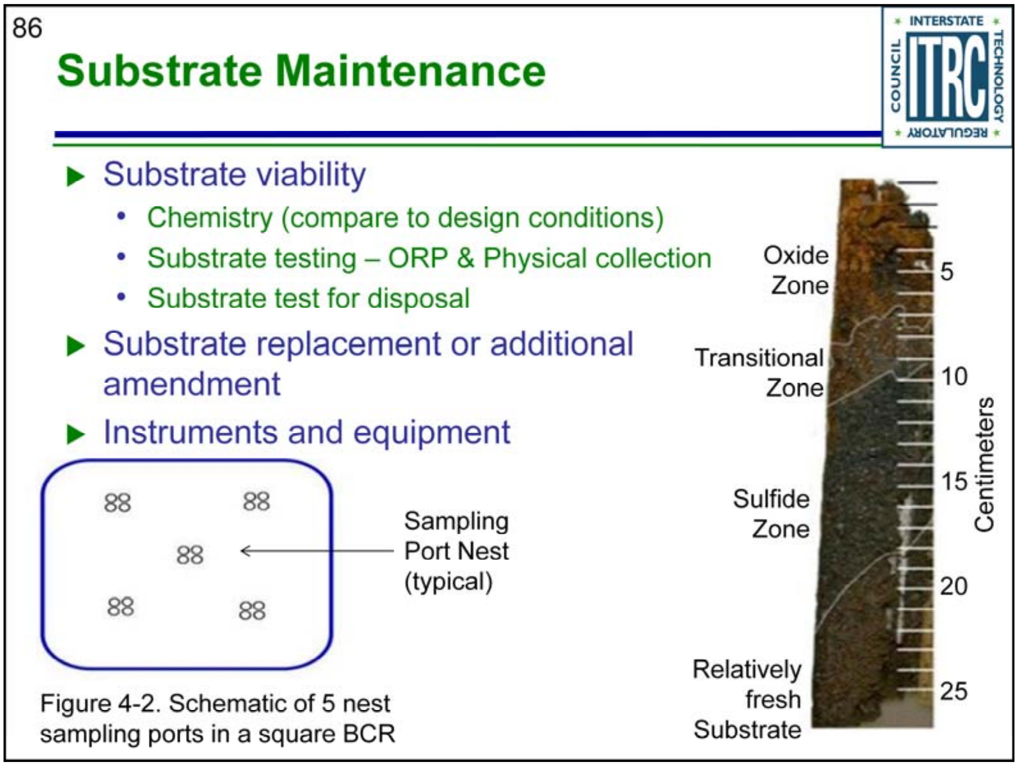
-Check operation of gravity feed units, look for clogging and water back up.

-Inspect drop inlet/outlets and weirs, look for clogging and water back up.

-Ensure pumping systems, if used, are operational and that required pump maintenance is performed as required by manufacturer.

-Check for clogged piping, short-circuiting, and channelization. These issues may or may not be evident with simple visual inspection. Systems may be designed with features for back flushing or changing flow path, and these operations should be performed as suggested by the system designer but may be on the order of once to twice a year.

-Check flow through pre- and post-treatment components to the system.

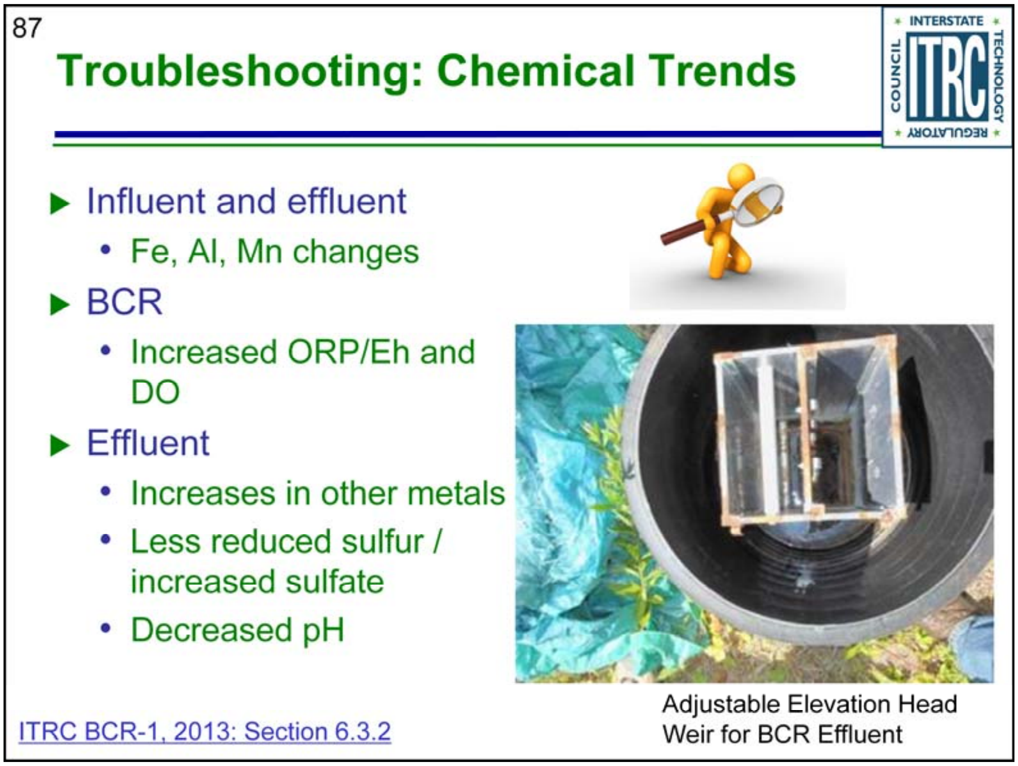


Substrate Maintenance.

ORP monitoring can determine the viability of the organic substrate. Multiple sampling ports at various pre-determined BCR depths can be monitored for ORP to determine where the ORP changes occur in different reaction zones

To estimate the time for substrate change-out, the substrate should be sampled after 6 months and after 1 year after steady-state operation was initiated. It is recommended that the BCR be resampled at the estimated half-life of the substrate to evaluate the reaction progress.

At one point in the life of the BCR the substrate may need to be replaced. Once the substrate is exhausted or no longer can be used, the waste substrate should be tested for disposal. Such tests include Toxicity Characteristic Leachate Procedure (TCLP) in addition other tests that may be required by the State or receiving waste disposal landfill or facility.



As the BCRs operate and their performance deteriorates, there may be a need to troubleshoot the performance of the BCRs to extend the substrate life.
Troubleshooting can include both Chemical and Physical trends. As these trends are compared against time of operation one can discern the type of problem that the BCRs can have.

Some example of TROUBLESHOOTING BCRs are as follows:

Sulfate - The difference between source water and reactor unit sulfate concentrations will indicate if sulfate reduction is occurring.

ORO- Lower ORP values in the biochemical reactor unit will indicate if oxygen has been removed and conditions are suitable for sulfate reduction.

pH - An increase in pH from source water may indicate the commencement of sulfate reduction, which produces alkalinity, or it may be due to other inorganic alkalinity sources provided in the reactor, but either way, a pH of 5 or greater (toward neutral) generally promotes more rapid growth and activity of sulfate reducers.

Sulfide – Lack of the presence of sulfide odor at the BCR effluent can be an indication that the BCR may not me performing as designed. Additionally, field assays for sulfide performed by an experienced field technician can be used to supplement or replace sulfate measurements to determine if sulfate reduction is occurring in the reactor.

Physical Trends during Troubleshooting

1.Plugging
2.Overflow and Flow Control Iron –
3.Short Circuiting
4.Gas Locked-up in BCR
5.Structural Integrity of berms, dikes and ponds
6.Erosion and storm water management

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Troubleshooting: Physical Trends

- Plugging
- Overflow and flow controls
- Short circuiting
- Gas lock-up in BCR
- Structural integrity
  - Berms/dikes
  - Ponds
  - Liners
- Erosion and stormwater management

Golinsky BCR, CA: Photo courtesy of Bruce Marvin

Section 6.3.2 in Guidance

Physical Trends during Troubleshooting

Plugging, whether visually present, at valves, or based on overflow condition

Overflow and Flow Controls

Short Circuiting

Gas Lock-up in BCR

Structural Integrity of berms, dikes ponds, and liners

Erosion of system components and storm water management

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Training Outline

- BCR basics
- Determining applicability
- Designing and implementing a BCR
- Challenges and solutions
  - Technical challenges
  - Regulatory challenges
  - Stakeholder concerns and issues
- Summary

ITRC BCR-1: Section 7, Section 8, Section 9

No associated notes.

Challenges and Solutions

- Technical
- Regulatory
  - Permitting
  - Water Quality Standards
  - Disposal of Residual Materials
  - Wetlands
- Stakeholder
  - Community, tribal concerns
  - Liability
  - Use of MIW as a Resource

Golinsky Biochemical Reactor, Lake Shasta, CA
Photo courtesy of Bruce Marvin

Now we will discuss and address some of the challenges and potential solutions related to using biochemical reactors. The photo on this slide is the Golinsky biochemical reactor, located near Lake Shasta, California. This site exhibits many of the technical challenges that we have discussed today. The Golinsky BCR is in a remote location, across the lake and a mile up an abandoned road from “civilization.” In constructing this BCR, materials had to be flown or floated in to the site. There is no infrastructure to speak of to support the BCR. We have already discussed most of these issues. Now we would like to move on to regulatory and stakeholder challenges.

Regulatory challenges include things like permitting, water discharge standards, disposal of residual materials, and wetlands.

Stakeholder challenges include community and tribal concerns, liability and the use of mining-influenced water as a resource.

Regulatory – Permitting

- Permit requirements vary
  - Location
  - Project phase
    - Construction
    - Operation

Construction of the BCR in Park City, UT
Photo courtesy Jeff Schoenbacher
Park City Municipal Corporation

Building and operating a biochemical reactor will likely require at least one permit. Permitting requirements will vary across states, localities and tribal regions. Required permits may range from land disturbance and erosion and storm water control issues to discharge permits for active mining operations. Since local, tribal, state and federal regulations may differ for each site, all permitting agencies should be consulted throughout the process to ensure that appropriate regulatory processes are being followed.

The photo shows horizontal placement of substrate during construction of the BCR in Park City Utah.

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Regulatory – Water Quality Standards

- Set to protect human health and the environment
- BCRs can meet water quality standards
- There may be some times when they do not meet standards
- This must be understood by all!

Collecting an effluent sample from BCR discharge point

Treating MIW in a biochemical reactor will improve water quality.

Water quality standards are generally set to protect human health or aquatic life, based on the present and future use of the receiving water body. As the BCR technology has matured, there are a growing number of situations where the goal is to meet water quality standards. BCRs can generally meet pH limits. However, because biochemical reactors rely to some degree on natural processes, the effluent water quality may not always meet water low chronic toxicity standards for metals. This is an issue that should be discussed and understood by all involved parties, including regulators, prior to using a BCR to treat mining influenced water.

Regulatory – Residuals and Wetlands

- Disposition of residual materials (for example, spent substrate)
- Wetlands
  - Mitigation
  - Attractive nuisance
  - Decreased BCR performance
- ITRC's Wetlands documents
  - Constructed Treatment Wetlands (WTLND-1, 2003)
  - Characterization, Design, Construction, and Monitoring of Mitigation Wetlands (WTLND-2, 2005)

Unintentional Wetland, Golinsky Biochemical Reactor

Regulatory challenges also include disposition of residual materials and impact to wetlands.

Disposition of Residual Materials – Residual materials, for example, spent substrate, can include high concentrations of metals. Prior to disposal of residual materials, you may need to plan to for testing to determine if the metals are economically recoverable, if the material must be disposed of as a hazardous waste, or if it is just a waste.

Wetlands are another challenge. There are federal, state and local laws that protect high quality coastal and freshwater wetlands. In constructing a BCR, wetlands may either be destroyed or created. If wetlands are destroyed, mitigation may be required. If wetlands are created, they can attract wildlife, effectively becoming an attractive nuisance. Unintentional wetlands which spring up in a BCR may decrease performance of the BCR. Because of these issues, federal, state and local authorities should be contacted to address regulatory challenges posed by mining-influenced water wetlands. The ITRC has two guidance documents*, Constructed Treatment Wetlands, 2003*, and *Characterization, Design, Construction, and Monitoring of Mitigation Wetlands, 2005*, for further information on wetlands.

This photo shows an example of unintended wetlands created after the biochemical reactor was constructed.

Stakeholder Concerns

- Community concerns
  - Noise
  - Attractive nuisance and safety
  - Hydrogen sulfide odor
  - Public outreach

BCR in Central City, PA.
Note the houses in the background

There are several stakeholder groups that are important when considering a biochemical reactor as a treatment technology. These groups include communities, Native American tribes, and volunteers. I will be discussing these groups in the next several slides.

Community Concerns - Up to now, we have focused on biochemical reactors which are located in remote areas and the associated issues. However, BCRs located near populated areas bring with them a different set of issues. During construction of the BCR, there will be additional human activity and machinery noise. People will need to periodically access the site to sample or maintain the BCR during operation. The BCR may be an attraction for curious wildlife or children. Additionally, there may be hydrogen sulfide odors during operation. Exposure to the gas may result in toxic effects. A good public outreach program, where the public is brought in as a partner, is essential throughout the planning, construction and operation of a BCR to address public concerns and facilitate community acceptance.

This photo shows a biochemical reactor located near residences (These residences are at the end of the red arrows).

Tribal Concerns are also important. Most Native American Tribes have a different perception of environmental protection and remediation than western societies. Many tribes have established Environmental Departments to which EPA has delegated programmatic authority, including regulatory authority under the Clean Water Act. Using this authority, many tribes have developed enforceable water quality standards. To ensure understanding and good cooperation throughout the BCR project, it is important to work with both the appropriate EPA tribal liaison and tribal leaders to address the issues.

Volunteer Concerns - In many areas of the country, mining-influenced water is the result of unregulated mining activities of the past. There is no responsible party to pay for site cleanup. In an effort to better their environment, local watershed or other volunteer groups have taken on projects using biochemical reactors to clean up mining-influenced water. While some of these groups are quite sophisticated in their knowledge and understanding of water quality issues and regulatory processes, others may be less so. When permits are required, these groups may need additional assistance in navigating the process. The group may have funding and resources for a limited cleanup effort that may not meet all regulatory requirements. Faced with requirements that they cannot meet, the groups may not implement the cleanup project. Liability issues may also prohibit volunteer groups from taking on these projects. As a result, projects that could result in environmental improvement end up not being done.

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Liability Concerns

- Liability of Good Samaritans
- Disposal of spent substrate
- Effluent compliance
  - NPDES versus Infiltration or Recharge

Sludge Disposal area, Iron Mountain Mine, California

The perfect should not be the enemy of the good

Liability is a significant issue for any group that gets involved in the cleanup of mining-influenced water. One of the significant challenges that volunteer groups face is the liability created when a group becomes involved in the cleanup of a site. To help limit liability and encourage volunteer groups to take on and complete projects, the state of Pennsylvania adopted legislation, known as the Good Samaritan Act, in 1999. Additionally, USEPA has developed a Good Samaritan Initiative that applies to hard rock mining sites. The initiative includes a memorandum, issued on December 12, 2012, a model comfort letter and a model settlement agreement. However, some people think that the USEPA has not gone far enough with their effort. Thus, the issue remains significant and local organizations who operate or plan to construct and operate treatment systems face risk and uncertainty.

“The perfect should not be the enemy of the good” refers to the issue I mentioned earlier, that projects that could result in environmental improvement may not be implemented due to liability or regulatory issues. Good Samaritan legislation, such as that implemented in Pennsylvania and USEPA, addresses this issue.

MIW as an Emerging Resource

- Hydrofracking
- Electricity production

Receiving stream, Lady Leith BCR, Jefferson County MT

On the positive side, MIW is being considered as an Emerging Resource. Particularly in areas where water availability is limited, MIW has great potential as an emerging resource. For example, the gas industry is considering using MIW for hydrofracking. To that end, the Pennsylvania Department of Environmental Protection has developed a white paper outlining a process for the reuse of MIW in hydrofracking operations. Eastern coalfield watershed groups have begun to used BCR-treated water to operate micro-hydro generators to produce electricity. Reuse of treated MIW faces many of the same challenges as cleanup of MIW. Discharge water quality and potential liability for perpetual cleanup must be addressed for potential reuse of reclaimed MIW.

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Key Take Away Messages

- BCRs are viable alternatives for treating MIW, even in remote areas
- BCRs are site-specific, not one size fits all
- BCRs are not *walk-away* systems, but require maintenance and monitoring
- Web based document is a convenient resource when considering a BCR

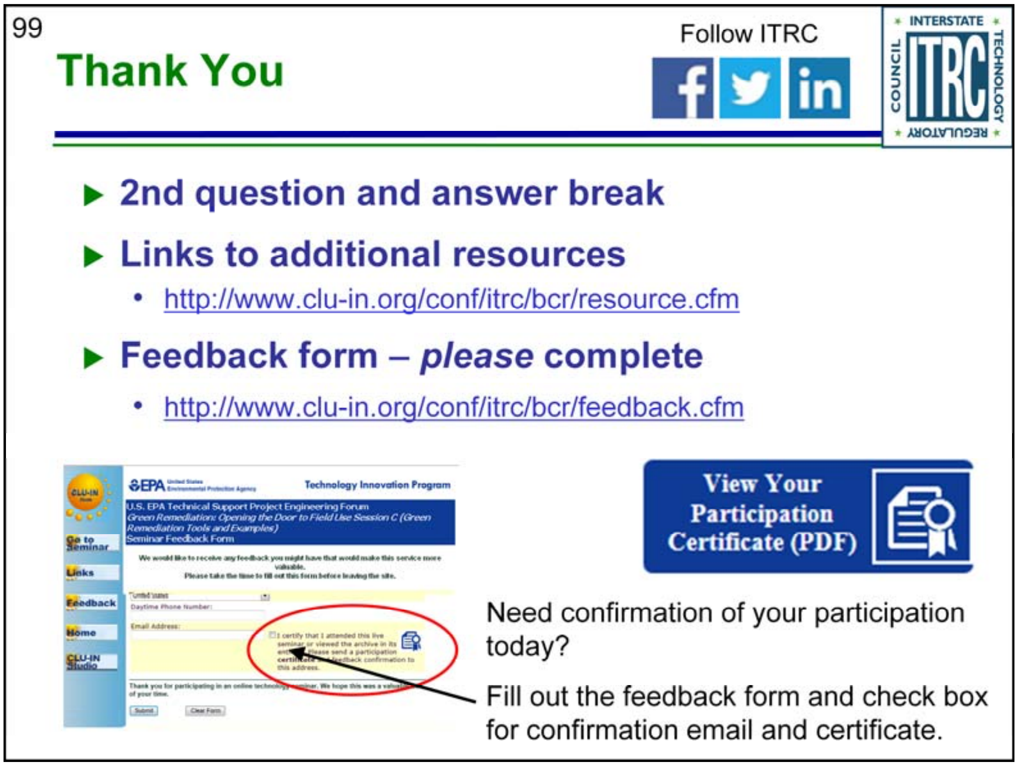
The key take-away messages for this training are –

BCRs are viable alternatives for treating mining-influenced water, even in remote areas

BCRs are site-specific, not one size fits all

BCRs are not walk-away systems, but require maintenance and monitoring

DTRC's web-based document is a convenient resource when considering a BCR



Links to additional resources:
http://www.clu-in.org/conf/itrc/bcr/resource.cfm

Your feedback is important – please fill out the form at:
http://www.clu-in.org/conf/itrc/bcr/feedback.cfm

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

How you can get involved with ITRC:

✓Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

✓Sponsor ITRC's technical team and other activities

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects