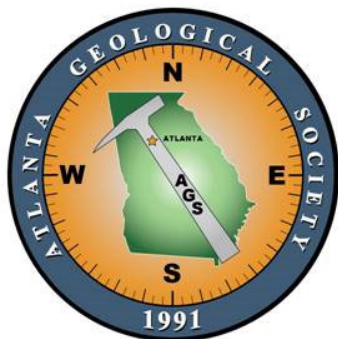




Atlanta Geological Society Newsletter

ODDS AND ENDS

Dear AGS members,

I trust you have had a good summer break and had a chance to get some beach sand in between your toes. We're going to get the second half of the year off with a bang with our Secondly, speaker; Dave Fenster, the current president of the Association of Engineering and Environmental Geologists. Over the years, the joint meetings that we have had with the AEG have been great for several reasons. The speakers and their presentations have been great; well prepared, technically interesting and a topic different from our usual fare. The abstract and biographic sketch are nearby, and I am looking forward to seeing the presentation. As this will be oriented towards the geotechnical, I encourage you to reach out to your geotechnical friends and contacts who may find this interesting and invite them to the meeting.

Secondly, we have a new program to encourage student attendance. A couple of us have said we'd cover the membership fees for 20 students; 10 from Georgia State and another 10 from any other program in the area. So, if you know some students or teachers, please spread the news and tell them to be in touch with me. We might have to order additional pizza or two and that would be a good thing.

As one more thing, I suggest you look into the amount of meltwater that has been shed off Greenland. Over a week's period a month ago, the National Snow & Ice Data Center (<http://nsidc.org>) estimated 55 billion tons of melt runoff was shed from Greenland due to the heat. That's about 13 trillion gallons. It's hard to relate to how much that is or what that means in the long term. I'm no climatologist but it does seem like one more piece of data about the changing climate.

Hope to see you Tuesday!
Ben Bentkowski, President

August Meeting

Join us **Tuesday, August 27, 2019** at the Fernbank Museum of Natural History, 760 Clifton Road NE, Atlanta GA. The social/dinner starts at 6:30 pm and the meeting starts at 7 p.m.

This month our presentation is **"Why is Applied Geology Important for Nuclear Power Plants Siting?"** presented by Dave Fenster. Please find more information about the presentation and Mr. Fenster bio on the next page.

Please come out, enjoy a bite to eat, the camaraderie, an interesting presentation and perhaps some discussion on engineering geology.

www.atlantageologicalsociety.org

facebook.com/Atlanta-Geological-Society

Atlanta Geological Society August Speaker

“Why is Applied Geology Important for Nuclear Power Plant Siting?”

Speaker Mr. Dave Fenster's Bio:

Dave retired as a general consulting engineering geologist in January 2018 after a 44-year career working primarily for large consulting firms. After starting at the City College of the City University of New York (CUNY) as an engineering major, he was graduated with a BA in History in 1967. He received an MA in history from the University of Illinois in 1968. Dave started taking geology courses at Queens College of CUNY while teaching in the South Bronx. He was awarded a teaching assistantship (Lecturer Part-time) and received a Masters in Geology in 1975. He is a Licensed Professional Geologist (PG) in California; Certified Professional Geologist in Virginia and was previously certified in Indiana and Missouri.

As an engineering geologist, Dave applied geologic principals to investigate sites for: geologic and seismic hazards assessments; critical facility site selection; radioactive and hazardous waste management; nuclear facility licensing, LNG facility permitting and certification; and NEPA compliance. His project experience includes: site investigations; report preparation; project management; and business development. Many projects have included Federal, state, and local regulatory compliance; permit acquisition and nuclear facility licensing. Prior to retiring, he had been a Principal Geologist and the Engineering Geology Supervisor and was recognized as an Elite Technical Specialist for Bechtel Power Corporation in Fredrick, MD and Reston, VA. (2006-2018). Most of his work for Bechtel included site investigations and report preparation for the current generation of commercial nuclear power plants. Dave began his career as a geologist with Dames & Moore in 1974 investigating sites for nuclear power plants, working on foundation and groundwater investigations and other aspects of applied geology. His experience with geologic field mapping led to interpretations of surface and subsurface data to develop the regional and site geology sections of Safety Analysis Reports filed with the US Nuclear Regulatory Commission in support of nuclear power plant licensing. As this work declined, Dave conducted environmental geologic investigations to characterize site groundwater and soil conditions and to determine whether clients were in compliance with environmental regulations. After leaving Dames Moore, Dave worked on the geologic isolation of high-level radioactive wastes while with Argonne National Laboratory (1982-1985), Roy F. Weston Inc. (1985-1991) and with Woodward Clyde/URS (1991-2006). At URS he supported FEMA while working on the Pre-Disaster Hazard Mitigation Program and other geology-related programs.

Dave joined the North-Central Section of AEG in 1982. He served as North-Central Section Program Chairman (1982-1984) and Secretary (1984-1985). He was appointed as Chairman of the Committee on Rock Mechanics and AEG's representative to the U.S. National Committee on Rock Mechanics (1984-1989). He was Chairman of the Committee on Radioactive Waste Management (1989-1991) and Chairman

of the Committee on High-Level Radioactive Waste Management (1991-1994). Dave served as Chairman of the Baltimore-Washington-Harrisburg Section (current DC-Maryland-Virginia Chapter) (2002-2004). He was an initial member of the Section Chapter Support Committee. He served on the Board of Directors of the AEG Foundation from 2006-2016 as Secretary for two years and as President for 2015. Dave was appointed as interim Vice President of AEG in 2017 and was elected as Vice President/President-elect for 2017-2018.

Dave has served as a peer reviewer for AEG's Environmental & Engineering Geology Journal. His term as Overseas Reviewer of the Quarterly Journal of Engineering Geology and Hydrogeology (Geological Society of London) expired in 2018.

Abstract:

Nuclear power plants are critical facilities in more ways than one. Initial siting and detailed site characterization require the input of experienced engineering geologists. The U.S. Nuclear Regulatory Commission (NRC) is charged with protecting the health and welfare of the public and the environment. As consultants working for industry, we are charged with obtaining geologic data from the region within which the site is located. We need to obtain even more detailed data from the site and surrounding area. Our careful documentation of geomorphic processes, stratigraphy, geologic and tectonic history, seismicity, the hydrologic setting and groundwater modeling, geologic hazards, and soil and rock properties are essential to providing the NRC with the data they need to make a finding, with reasonable assurance, that the site is suitable for the safe construction and operation of a nuclear power plant. Detailed site investigations are necessary to define in our understanding of uncertainties regarding site characteristics. Ages of faulting in the site vicinity or at the site, the age and extent of karst and the presence of other geologic hazards are key aspects of determining site suitability.



Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater

Groundwater in contact with nonaqueous phase sources of organic contaminants can be challenging and expensive to treat when it requires recovery, often requiring multiple unit processes for ex situ treatment of the extracted water. These processes are aimed at not only removing the contaminants from the water but also dealing with them after removal. This complexity is exacerbated when the source is a mixture of different contaminant types. While there are physical and chemical technologies that can handle ex situ treatment of such contaminant mixtures dissolved in groundwater, we will explore the application of ex situ bioreactors as a first step to significantly reduce contaminant mass and precondition water for subsequent polishing treatment via more conventional means. This approach harnesses natural processes to degrade the contaminants and avoid the need to deal with them in a secondary waste management step. This type of pretreatment can make sorptive technologies such as granular activated carbon (GAC) more effective and potentially avoid or reduce the need for other higher energy treatment technologies such as air stripping or advanced oxidation processes (AOP).

For the purposes of this discussion, we will look at the various bioreactor technologies most often used for treating water with high concentrations of organic contaminants, consider what has evolved with the overall reliability of such technology, and then consider several case studies involving bioreactor application to groundwater with high-concentration contaminant mixtures.

Bioreactor Technology and Groundwater Treatment

The bioreactor technologies available today that can be applied to the treatment of groundwater with high-concentration organic contaminant mixtures were originally developed for the treatment of municipal wastewater (e.g., sanitary wastewater). Understanding of biological degradation of organic matter and nitrogen was well established as early as the 1920s, and the earliest forms of bioreactors to treat municipal wastewater were septic tanks, Imhoff tanks, and lagoons.

The fundamental premise of any bioreactor technology (aerobic or anaerobic) is to provide contact between a microbe population and the constituents of concern that they can utilize as food (or that can be co-metabolized with another food source). Adequate treatment of dissolved contaminants in this manner requires the right amount of biomass and adequate residence time within the reactor, typically referred to as hydraulic retention time (HRT). Cultivating the right amount of biomass requires a means to control and maintain environmental conditions that are favorable to the proliferation of the microbes being harnessed. Among other things, this can involve optimizing the concentration of dissolved oxygen, pH, alkalinity, temperature, or nutrients for growth (i.e., primary food source, nitrogen, phosphorous, trace metals/micronutrients, etc.).

As might be expected, regardless of biomass levels, easier to degrade COCs generally require a shorter HRT and more recalcitrant COCs a longer HRT. In addition to microbial contact and HRT, a means of separating the biomass from treated effluent is required to prevent fouling of the downstream unit treatment processes. Recycling this biomass also helps maintain an adequate microbial inventory to continuously treat contaminants to the target concentrations within the constraints of the HRT. This is accomplished either within the treatment vessel itself or through an external process that uses a recycle loop to return separated biomass back into the bioreactor.

The methods employed to provide bacterial contact and manage biomass inventory are generally what differentiate the two main types of bioreactors: suspended growth reactors and fixed-film reactors. With suspended growth bioreactors, the bacteria grow suspended within the water column and are thoroughly mixed with the water entering the bioreactor to maximize contact with COCs. By comparison, in fixed-film bioreactors the bacteria grow as biofilms on an inert support medium (e.g., polyethylene packing similar to those used in air strippers, sand media, etc.) which the water and COCs flow through/around.

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)

The following provides an overview of selected suspended growth and fixed film technologies that have been applied to treat extracted groundwater with high-contaminant concentrations using aerobic pathways. Anoxic bioreactors have been applied for the treatment of groundwater impacted with nitrates/nitrites, perchlorate, and selenium, but typically these impacts do not coincide with high concentrations of organic contaminants. Anaerobic bioreactors are viable for the treatment of groundwater, but their application is best suited to sites with relatively high sulfate concentrations that require treatment and/or chemical oxygen demand (COD) concentrations above 1300 mg/L where anaerobic bioreactors require less energy than aerobic bioreactors. This is not intended to be a comprehensive list of what is possible, just a sampling for the purposes of our focus.

Suspended Growth Bioreactors

A suspended growth bioreactor system requires a reactor vessel or multiple vessels for flexibility, an oxygen source, mixing equipment to ensure the bacteria are kept in constant suspension and in contact with the COCs (note that most aeration technologies achieve oxygen transfer and complete mixing simultaneously), and a means to separate biomass from treated effluent. The liquid content of the bioreactor (composed of water, biomass, organic solids, inert solids, etc.) is referred to as “mixed liquor” and, more commonly, as activated sludge. Mixed liquor suspended solids (MLSS) refers to the solid portion of the mixed liquor, which is made up of organic (volatile) and inorganic/inert (nonvolatile) components. The volatile portion of the MLSS, denoted as mixed liquor volatile suspended solids (MLVSS), consists mainly of biomass. MLVSS is the parameter used to determine the biomass inventory in the bioreactor. MLSS employs the same analytical method as Total suspended solid (TSS) and MLVSS uses the same analytical method as volatiles suspended solids (VSS).

Microorganisms that settle and thicken well (referred to as floc forming) include a mixture of bacteria, protozoa (e.g., amoeba, flagellates, free-swimming ciliates, stalked ciliates, etc.), and metazoa (e.g., nematodes, flatworms, rotifers, and waterbears). The presence of abundant protozoa (especially flagellates, free-swimming ciliates and stalked ciliates) and some metazoa (especially rotifers) are indicators of a well-maintained system of floc forming biomass with excellent settling characteristics, and these microorganisms can be observed in concentrations as high as 50,000 per mL and up to 200 per mL, respectively, in suspended growth bioreactors. The presence of amoebas, nematodes, waterbears, and filamentous biomass are indicators of operational issues resulting in biomass with poor settling characteristics or, in the case of abundant filamentous biomass, form a voluminous sludge (i.e., poor thickening characteristics, referred to as sludge bulking). Good settling and thickening characteristics in a suspended growth bioreactor allows for optimal biomass inventory management, whereas poor settling and thickening characteristics will typically result in suboptimal biomass inventory and impaired treatment performance. Some causes of nuisance microorganisms taking over a population include low dissolved oxygen, young sludge, old sludge, low organics relative to biomass inventory, nutrient deficiency, and low pH. Some other operational concepts for suspended growth bioreactors:

- **MLSS Concentration Ranges**—For typical groundwater activated sludge processes are 1500 to 4000 mg/L. Depending on the presence of dissolved iron and other metal species that can form precipitates within the bioreactor and aquifer solids, the MLVSS could be as low as 50% of the MLSS (i.e., 50% of the solids inventory consists of inerts). It is not recommended to operate a suspended growth bioreactor with a MLVSS:MLSS ratio of less than 0.5:1.
- **Sludge Age/Solids Retention Time**—Sludge age is defined as the mean cell residence time (MCRT) or the solids retention time, is the time the active biomass is reproducing and degrading organics within the system. MCRT is controlled by the loss of bacteria as a result of the wasting rate of the settled bacteria (either from a

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)

clarifier or membrane bioreactor blowdown) and by the uncontrolled loss of bacteria in the treated effluent. The typical MCRT for activated sludge in groundwater treatment ranges from 10 to 20 days. Operational problems will occur if the solids retention time is too short (surfactants are produced creating foaming issues and/or poorly settling solids) as well as too long (proliferation of filamentous bacteria that produces a voluminous sludge and a thick brown foam) that require corrective measures such as application of antifoaming agents and chlorine to destroy filamentous biomass.

- **Food to Microorganisms Ratio (F:M Ratio)**—The F:M ratio refers to the ratio of the organics available to be utilized by the microorganisms as “food” to the available microorganisms (biomass inventory). The F:M ratio is defined as the ratio of the total mass in pounds of BOD per day (lb BOD/day) to the total mass in pounds of MLVSSs (lb MLVSS). Typical F:M ratio values for groundwater applications range from 0.1 to 1.0 lb BOD/lb MLVSS/day.

Suspended growth biological treatment has been successfully applied in the pretreatment of groundwater with high concentration contaminant mixtures and are more tolerant of nuisance constituents such as iron. Suspended growth biological treatment technologies are good candidates for pretreatment of groundwater with the following characteristics:

- Organic constituents that are degradable under aerobic conditions.
- Moderate to high organic loading: BOD concentrations of 100 mg/L or greater.
- Iron concentrations of 10 mg/L to 50 mg/L (note that iron concentrations greater than 50 mg/L may require pretreatment).
- Alkalinity and hardness concentrations exceeding 150 mg/L.
- TSS concentrations greater than 20 mg/L (e.g., geologic formation containing fines).

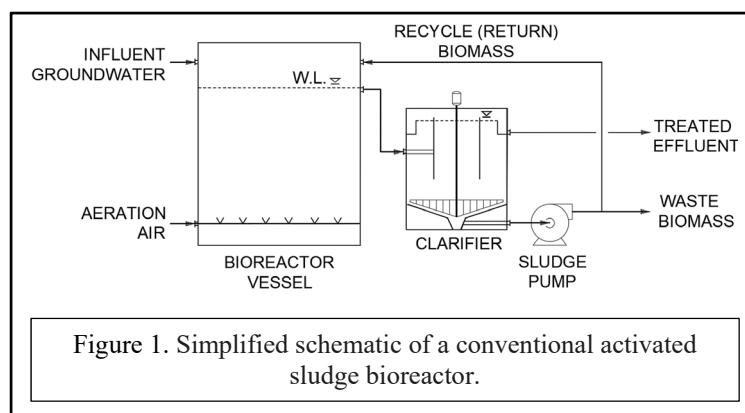
Treatment using a suspended growth bioreactor requires a moderate to high concentration of organic carbon to provide sufficient food sources to maintain the microbial population and maintain a stable microbial culture. Dissolved iron will precipitate in the presence of oxygen and form iron hydroxide. Iron hydroxide becomes complexed with water to form a large molecule that promotes the agglomeration of bacteria and other particulates (aquifer solids, carbonate precipitates, as well as other metals that precipitate) into flocs. This characteristic is extremely beneficial for suspended growth biological systems because better flocs result in more surface area of active biomass (increases the bacteria contact with organics), facilitating improved settling characteristics of the biomass (improving the efficiency at which the biomass can be separated from treated effluent and making it easier to maintain the target biomass inventory). The most often used types of suspended growth bioreactor systems for groundwater treatment are complete mix reactors (also known as “activated sludge” bioreactors), sequencing batch reactors, and membrane bioreactors. A more detailed description of each of these suspended growth bioreactor systems follows.

Activated Sludge

A complete mix system consists of one or multiple vessels in which the concentration of contaminants and suspended biomass remains constant throughout the tank, and mixing occurs instantaneously when contaminated groundwater enters the vessel(s). Refer to Figure 1 for a simplified schematic of a conventional activated sludge bioreactor. In the bioreactor, groundwater is continuously introduced, and treated effluent is continuously removed from the system with the mixed liquor. Therefore, a downstream process is required to

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)

separate suspended biomass from the treated effluent (gravity sedimentation by the clarifier in conventional complete mix systems and by membranes in membrane bioreactors) and returned to the bioreactor. Activated sludge bioreactors (commonly referred to as aeration basins for the mechanism used to transfer oxygen and impart mixing) consist of a reactor vessel (aeration basin) that incorporate a separate clarifier to separate biomass from the treated effluent via gravity settling. Settled biomass is returned to the reactor vessel to maintain the target MLSS/MLVSS concentrations and is wasted to maintain the target MCRT.



The advantages of the activated sludge system is that it is a very well established and widely implemented technology with many decades of operational and optimization information readily available for the operator to reference. The main disadvantage is its relatively large footprint with the aeration basin, clarifier, and aeration and pumping systems.

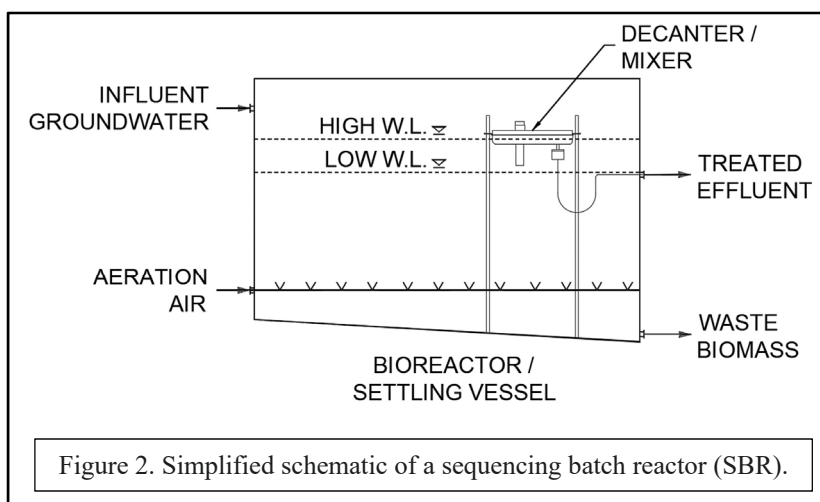
Sequencing Batch Reactors

A sequencing batch reactor system typically includes a tank, aeration and mixing equipment, a decanter, pumps, piping and appurtenances, and a process control system that includes level sensors, timers, automatic switches, and valves that sequence and time the five different operations. Decanters, which can be either floating or fixed, remove the clarified effluent from the reactor. In a single vessel, a sequencing batch reactor accomplishes equalization, aeration, and clarification in a timed sequence. The mixed liquor remains in the reactor during each phase of the sequencing batch reactor cycle. Refer to Figure 2 for a simplified schematic of an sequencing batch reactor (SBR). Each cycle of a sequencing batch reactor system consists of five steps: fill, react, settle, decant, and idle. During the fill stage, groundwater is distributed through the settled sludge, and biodegradation is initiated. The reactor is filled with contaminated water and can be aerated, depleted of oxygen, or a combination of both. During the react step, influent flow ceases and aeration/mixing continue until biodegradation of the organic constituents in the groundwater is complete. Sludge wasting also occurs during the react step to maintain the target MCRT. Wasting during this phase ensures a uniform discharge of solids based on the mixed and aerated conditions in the reactor. During the settling step, the aeration/mixing cease and quiescent conditions allow the biomass to settle. Clarified effluent remains above the sludge and is removed from the tank during the decant phase. During the idle stage, the reactor is waiting for the next fill stage. This phase allows a second sequencing batch reactor system to complete its fill stage and begin the react stage, increasing operational flexibility.

The advantages of the sequencing batch reactor are its simplicity of operation, small footprint, flexible design, and ability to maintain a high-quality effluent under a variety of influent flow and organic-loading conditions.

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)

The sequencing batch reactor system eliminates the need for separate primary and secondary clarifications and a sludge recycle system because the sludge remains in the reactor at all times.



Membrane Bioreactors

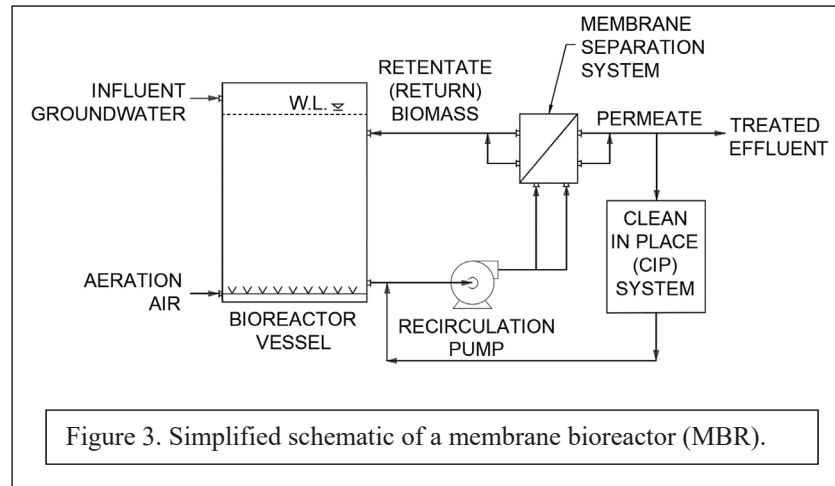
The membrane bioreactor (MBR) combines the suspended growth biological treatment with membrane filtration to provide an improved level of organic constituent removal. The membrane separator is used for solids removal and can replace the secondary clarification and effluent filtration steps. The bioreactor can operate at a much higher mixed liquor concentration because the need for sedimentation is eliminated. A membrane bioreactor can be configured with either internal or external membrane modules. In a system with an internal membrane system, membrane modules are installed inside the suspended growth bioreactor. The membrane is subject to a vacuum to draw treated effluent (permeate) through the membrane while leaving solids in the reactor (retentate). Compressed air is introduced through a manifold at the base of the membrane to scour the membrane surface and oxygenate the water. A backflush process using a low concentration of chlorine can also be used to clean the membrane. An external membrane system consists of membrane modules outside the suspended growth bioreactor (refer to Figure 3 for a simplified schematic). Mixed liquor is withdrawn from the bioreactor and pumped at relatively high pressure through the membrane module; the retentate is returned to the bioreactor and the permeate is discharged as treated effluent. The membrane modules in the external membrane system operate in the same manner as the internal membrane system. Since the need for a good settling floc is not necessary, MLSS concentrations can be maintained between 3000 and 15,000 mg/L, much higher than the other suspended growth bioreactor types.

The advantages of using a membrane bioreactor are that it can handle increased volumetric loading rates, sludge production is significantly less than conventional systems, a smaller footprint is required, and the system can be easily expanded with additional modules. The disadvantages of using a membrane bioreactor are that the capital costs are higher, the cost for membrane replacement is potentially high, and membrane fouling will need to be controlled.

Fixed-Film Bioreactors

With fixed-film bioreactors an inert medium is placed within the reactor vessel to provide the following functions: (1) a surface to support the attachment and growth of bacteria as a biofilm and (2) the means to increase the surface area of the biomass to facilitate the thorough contact with the groundwater COCs.

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)



Unlike suspended growth bioreactors that rely on methods to keep biomass within the vessel (e.g., clarifiers and sludge pumps, membrane separation), fixed-film bioreactors require a means to control excess biomass. In a well-designed and healthy system, the biomass inventory is self-regulating; excess biomass sloughs from the support medium and exits in the treated effluent. Some fixed-film bioreactor designs control biofilm simply by introducing oxygen (e.g., aeration) or through a mechanical shearing of the excess biomass from the medium. There are two general classes of fixed-film bioreactors:

- **Trickling media:** Trickling media-style bioreactors are designed to distribute the wastewater stream in a thin film over the medium beds and biomass. The wastewater is sequentially distributed over a discrete portion of the medium, not the entire bed, as a means to control excess biomass (because the medium is not submerged, gravity promotes sloughing of the thickened biofilm). The COCs transfer into the biofilm; the bacteria degrade the organics; and the waste by-products (carbon dioxide and water) transfer back to the water film. Oxygen transfers from the atmosphere through the water film and to the biofilm. One important advantage of trickling media systems is that oxygen can be supplied at lower costs. The most common trickling media bioreactors are trickling filters (Figure 4) and rotating biological contactors.
- **Submerged media:** This class of bioreactor employs a biomass support medium that is completely submerged within the reactor vessel. Excess biomass is typically controlled with aeration (e.g., coarse or fine bubble aeration provides a scouring action to promote sloughing of the thickened biofilm) or through the mechanical shearing of the biomass from the medium. The most common submerged media bioreactors are the submerged fixed-film bioreactor (Figure 5), the moving bed bioreactor (similar configuration to the submerged fixed-film bioreactor with the exception that the media consists of fairly small wheels, rings, or similar media that are buoyant and freely suspended within the vessel rather than fixed in place), the fluidized bed bioreactor (Figure 6), and biological GAC. BioGAC systems are conventional GAC systems where biomass accumulates in the lead vessel, by design, to facilitate biological treatment and extend the life of the carbon beds. BioGAC is applicable to low concentration COCs (low biomass yield is important to minimize the number of backwash cycles required to control excess biomass and fouling of the GAC bed).

Fixed-film bioreactors have been utilized for the treatment of hazardous organic chemicals in groundwater most typically when the organics/COCs concentration and rates of degradation are too low to support the required F:M and MCRT for a suspended growth bioreactor. Because of the attached growth of biomass, the MCRT of fixed-film bioreactors is higher than that of suspended growth bioreactors under low organic loading conditions

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)

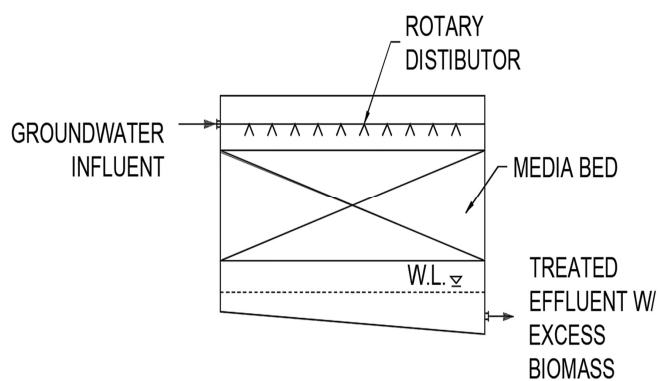


Figure 4. Simplified schematic of a trickling filter bioreactor (biotrickling filter).

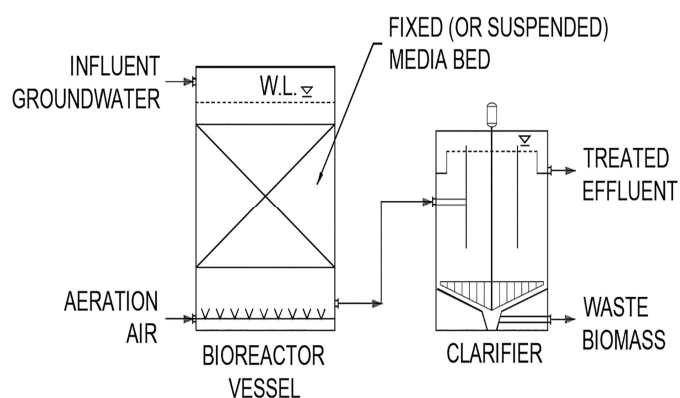


Figure 5. Simplified schematic of a submerged fixed-film bioreactor (i.e., fixed media bed) and a moving bed bioreactor (i.e., suspended media bed).

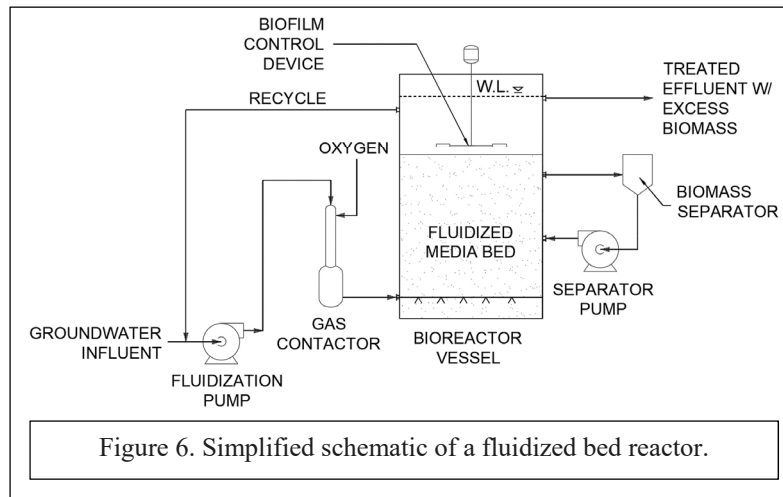
(i.e., BOD concentrations less than 100 mg/L), fixed-film bioreactors are more suitable for the treatment of low concentrations of organic compounds. Therefore, for groundwater containing high concentration contaminant mixes, fixed-film bioreactors are best suited for polishing treatment. When using GAC as a polishing treatment step downstream of a suspended growth bioreactor, BioGAC conditions can be developed by inoculating with sludge from the suspended growth bioreactor (these conditions are likely to develop over time regardless). Automated backwash systems with in-line pressure monitoring is recommended to control the excess biomass in the BioGAC vessels.

Bioreactor Reliability

The microbial community that a bioreactor relies on to effect water treatment is susceptible to stress from sudden and significant changes in organic loading, flow rates, or makeup of the influent characteristics. Management of the biomass inventory by monitoring the MLSS/MLVSS, BOD, F:M ratio, and MCRT are integral to reliable operation of the bioreactor (these parameters should be monitored at least weekly). Further, the performance of the bacteria can be affected by environmental conditions including dissolved oxygen, temperature, pH, and total dissolved solids (TDS)/salinity (TDS becomes inhibitory near 20,000 mg/L). Consequently, it is important that these parameters be adequately monitored and maintained in the right range to support the specific microbial community being harnessed. Also, periodic monitoring is recommended for constituents that may be in the groundwater at concentrations sufficiently high to inhibit performance as a toxicant. These constituents may include certain heavy metals, cyanide, sulfide, and ammonia.

The key to reliable operation of a bioreactor technology is to monitor key parameters and discern any trends that could lead to a potential upset condition. Catching a negative trend early and implementing a corrective action should mitigate or even prevent a process upset. In-line monitors can provide real-time data to the Supervisory Control and Data Acquisition (SCADA) Systems that most systems will incorporate, that can be used to produce routine reports and/or show a dashboard of operational trends. Suggested monitoring includes the following:

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)



- **Settling Tests:** Routine collection of mixed liquor for settling tests is a good practice to complete a minimum of once per week. The volume of the settled sludge will provide an indication of reliable operation of the bioreactor (poorly settling solids will result in a larger volume of sludge than normal that could be indicative of a changed condition or stress).
- **Photomicrographs:** Microscopes with integral digital cameras are now readily available at reasonable prices. Examining samples of the mixed liquor at a 50× magnification (at a minimum) will allow the operators to assess the relative health of the microbial population and the presence of higher organisms such as rotifers, free swimming ciliates, flagellates, and stalked ciliates are indicative of a healthy biomass that should enable reliable performance. The presence of abundant filamentous biomass, higher organisms such as nematodes, water fleas, and water bears are indicative of problems that could impair performance.
- **Dissolved Oxygen:** Maintaining a residual dissolved oxygen concentration of at least 1.0 mg/L will ensure that the aerobic bioreactor will not be oxygen limited. Oxygen delivery is one of the most energy intensive elements of the aerobic bioreactor technologies (biotrickling filters are the exception). Significant improvements to in-line dissolved oxygen probes have been made (e.g., electrolyte-free probes), resulting in more accurate measurements with less maintenance and calibration required.
- **Temperature:** Maintaining a temperature range above 50° Fahrenheit and below 100° Fahrenheit is typical for most groundwater applications (note that average shallow groundwater temperatures can be 50° Fahrenheit and even lower in parts of the United States). In-line temperature monitoring is reliable and low maintenance.
- **pH:** Most bioreactors perform optimally at pH range of 6.5 to 8.0. In-line pH probes are reliable with routine maintenance and calibration.

While the core technology around the bioreactors themselves has not changed much since the 1990s (when MBRs were in the early stages of implementation for wastewater applications), the sensors and digital tools available today automate much of the monitoring required to maintain optimal bioreactor health and support much denser data acquisition for trend building and preemptive alerts (refer to Figure 7 for an example SCADA process screenshot and operational parameters such as pump run times and flow totalizer data). The SCADA system allow remote monitoring of the treatment system, including status of motors, blowers, alarms, and provides graphing tools to evaluate the trends from in-line process instrumentation (e.g., pH, DO, temperature, etc.).

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)

Further, digital camera technology allows operators to capture detailed photos of settling tests, photomicrographs, operational issues such as foaming, turbidity, to be shared in real time with subject matter experts to verify optimal operation, facilitate rapid diagnosis of issues, and rapidly develop corrective actions (refer to Figure 8 for example photos).

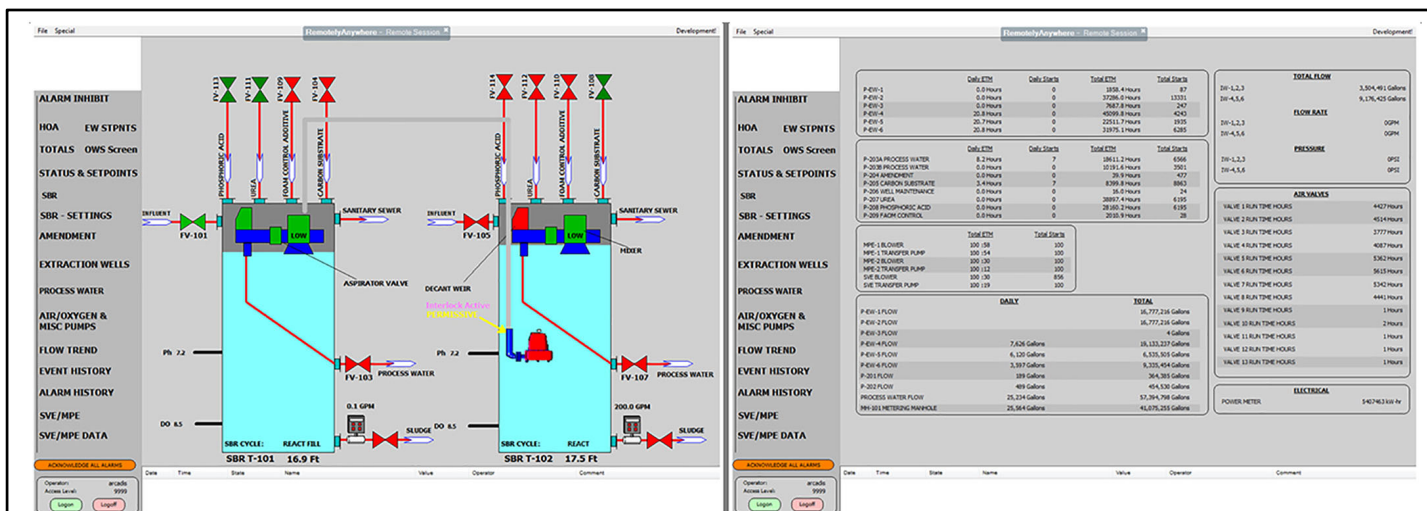
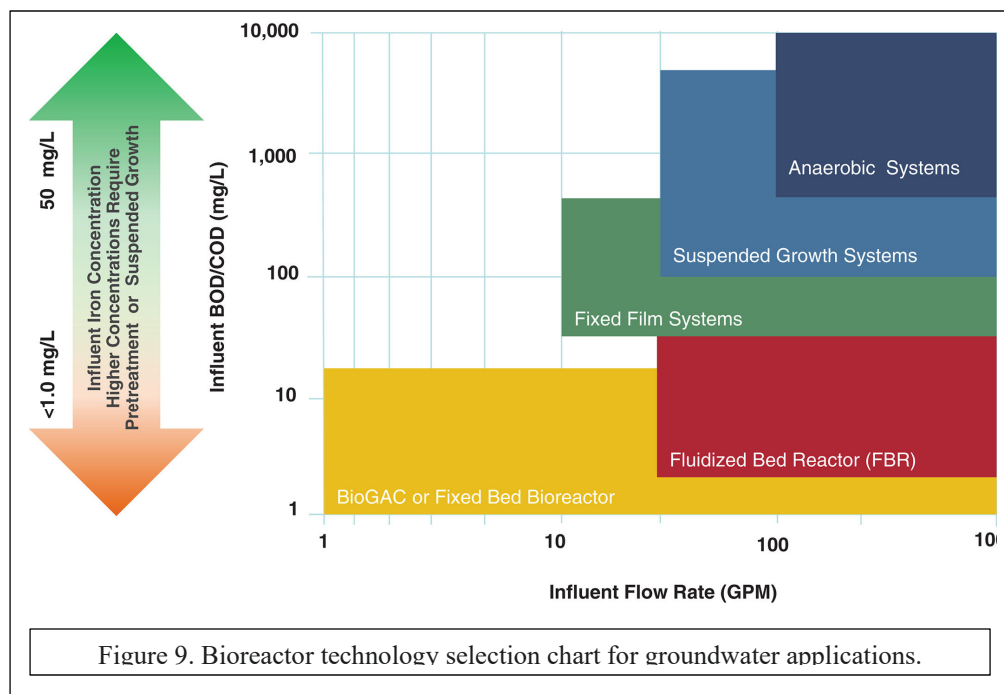


Figure 7. Example SCADA process screenshot for an SBR system treating groundwater (left). Example summary screen of totalizer flows and run times for the SBR system (right).

Application to High-Concentration Mixed Contaminants

Figure 9 presents the applicability of various classes of bioreactor technologies based on the relative strength of the organics in the groundwater (i.e., BOD and/or COD concentrations). It is common for relatively high concentrations of dissolved iron to be present at groundwater remediation sites. As Figure 9 indicates, some of the bioreactor technologies may require a pretreatment step to remove iron as a means to prevent fouling/scaling resulting from precipitation of iron. For sites with high-concentration mixed contaminants (i.e., BOD concentrations above 100 mg/L), suspended growth bioreactors will be a good application for use as a pretreatment process in a sequential treatment system, particularly when emerging contaminants are also present. A summary of select groundwater COCs that have been treated using bioreactors is summarized in Table 1 below.

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)



Aerobic bioreactors are versatile and can treat petroleum hydrocarbons, VOCs, SVOCs, some CVOCs such as 2-chloroethanol and 1,2-dichloroethane (1,2-DCA), and 1,2-dichloroethene, phenolic compounds, alcohols, ammonia and emerging contaminants such as bis(2-chloroethyl) ether (BCEE) and 1,2,3-trichloropropane. Suspended growth aerobic bioreactors are very effective at removal of BOD and COD and remove relatively high concentrations of dissolved iron (up to 50 mg/L). Thus, for groundwater containing high concentrations of mixed COCs, suspended growth aerobic bioreactor technologies can reduce the organic load to downstream treatment processes. This can support the design of polishing steps that could handle the source groundwater without the bioreactor (providing confidence in an upset situation) but together with the bioreactor can be operated just as effectively and far more efficiently. The following is an example of where this type of approach is being considered.

Example Project/Case Study

A former specialty chemicals plant operated from the early 1950s through 2001 when the plant was closed. All production infrastructure and most plant buildings have been demolished, leaving concrete pads and roads covering a substantial portion of the ground surface. However, below the surface, the legacy of soil and groundwater impacted by half a century of production remains. A mixed dense nonaqueous phase liquid (DNAPL), consisting of the six primary site COCs: BCEE; Bis(2-Chloroethoxy)methane (BCEM); 2-Chloroethanol; 1,2-DCA; 1,4-Dioxane; and 1,2,3-TCP is present in the source zone and has been delineated in high resolution using multiple lines of evidence including DyeLIF. A network of groundwater extraction wells currently provides hydraulic control for the dissolved phase plume as an interim measure, while remedial options for the source are being evaluated. The current stream of extracted groundwater (approximately 70 gpm) is being treated with GAC before being discharged to the public treatment works. An iron removal pretreatment step is required before the GAC because of exceptionally high iron content of the groundwater (approximately 100 mg/L iron) related to both reducing conditions and low pH. In addition to elevated iron, other geochemical parameters such as high salinity from brackish groundwater and elevated alkalinity and hardness (CaCO_3)

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)

pose challenges for the treatment infrastructure.

Several options are being considered for source zone treatment at the site, including in situ thermal remediation, which would require treatment of a higher volume, higher concentration effluent stream. In addition, once source zone treatment is complete, one option being considered for treatment of the dissolved phase plume is directed groundwater recirculation, which would also require an increased capacity for treatment of high-concentration groundwater.

Between 2015 and 2017, bench-scale treatability tests and field-scale pilot tests of several water treatment technologies were conducted to be applied in an upgraded wastewater treatment system during source zone remediation, particularly testing for conditions expected during in situ thermal remediation. The wastewater treatment technologies tested on the site groundwater were: (1) AOP using combinations of ultraviolet (UV) light with oxidizing agents such as hydrogen peroxide or titanium dioxide as well as ozone with hydrogen peroxide, (2) regenerable adsorptive media (AMBERSORB™ and OPTIPORE™), (3) steam stripping, and (4) bench-scale suspended growth bioreactor. Each technology was tested independently and provided valuable information about which contaminants each technology would be most effective at treating. It became clear, however, that a treatment train consisting of more than one of these technologies would be required to best treat the groundwater stream to the anticipated targets.

Based on the findings of the treatability testing, several variations of multistep treatment trains were proposed that each included a suspended growth bioreactor to pretreat the groundwater and decrease the high organic load of the stream, followed by a polishing technology to remove some of the more recalcitrant components and achieve the low levels required for reinjection of the groundwater. In 2018, a field-scale pilot test program was developed to test these treatment trains with the following two objectives for the testing: (1) confirm the operational reliability of a bioreactor technology for pre-treatment of groundwater at the site and (2) identify opportunities to optimize the overall treatment approach. A 3- to 4-month test duration was selected to provide enough time for ramping up the SBR operation to steady-state conditions (a process that typically takes four to 8 weeks).

In October 2018, the pilot system was installed at the site, designed to treat 100 gal per day at an HRT of 2 days. The pilot system initially consisted of an equalization tank, a pilot-scale SBR and fabric media filtration system, a GAC adsorber, and appurtenant pumps, blower, chemical metering systems (for biomass growth nutrients and pH adjustment), and controls. The pilot system was inoculated with seed sludge from a POTW (Publicly Owned Treatment Works) and from a landfill leachate bioreactor. Influent to the pilot system was blended from several groundwater sources at the site to gradually increase the COC loading to the pilot system to build up biomass, and the HRT was reduced from 4 to 2 days until steady state was achieved in early December 2018. In January 2019, a pilot-scale AMBERSORB™/OPTIPORE™ regenerative adsorption system was installed to provide additional polishing treatment of 1,4-dioxane after the GAC to assess treatment effectiveness (relative to AOP) and the efficacy of bed regeneration. Near the end of the pilot test, samples were collected from the GAC/filtration/GAC treatment train effluent and submitted for bench-scale testing of UV/peroxide AOP for polishing treatment of 1,4-dioxane.

After steady-state conditions were established, the pilot system was operated for 76 days and produced the following findings (refer to Table 2 for a summary of the pilot test relative to SBR performance):

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)

- Influent concentrations of COCs were variable throughout the pilot test.
- Influent dissolved iron was as high as 100 mg/L.
- Biomass was relatively slow growing and MLSSs stabilized at approximately 2000 mg/L, with 25 to 30% MLVSSs (i.e., iron solids predominated).
- An upset condition caused by a mechanical issue that wasted a significant portion of the SBR's biomass inventory resulted in a slow recovery until supplemental carbon was added. Prior to the upset, some 1,4-Dioxane removal took place, but did not recover after the upset.
- Supplemental carbon was added (0.1 lbs of carbon substrate to 0.125 lbs of BOD per day) and improved the MLSS to 2400 mg/L with 40% MLVSS (refer to Figure [10](#)).
- The supplemental carbon produced a better floc and clearer supernatant (refer to Table [2](#) for the average pilot test performance during this period).
- SBR was able to remove greater than 90% of BOD and greater than 80% of COD (refer to Table [2](#) for a snapshot of the performance prior to ending the pilot test program).
- BCEM, BCEE, 1,2-DCA, and 1,2,3-TCP removal also improved.
- SBR, filtration, and GAC can produce an effluent with only residual 1,4-dioxane (1,4-dioxane sorbs, but has rapid breakthrough). The GAC usage is estimated to range between 1 and 4 pounds per 1000 gallons (lb/1000 gal) treated with biological pretreatment and filtration, depending on the operational phase (startup and periods of upset result in the higher usage, and the lower range is expected when the SBR performance is optimized). Prior GAC usage estimates without pretreatment range between 20 and 30 lb/1000 gal treated, based on 1,2-DCA and 1,4-dioxane treatment, respectively.
- UV/peroxide AOP can meet discharge limitations for 1,4-dioxane. However, it is important that GAC remove the other residual COCs for cost-effective implementation due to poor kinetics, requiring a larger reactor, and much higher UV and peroxide dose. With SBR, filtration, and GAC pretreatment, the treatment objectives for 1,4-dioxane can be met with a UV dose of up to 30 kW/h per 1000 gal treated and a peroxide dose of up to 60 mg/L. Based on the pilot test results, a 50% reduction in capital costs and a 75% reduction in operating costs for UV/peroxide AOP when compared to a system with minimal pretreatment (i.e., iron and suspended solids removal).
- AMBERSORB™/OPTISORB™ can meet discharge limitations for 1,4-dioxane. Further, the technology can meet discharge limitations for BCEM, BCEE, 1,2,3-TCP, and 1,2-DCA during upset conditions (if GAC is allowed to breakthrough). However, the capital and operational costs are higher than UV/peroxide AOP for 1,4-dioxane treatment, and more frequent GAC replacement is less costly during process upsets.

BOD, Biological oxygen demand; COD, Chemical oxygen demand; BCEM, Bis(2-chloroethoxy)methane; BCEE, Bis(2-chloroethyl) ether; 1,4-D, 1,4-Dioxane; 1,2,3-TCP 1,2,3-Trichloropropane; 1,2-DCA, 1,2-Dichloroethane.

In summary, the pilot test demonstrated that an SBR is a suitable technology for pretreatment of the challenging groundwater at the site, reducing the organic loading (i.e., BOD/COD) as well as reducing the concentrations of target COCs and nuisance constituents such as iron. As a result, the downstream polishing treatment processes can be optimized to achieve treatment objectives at a much lower cost. The SBR pretreatment step saves up to 50% in capital and over 50% in operational cost from a conventional system without biological pretreatment (e.g., iron pretreatment followed by GAC followed by UV/peroxide AOP). For the full-scale system envisioned, this would equate to at least \$18.7 M in savings over a 10-year period of performance (uninflated and undiscounted basis).

Evolution of Bioreactor Technologies for High-Concentration Contaminant Mixes in Groundwater (Continued)

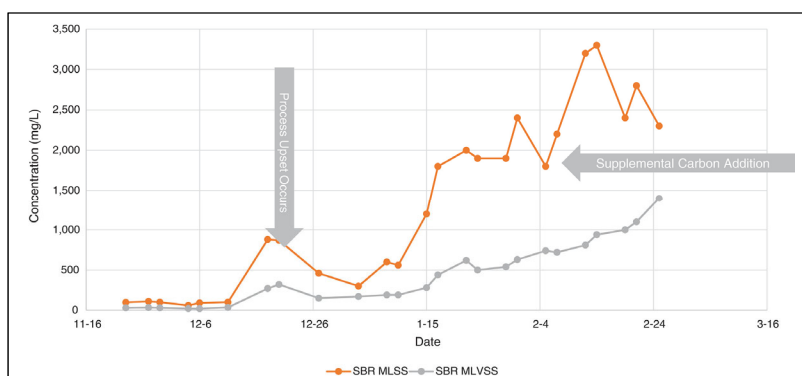


Figure 10. Pilot test SBR mixed liquor suspended solids. On December 18, 2018, the aeration blower continues to operate during the settle and decant phases, resulting in the wasting of a significant amount of biomass. On February 6, 2019, supplemental carbon is added (0.1 lbs dog food per 0.125 lbs of BOD per day) until pilot test is completed on February 25, 2019.

The Improved Opportunity for Harnessing Nature

In site remediation/restoration circles there has been a lot of focus over the past several decades on the creation of in situ biological reactive zones that effectively stimulate naturally occurring microbes to treat subsurface contaminants, borrowing from the theory learned from above-ground applications. The overall advancement of remediation technology has also created the opportunity to make more effective use of above-ground bioreactors. In situations where in situ bioremediation would be untenable and contaminant recovery is part of the strategy, above-ground bioreactors may be a great way to capture the power of natural processes. This is especially true where dissolved contaminant concentrations will be high and includes a mixture of different contaminant types that are not necessarily all easily handled. As can be seen from the example, a bioreactor can potentially precondition water by not just removing a big portion of the contaminant mass load but mineralizing it to reduce the need to further manage it as a waste. Other water quality components that may make treatment challenging can also be addressed to dramatically lower the cost of polishing to a target.

Read more about this article at: <https://ngwa.onlinelibrary.wiley.com/doi/10.1111/gwmr.12345>

Vanishing Arctic ice will open the way for more science voyages, analysis suggests

Early this month, the U.S. Coast Guard icebreaker *Healy* embarked on a journey through the Arctic seas off of the coast of Alaska, helping researchers conduct studies of Arctic algae blooms, atmospheric chemistry, birds, and marine mammals. And more research vessels could soon be plying the same frigid sea lanes, according to a new report. It suggests that science voyages into the Arctic will become more common—along with other types of shipping—as sea ice in the region decreases because of climate change, and nations such as China launch new ice-capable ships.

Vanishing Arctic ice will open the way for more science voyages, analysis suggests (Continued)

But obtaining funding and ship time to conduct studies of one of Earth's fastest-changing regions could still be a challenge, researchers say.

The draft study, prepared by the Committee on the Maritime Transportation Systems (CMTS) in Washington, D.C., examines possible scenarios for maritime activity, out to 2030, in the Arctic waters controlled by the United States. It concludes that vessel activity in U.S. Arctic waters increased by 128% between 2008 and 2018, rising from just 120 vessels in 2008 to a peak of 300 vessels in 2015. (There has been a decline in vessel traffic in more recent years because Royal Dutch Shell, an oil and gas company headquartered in the Netherlands, pulled out of efforts to drill in the area.)

Cargo ships accounted for the most traffic, making 31% of total trips from 2015 to 2017. Tow and tug boats accounted for about one-fifth of traffic over the same period. Trips by research vessels have been gradually rising since 2008, the report concludes and accounted for 4.8% of total traffic from 2015 to 2017.



The report examines four scenarios for vessel activity growth through 2030. The “most plausible” scenario, the authors say, is that vessel activity in the region will rise at an annual rate of 2.3%, with 377 ships sailing into U.S. Arctic waters by 2030.

One trend that will boost ship traffic, the report says, is the expansion of the summer shipping season, when sea ice is at its lowest extent. That season, which the report defines as the period when more than 10 vessels are in Arctic waters, has been lengthening by about 10 days per year in recent years. It lasted 180 days in 2018, up from 159 days in 2016.

Arctic shipping could also get a boost from new additions to the world's fleet of ships capable of handling icy Arctic seas. The U.S. Coast Guard now maintains two icebreakers, the aging *Polar Star*, which mostly operates in the Antarctic, and the *Healy*, which mostly operates in the Arctic. But the Coast Guard is now seeking funding to add as many as six “polar security cutters” in coming years, with the design and construction of one already underway.

Other nations, meanwhile, are also expanding polar fleets. China launched one icebreaker, the *Xue Long 2*, last year, and Russia has said it wants to launch three new nuclear-powered icebreakers in the early 2020s.

Vanishing Arctic ice will open the way for more science voyages, analysis suggests (Continued)

The expected opening of the Arctic to greater ship traffic is also turning the heads of scientists, who are increasingly interested in the region's role in global marine and atmospheric systems. "The more research we get up there, the more we'll understand and the more rapidly we'll understand," says Larry Mayer, a marine geophysicist at the University of New Hampshire in Durham. At the same time, he says, it's ironic that planetary warming is clearing the path for new seaborne expeditions. "The ultimate disadvantage is the circumstances, that have created [a] situation which I don't think is healthy for the earth or healthy for the Arctic."

"The overall picture is mixed," says Julie Brigham-Grette, a geologist at the University of Massachusetts in Amherst. "We're opening up an entire environment that has otherwise been cut off from human influence."

Doing science in the Arctic, however, is notoriously expensive. It costs about eight times more to do studies in the Arctic than at lower latitudes, according to an analysis published in *Arctic Science* in 2018. And Brigham-Grette notes that global funding for Arctic research is relatively limited. The field receives less than less than 3% of the funds spent on science by nations with an interest in the Arctic, according to an article published in *Polar Research* in 2018.

CMTS expects to post its final report on Arctic shipping on its website in late September

Read more about this article at: <https://www.sciencemag.org/news/2019/08/vanishing-arctic-ice-will-open-way-more-science-voyages-analysis-suggests>

Europe's record heat melted Swiss glaciers

The sweltering heat wave that roasted much of Europe last month has since moved north, where it's wreaking havoc on the Greenland ice sheet. But while all eyes are currently trained on the Arctic ice, scientists are finding that Europe's coldest places have also suffered.

According to initial findings from the Swiss Glacier Monitoring Network (GLAMOS), Swiss glaciers experienced unusually high melt rates during the last heat wave, which occurred in late July, and an earlier heat wave that struck the continent in late June.

Matthias Huss, a glaciologist with Swiss University ETH Zurich and head of GLAMOS, tweeted last week that the nation's glaciers lost about 800 million metric tons of ice during the two heat waves alone.

"Absolutely exceptional for a period of only 14 days in total!" he commented in the tweet.

The estimate is still preliminary, he told E&E News in an interview. It's based on an early analysis of on-site measurements at certain sites, combined with a model that scales up the measurements to estimate total ice losses throughout the country. A more detailed analysis will follow at the end of the summer, which will estimate the season's cumulative losses and compare them to previous summers.

But the data already suggests that the losses this year have been unusually rapid.

During the winter, the region received an above-average amount of snowfall, Huss pointed out. So the glaciers actually started the summer with a high level of snow cover and were doing "extraordinarily well" compared to the last few seasons, which have logged particularly strong losses, he noted. Scientists were hopeful that they'd end the

Europe's record heat melted Swiss glaciers (Continued)



But once the first heat wave struck, the snow began to rapidly melt away.

"Now, because of these two heat waves, we have tracked very fast downward," Huss told E&E News. "And we are now at the average of the last 10 years, or even already a bit below."

Across the European Alps, other regions have also been feeling the heat this summer. The Tignes ski resort in the French Alps announced at the end of July that the nearby Grande Motte Glacier was no longer safe for skiers after this summer's excessive melting.

And about 50 miles to the north at Mont Blanc, the highest mountain in the European Alps, mountaineer Bryan Mestre was stunned to stumble across a large pond of liquid water pooled on top of the snow as he hiked through in late June. Just 10 days earlier, before the first heat wave set in, the same area had been completely frozen. His Instagram post has been widely shared by media outlets around the world.

It's the latest continuation of a long trend. According to Huss, alpine glaciers have been retreating since at least the mid-19th century. And the losses seem to be accelerating over the last few decades.

The most impressive changes have been observed at the region's largest glaciers, he noted. Aletsch Glacier, the largest glacier in the Alps, has retreated by nearly 2 miles since the year 1870. The pattern isn't limited to Swiss glaciers. Scientists have observed declines across Europe, including glaciers in the mountains of France, Austria, and Italy. And as long as global temperatures continue to rise, the losses are expected to continue.

One recent study published earlier this year in *The Cryosphere* estimated that about a third of all the glacier volume in the European Alps could be lost by the year 2100, even if world nations manage to meet the climate targets outlined in the Paris Agreement. Under a scenario in which greenhouse gas emissions continue at their current levels, more than 90% of the ice could disappear.

Other studies have made similarly dire projections for mountain glaciers in other parts of the world, including the Hindu Kush and the Himalayas.

Summers like this one, marked by extraordinary heat waves and high levels of melt, only exacerbate the problem.

"Now we are really seeing almost every year another extreme year," Huss said. "And this is what is actually a problem."

Read more about this article at: <https://www.sciencemag.org/news/2019/08/europes-record-heat-melted-swiss-glaciers>

Cataclysmic collision could explain Jupiter's fuzzy core

Jupiter harbors a deep mystery: Rather than the distinct core scientists expected, it has a fuzzy center, according to recent observations by NASA's Juno spacecraft, which extends for up to half the planet's radius.

One possible explanation is a cataclysmic head-on collision some 4.5 billion years ago between a young Jupiter and one of the many large protoplanets that likely populated the early solar system, planetary scientists report today in *Nature*. Such an event would have seen Jupiter absorb the protoplanet, which would have been 10 times Earth's mass, causing their two dense cores to combine and diffuse after only 10 hours, as seen in the simulation above. Over time, cooling and winds could sweep some of the fuzzy core upward, explaining Jupiter's puzzling enrichment in elements like carbon and nitrogen close to its surface.

An impact is not the only way to explain the diffuse core. It may have instead formed simply through erosion, the researchers say, or gas could have been a building block of the planet from its very start, rather than later on. But such a collision is plausible, as evidence now suggests the early solar system was a violent, impact-filled realm driven by the jostling of Jupiter and Saturn.

Many researchers suspect the tilts of several gas giants—including Uranus, which rotates on its side—were caused by such collisions. It appears Jupiter, although barely tilted, may not have escaped the barrage it helped shape unscathed.

Read more about this article at: <https://www.sciencemag.org/news/2019/08/cataclysmic-collision-could-explain-jupiter-s-fuzzy-core>

Galaxy hunters spot hidden giants in the early universe

Astronomers have filled in a big hole in the puzzle of how the universe evolved. Using multiple telescopes to peer out into space and back in time, they have spotted a hidden population of large galaxies dating back to when the universe was less than 2 billion years old that are invisible to optical telescopes like the Hubble Space Telescope (HST). The galaxies' surprising abundance so early in the history of the universe may challenge conventional theories of galaxy formation, the observers say.

"This paper demonstrates that we were missing 90% of the massive galaxies," says Mauro Giavalisco, an astronomer at the University of Massachusetts in Amherst who was not involved in the new work. "I think it will spur a lot of further research."

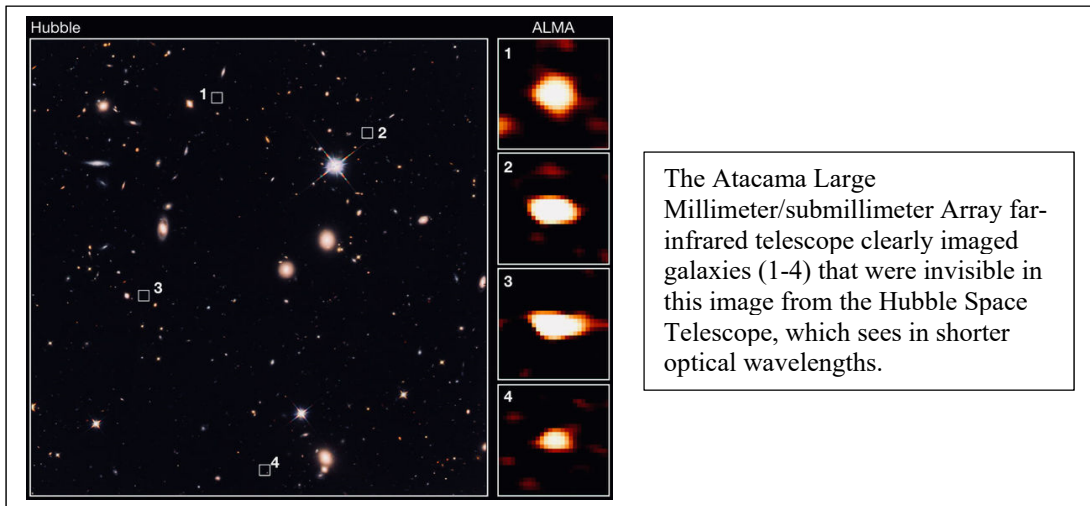
For astronomers, proving that an ultrafaint spot of light on the sky is a distant galaxy is no mean feat. To do so, they use a trick that depends on the spectrum of light the galaxy pumps out. Stars crank out copious light, but the hydrogen gas from which the star forms absorbs wavelengths that are shorter than a specific part of the ultraviolet (UV) wavelength, creating a distinct cutoff light's spectrum. Before it reaches human observers, the light is redshifted: stretched to longer wavelengths by the expansion of the universe. That slides the cutoff into another part of the spectrum: visible or near-infrared wavelengths. Searching for this telltale feature, the HST has found hundreds of galaxies that were shining when the universe was less than 2 billion years old.

This technique has one big problem, however: It's keenly sensitive to smaller, younger galaxies, but blind to bigger, older ones. In the larger, more mature galaxies of this early epoch, there were more supernovae, and dust from these stellar explosions absorbed most of the UV light. That would have obliterated the telltale spectral cutoff. In fact, to observers on Earth, early massive galaxies are simply invisible at optical wavelengths, says Tao Wang, an astrophysicist at the University of Tokyo.

Galaxy hunters spot hidden giants in the early universe (Continued)

Now, Wang, David Elbaz, an astrophysicist at the French Alternative Energies and Atomic Energy Commission in Saclay, and an international team have found a way to spot the missing galaxies by turning their enemy—dust—into an ally. The dust that absorbs starlight must heat up and radiate at longer infrared wavelengths, which Wang, Elbaz, and colleagues could look for.

The researchers confined their search to three tiny patches of the sky that the HST had imaged with great sensitivity. They used NASA’s Spitzer Space Telescope to scan those patches at midinfrared wavelengths. Spitzer spotted 63 candidate galaxies, but the scope lacked the spatial resolution to clinch the identifications. So the researchers then studied each candidate at longer far-infrared wavelengths using the international Atacama Large Millimeter/submillimeter Array (ALMA), an array of 66 dishes in the high desert of northern Chile. Those observations confirmed 39 of the candidate galaxies, the researchers report today in *Nature*. What’s more, by searching previously taken images, the team revealed that these ancient galaxies are invisible to the HST—leading them to classify the galaxies as “H-dropouts.”



The Atacama Large Millimeter/submillimeter Array far-infrared telescope clearly imaged galaxies (1-4) that were invisible in this image from the Hubble Space Telescope, which sees in shorter optical wavelengths.

Data from ALMA and other telescopes show the newly found galaxies typically weigh about 100 billion solar masses and are filled with dust gently warmed to about 35 K—just as one would expect if it were being heated by stars in a typical star-forming galaxy and not by, say, the massive black hole at the center of a quasar. If there are just as many of these ancient galaxies in the rest of the sky, they must account for half of all star production at the time in the universe, the scientists estimate. “They really seem to be quite common sources in the early universe,” says Giulia Rodighiero, an astronomer at the University of Padova in Italy who was not involved in the work. “So, they really represent the average mode of galaxy assembly” in the youthful universe.

Spotting these early galaxies should be a boon to theorists modeling galaxy formation and evolution, Elbaz says. In fact, he argues, the observations already challenge the prevailing theory. “You would not expect to make so efficiently galaxies so massive so early in the universe,” he says.

Others are less sure. Rather than clashing with the prevailing theory, the new observation will probably help firm it up, Giavalisco says. “At this stage, discoveries like this are very important because they inform the theory,” he says. Rodighiero notes that the same models already have problems re-creating dusty galaxies later in the history of the universe, so the new observations are not the only challenges for theorists. Both note that theorists modeling galaxy evolution must still rely on approximate models of star formation, which lie at the crux of the issue.

Galaxy hunters spot hidden giants in the early universe (Continued)

The observations demonstrate the power of ALMA, which has unprecedented spatial resolution at these far infrared wavelengths. In 1998, astronomers used the James Clerk Maxwell Telescope, a single 15-meter infrared dish on Mauna Kea in Hawaii, to spot an early galaxy, Elbaz says. But the telescope had such poor resolution it took 14 years to pinpoint the source on the sky. In contrast, Elbaz says, the ALMA dishes nailed down each new galaxy by focusing on it for less than 2 minutes.

Read more about this article at: <https://www.sciencemag.org/news/2019/08/galaxy-hunters-spot-hidden-giants-early-universe>

Sea of Galilee earthquakes triggered by excessive water pumping

One evening in September 2013, windows rattled and ceiling fans swayed in northeastern Israel as a small earthquake rumbled beneath the Sea of Galilee—the water Jesus is said to have walked on—also known as Lake Kinneret. Four more tremors struck over the next 4 days. Then, in July 2018, a dozen small earthquakes shook the same spot beneath the lake on a fault—the slip surface along which an earthquake ruptures.

Although far more powerful earthquakes have struck the Levant, swarms such as these are rare and mysterious. A new study suggests human activity is to blame. Pumping too much water from the region too quickly may have “unclamped the fault,” the authors argue. And, they add, Californians and others living above major faults better pay attention, lest a similar appetite for water trigger a far larger, more dangerous quake.

Researchers have long known that humans can cause earthquakes by injecting fluid into the ground—a technique used in hydraulic fracturing, or fracking, to break open rocks and release natural gas or petroleum. Pumping water into geothermal vents to generate steam for heating and electricity has also triggered temblors. But earthquakes set off by pumping fresh water *out* of underground aquifers haven’t received much attention, says study co-author Emily Brodsky, a seismologist at the University of California (UC), Santa Cruz. “This is not the first example of groundwater extraction triggering earthquakes, but it’s uncommon,” she says.

For decades, Lake Kinneret provided up to a third of Israel’s domestic water supply, but a booming population and declining rainfall caused lake levels to fall precipitously. In the 1990s, Israeli officials encouraged people to pump groundwater from the wells surrounding the lake instead. After the 2013 and 2018 earthquake swarms, Nadav Wetzler, a geologist with the Geological Survey of Israel in Jerusalem, wondered whether the events were connected.

To find out, he, Brodsky, and colleagues compared the dates, locations, depths, and magnitudes of the earthquakes to regular measurements of groundwater levels in the region’s aquifer. They found that the quakes, most of which registered relatively harmless magnitudes between 3 and 4, occurred after steep groundwater declines from 2007 to 2013, and again from 2016 to 2018.

Injecting water into aquifers is thought to trigger earthquakes by increasing the water pressure in pores within the rocks, lubricating faults and allowing them to slip more easily. But how might removing groundwater trigger an earthquake swarm? In a paper published last week in *Geophysical Research Letters*, the authors suggest a model in which extracting groundwater reduces the gravitational load on a fault—lessening the forces that push rocks on either side of the fault together to keep it locked. “Pulling the water out allows the rocks to kind of relax away from one another, and therefore unclamps the fault,” Brodsky explains.

It’s a reasonable explanation, says earth scientist Manoochehr Shirzaei at Arizona State University in Tempe. He says scientists have traditionally assumed that freshwater fluid removal can’t easily trigger earthquakes.

Sea of Galilee earthquakes triggered by excessive water pumping

“This is one of the first studies to show that it can.”

Wetzler says the 2018 earthquake swarm, although relatively small, was a “wakeup call” for Israeli seismologists and government officials to improve earthquake readiness and bring buildings up to code. The Dead Sea Transform fault, which runs underneath the Sea of Galilee and the Dead Sea and accommodates the grinding motion between the Arabian and African tectonic plates, has been responsible for far larger earthquakes. Historical records reveal that in 1138, for example, a quake with an estimated magnitude between 7 and 8 hit the region, killing some 230,000. More recently, a 6.25-magnitude earthquake in 1927 killed close to 300.

Though the 2013 and 2018 swarms were comparatively mild, Brodsky says officials should be wary of them, no matter their initial cause, as small quakes can trigger larger ones. “Earthquakes beget earthquakes,” she says. “Once the rock breaks, it doesn’t know how it started.”

That means Californians should also appreciate the link between groundwater and seismicity, Wetzler says. In recent years, aquifers underneath California’s Central Valley have been overpumped, even amidst severe drought conditions. Worryingly, Wetzler adds, the nearby San Andreas fault, responsible for some of California’s largest earthquakes, is similar to the Dead Sea Transform.

The findings may even help explain why California sees slightly more earthquakes during the state’s dry summers, when groundwater pumping is at its peak, than in comparatively wetter months, says Roland Burgmann, a geophysicist at UC Berkeley. “We used to say there’s no such thing as ‘earthquake weather,’ but now it’s looking like there might be a subtle connect

Read more about this article at: <https://www.sciencemag.org/news/2019/07/sea-galilee-earthquakes-triggered-excessive-water-pumping>

Dinosaur-age landscapes lurk in Southern Hemisphere

Climbing to the top of the Urucum plateau, a shock of rust-red land thrust 1 kilometer above the Brazilian savanna, is a journey into Earth's deep past. Despite the region's heavy, erosive rainfall, the surface of the plateau has remained largely unchanged for some 70 million years, making it Earth's oldest known landscape. Walk along it and you're only a few meters below the surface that dinosaurs once trod.

That startling picture emerges from a study published this month in *Earth and Planetary Science Letters* by a team led by Paulo Vasconcelos, a geochemist at the University of Queensland in Brisbane, Australia. Until recently, scientists could estimate erosion only by looking at the sediment sloughed off of a surface. But new geochemical tools developed by, among others, Vasconcelos and his colleagues measure erosion from rock that's left behind. "They all converge to the same story," Vasconcelos says. "Though it's taken some time to convince people."

Earth scientists say ancient landscapes could exist atop other inselbergs, a German term for the isolated plateaus that dot geologically quiet regions in the Southern Hemisphere that have not been reshaped by plate tectonics or planed away by ice sheets. Geologists had suspected that these inselbergs, found in Brazil, Australia, and southern Africa, are old—enduring while erosion stripped away the surrounding landscape. Now, that history is emerging. "It's almost like the movies," says William Dietrich, a geomorphologist at the University of California, Berkeley. "You expect to see exotic animals wandering around."

Dinosaur-age landscapes lurk in Southern Hemisphere (Continued)

For decades, geomorphologists have fixated on regions where plate tectonics accelerates geologic change, thrusting up mountains, opening rifts, and creating traps for oil and gas. "Where do most geologists go?" asks Paul Bierman, a geologist at the University of Vermont in Burlington. "They go to the mountains. Or to oil." But the new geochemical tools are turning geoscientists on to the charms of the planet's slow parts.

Vasconcelos and his team used four different geochemical dating systems to flesh out the story of the Urucum plateau and its neighbor, the Santa Cruz. One took advantage of grains of the mineral manganese oxide that formed when the surface was first exposed to rain. The grains incorporated trace amounts of radioactive potassium, which has steadily decayed into argon ever since, providing a clock that shows the landscape formed 60 million to 70 million years ago. Another gauge of erosion comes from a set of isotopes—of helium, beryllium, and aluminum—that form when cosmic rays bombard surface rocks. The high abundances of these isotopes suggest the plateaus shed only 1 meter of material every 10 million years; the surrounding landscape, meanwhile, likely eroded at 100 times that rate, the group concludes. "They put together an erosional history that's very compelling and exceptional," Dietrich says. "I don't know something so cleverly dated."

The results raise a new question, says Jane Willenbring, a geomorphologist at the Scripps Institution of Oceanography in San Diego, California: "What makes landscapes persist for millions of years?" Until now, the oldest known surfaces had been found in parched regions like the Atacama Desert in Chile or the dry valleys of Antarctica, where water-driven erosion is slow. Paradoxically, the longevity of the Brazilian plateaus depends on water, says Ken Farley, a geochemist at the California Institute of Technology in Pasadena and a co-author of the paper. They are rich in a type of iron oxide called hematite, which reacts with quartz dissolved in

rainwater to form tough blocks of rock that armor the soil. "It's just iron oxide, nothing else there," Farley says.

Similar plateaus protected by iron or silica probably exist throughout the slow lands. "Vasconcelos's finding has the potential to motivate other researchers to come back to ancient and slow landforms," says Fabiano Pupim, a geomorphologist at the Federal University of São Paulo in Diadema, Brazil.

One lure is the long histories they hold. "This surface has seen a lot of geochemical processes," Vasconcelos says. "If something very drastic happened on the entire planet, a signature should be left." He's developing a technique to tease out rainfall and temperature histories from oxygen isotopes in goethite, an iron oxide that caps inselbergs in Brazil and Australia. These surfaces can also help scientists judge how often rare, powerful intraplate earthquakes strike a region. If the ancient cap is unbroken, any faults found in the rock below it must be associated with even older earthquakes, says Bierman, who recently used an isolated ancient plateau in South Africa to judge the seismic hazard to a nuclear power plant.

Inselbergs hold another gift: deposits of concentrated iron ore, protected from washing away by the impermeable surface. Left alone, the Urucum might exist for another 30 million years. But now, humanity is doing the job much faster. When the team visited earlier this decade, most of the plateau's surface had been lost to mining, Farley says. "If we went back there, I'm not sure this material would be left."

Read more about this article at: <https://www.sciencemag.org/news/2019/06/dinosaur-age-landscapes-lurk-southern-hemisphere>

Skull fragment from Greek cave suggests modern humans were in Europe more than 200,000 years ago

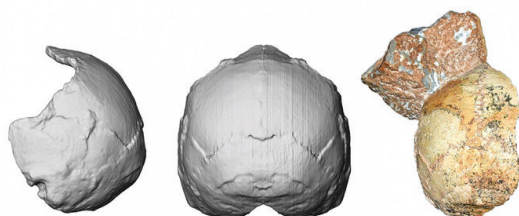
In the late 1970s, anthropologists exploring a cave on the rugged coast of southern Greece found two mysterious hominin skull fossils. Time had left them fragmented and distorted, and the jumbled stratigraphy of the cave made them hard to date. For decades, the fossils sat on a shelf, their identity unknown. Now, a state-of-the-art analysis of their shape together with new dates suggest one skull might represent our own species, living in Greece more than 200,000 years ago. The findings, reported in *Nature* this week, would make this the oldest known *Homo sapiens* fossil found in Europe, by at least 150,000 years.

If so, *H. sapiens*'s first forays out of its African cradle likely happened earlier and extended much farther than most paleoanthropologists thought, into territory dominated by Neanderthals, our extinct cousins. "And then [*H. sapiens*] disappeared" from Europe, says Eric Delson, a paleoanthropologist at the City University of New York in New York City, until a later wave successfully spread across the continent about 50,000 years ago. But because the evidence is no more than a piece from the back of the skull, some researchers aren't sure the fossil can be definitively identified as *H. sapiens*. And others question the old date.

Katerina Harvati, a paleoanthropologist at the University of Tübingen in Germany, has long suspected that southeast Europe was a hot spot for ancient humans. Not only is the region "at the crossroads of three continents"—Africa, Asia, and Europe—but it enjoyed a relatively mild climate when other parts of Europe were covered by glaciers, she says. So she was thrilled to receive permission to study the fossils, which are named for the cave. The first individual, Apidima 1, is represented by the skull piece. The second, Apidima 2, is more complete and includes the face.

The Apidima 1 skull fragment was more complete on one side than the other, and Apidima 2's skull and face were distorted. So Harvati began by figuring out what they originally looked like. She and her team scanned both fossils with x-rays and created 3D reconstructions. They digitally broke Apidima 2 into 66 bone fragments and painstakingly reassembled them into what was likely their original shape. The result showed the face of a typical Neanderthal, jutting from the skull and complete with protruding brow ridges. The ratio of uranium to its decay products in the bones revealed an age of about 170,000 years old.

For Apidima 1, Harvati and her team created a mirror image of the fossil and stitched the two together to see the full shape of the back of the skull. It was short and round, like the skulls of *H. sapiens*, and lacked a ridge and furrow that Neanderthal skulls typically have at the back. "You couldn't bend [the Apidima 1 reconstruction] into a classic Neanderthal cranium," agrees Christoph Zollikofer, a paleoanthropologist at the University of Zurich in Switzerland who wasn't involved in the research. Harvati and her team concluded that the skull most likely belonged to *H. sapiens*.



Investigators scanned a fragment from the back of an ancient hominin's skull (right) and digitally reconstructed it (left and center), revealing the rounded skull of *Homo sapiens*, rather than an elongated Neanderthal skull.

Skull fragment from Greek cave suggests modern humans were in Europe more than 200,000 years ago

The finding startled Harvati herself—especially because the uranium dating of Apidima 1 put its age at 210,000 years old. That makes it at least 15,000 years older than the next oldest fossil of our species found outside of Africa, in Misliya Cave in Israel. It's about 100,000 years younger than the oldest known *H. sapiens* fossils in the world, from Jebel Irhoud in Morocco. But Warren Sharp, a uranium dating expert at the University of California, Berkeley, points out that the Apidima 1 samples actually returned dates ranging from more than 300,000 years old to less than 40,000 years old. "It's not a well-behaved sample," he says. "You have this huge spread of apparent ages, and you don't know if any of them are any good."

Researchers are also divided on whether Apidima 1 convincingly represents a member of our species. "[Apidima 1] pretty clearly preserves enough of the cranium to demonstrate that it is definitively *Homo sapiens*," Delson says. But not everyone agrees. "It's plausible," says Susan Antón, a paleoanthropologist at New York University in New York City. "But for me it's not a slam dunk."

In ancient humans, the shape of the back of the skull doesn't always predict the shape of the face, she says. The Jebel Irhoud skull, for example, has an archaic, elongated back but a distinctly modern face. Zollikofer adds that the Neanderthal lineage may encompass more anatomical variations than researchers yet realize—perhaps including a short, round skull. "It highlights the scarcity of our knowledge," he says. In fact, Marie-Antoinette de Lumley, a paleoanthropologist at CNRS, the French national research agency in Paris, has recently argued that both skulls are actually ancestors of Neanderthals.

Israel Hershkovitz, a paleoanthropologist at Tel Aviv University in Israel who found the fossils in Misliya Cave, thinks that because members of *H. sapiens* were in the Middle East about 200,000 years ago, they could have made an early excursion to southern Europe, too. Harvati points out that some Neanderthal genomes preserve a trace of an interbreeding event with *H. sapiens* that took place before 200,000 years ago, a sign that our ancestors must have entered Neanderthal territory early, before vanishing again. Perhaps "they didn't like the climate, or didn't like the fauna to eat, or didn't like having Neanderthals around, and pulled back," Delson says.

But Hershkovitz isn't convinced Apidima 1 represents those ancient pioneers. Without more complete fossils and confirmation of their dates by other techniques, he says, "The evidence is very weak."

Read more about this article at: <https://www.sciencemag.org/news/2019/07/skull-fragment-greek-cave-suggests-modern-humans-were-europe-more-200000-years-ago>

August 2019 Atlanta Geological Society PG Cansisate Workshop

Date: Saturday, **August 31, 2019**
Time: 10:00 am to 12:00 pm
Venue: Fernbank Science Center
(check-in with the receptionist for the specific classroom location)
156 Heaton Park Drive, N.E.
Atlanta, GA 30307
678-874-7102
<http://fsc.fernbank.edu/>

Speaker: Marian Buzon, PhD

Subject: **Mineralogy**

Please join us for a Saturday morning of mineralogy. Marian is an assistant professor of geology in the Geosciences Department at the University of West Georgia. She earned her B.S. in geology at the State University of New York in New Paltz and her Ph.D. in geology at the University of Idaho, where she specialized in mineralogy. Her research there involved characterizing commercial talc products and ores: a project motivated by recent talc-asbestos litigation. She currently teaches Physical Geology, Mineralogy and Crystallography, and a seminar titled: How geology shapes society. She has a continued interest in characterizing and sourcing minerals and enjoys learning about issues between minerals, human health, and litigation. She is currently pursuing research characterizing and understanding the history of rocks local to the West Georgia area.

Please join us and forward this message to anyone interested in becoming a Georgia Registered Professional Geologist, or anyone who might be interested in the topic. Two Professional Development Hours are available for attendees of the class. The classes are open to all, membership in the AGS is not required; if you would like to join an application form is attached.

For more information on becoming a member, visit www.atlantageologicalsociety.org. Contact us at the addresses below if you have questions about the workshop or the exams.

Atlanta Geological Society
Professional Registration/Career Development Committee
Ken Simonton, P. G., kws876@gmail.com
Ginny Mauldin-Kenney, ginny.mauldin@gmail.com

Fernbank Events & Activities

Geology Rocks

Friday, August 23, 2019 2:30 PM

Discover how the rocks of Georgia formed with hands-on experiments and touchable specimens.

Recommended for ages 8+

Fernbank Forest Night Walk SOLD OUT

Friday, August 23, 2019 8:00 PM

Join a Fernbank scientist to experience the unique nocturnal world that awakens at dusk.

Sensory Morning

Saturday, August 24, 2019 9:00 AM

Join us for a series of special sensory events, designed for guests with sensory sensitivities, special needs or various physical abilities who might benefit from a less-crowded environment.

Folk Tales

Saturday, August 24, 2019 11:00 AM

Hear a story for young visitors from cultures around the world, with a fun activity. Recommended for ages 1+

Nature Walk

Saturday, August 24, 2019 11:00 AM

Get a closer look at nature in WildWoods and Fernbank Forest with a Fernbank educator. Recommended for ages 8+

Live Animal Encounter

Saturday, August 24, 2019 2:00 PM

Get up close and personal with a member of Fernbank's animal collection. Recommended for ages 4+

Cosmic Quest

Saturday, August 24, 2019 3:00 PM

Blast off for an exploration of space that will take you from Earth through the universe. Recommended for ages 8+

Folk Tales

Sunday, August 25, 2019 11:00 AM

Hear a story for young visitors from cultures around the world, with a fun activity. Recommended for ages 1+

Live Animal Encounter

Sunday, August 25, 2019 12:00 PM

Get up close and personal with a member of Fernbank's animal collection. Recommended for ages 4+

Ranger Explorations

Sunday, August 25, 2019 1:30 PM

Join a Fernbank Ranger for fun and informative outdoor activities in WildWoods. Recommended for ages 6+

Cosmic Quest

Sunday, August 25, 2019 3:00 PM

Blast off for an exploration of space that will take you from Earth through the universe. Recommended for ages 8+

Tadpole Tales

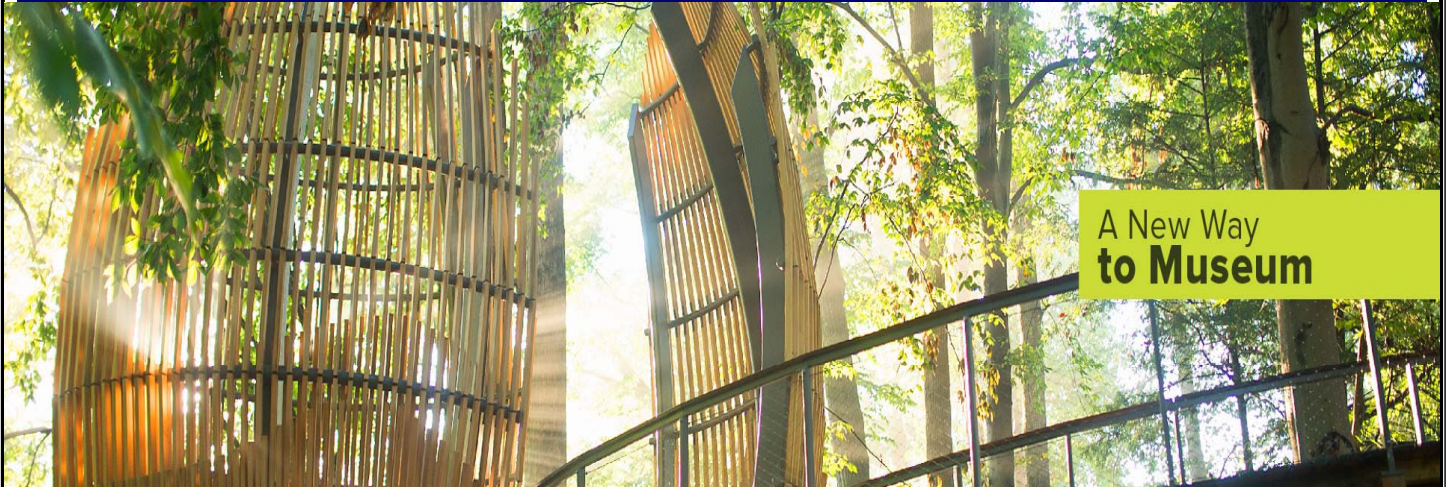
Monday, August 26, 2019 11:30 AM

Preschoolers will enjoy a story and special activity with a Fernbank educator. Recommended for ages 1+



FERNBANK MUSEUM

of NATURAL HISTORY



A New Way
to Museum



A New Way to Museum

Take a walk on the wild side as you explore 75 acres of new outdoor nature adventures. WildWoods and Fernbank Forest combine to highlight the natural world through immersive trails, educational programming, hands-on exhibits and beautiful scenery.

New for Summer! Experience the wonders of nature on Fernbank's giant 4-story screen with Backyard Wilderness 2D, and enjoy hands-on nature adventures outside in WildWoods.



Superpower Dogs

On view May 17 through September 12, 2019

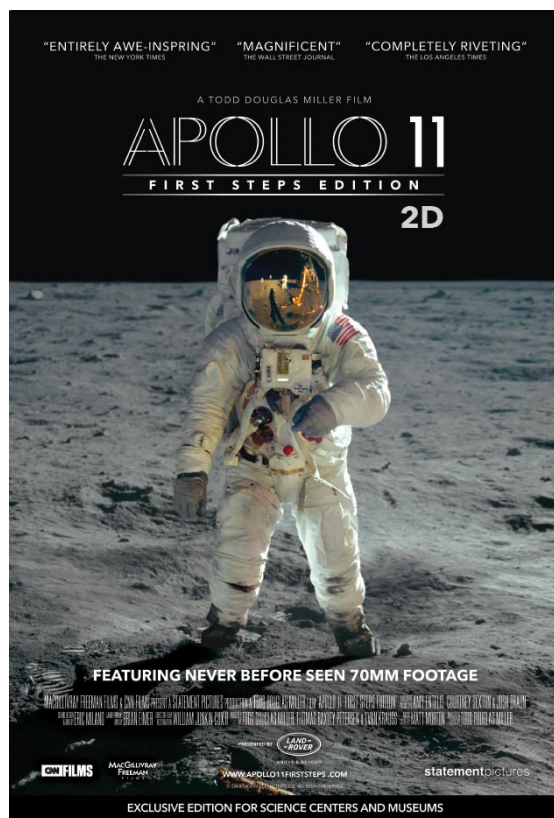
In this inspiring true story narrated by Chris Evans, our best friends are also real-life superheroes. Journey around the globe to meet remarkable dogs who save lives and discover the powerful bond they share with their human partners. Follow 'Halo,' a rookie puppy training to join one of the most elite disaster response teams in America. Meet 'Henry,' an avalanche rescue expert in the mountains of British Columbia, 'Reef,' a Newfoundland lifeguard with the Italian coastguard, 'Ricochet,' a Californian surf legend helping people with special needs, and the Bloodhound brothers, 'Tipper and Tony,' who are leading the fight to save endangered species in Africa.



FERNBANK MUSEUM of NATURAL HISTORY

Fernbank Museum of Natural History
(All programs require reservations, including free programs)

Now showing in the Fernbank IMAX movie theater:



Apollo 11 2D

Showing May 31 through December 5, 2019

In this special giant-screen edition created exclusively for science centers and museum theaters of Todd Douglas Miller's critically acclaimed Apollo 11 documentary, the filmmakers reconstruct the exhilarating final moments of preparation, liftoff, landing and return of this historic mission—one of humanity's greatest achievements and the first to put men on the moon. With a newly-discovered trove of never-before-seen 70mm footage and audio recordings, Apollo 11: First Steps Edition 2D joins Neil Armstrong, Buzz Aldrin and Michael Collins, the Mission Control team and millions of spectators around the world, during those momentous days and hours in 1969 when humankind took a giant leap into the future.

Great Bear Rainforest 3D

Showing May 3 through December 31, 2019

Hidden from the outside world, the Great Bear Rainforest is one of the planet's most exquisite and secluded wildernesses. Found on Canada's rugged Pacific coast, it is the largest temperate coastal rainforest in the world and is home to indigenous First Nations peoples, who have provided stewardship of the forest for millennia. Embark on a remarkable journey into a land of grizzlies, coastal wolves, sea otters, and humpback whales—and discover the secret world of the Spirit Bear. Narrated by Ryan Reynolds.

AGS Officers

President: Ben Benthowski

bbentkow@gmail.com

Phone (770) 296-2529

Vice-President: Steven Stokowski

sstokowski@yahoo.com

Secretary: Rob White

Phone (770) 891-0519

robeth@bellsouth.net

Treasurer: John Salvino, P.G.

Phone: 678-237-7329

johnsalvino@bellsouth.net

Past President

Shannon Star George

shannonsgeorge@gmail.com

AGS 2019 Meeting Dates

Listed below are the planned meeting dates for 2019. Please mark your calendar and make plans to attend.

2019 Meeting Schedule

September 24

October 29

November 26

December 31

PG Study Group meetings

September 28

October 26

November 30

December 28

AGS Committees

AGS Publications: Open

Career Networking/Advertising: Todd Roach

Phone (770) 242-9040, Fax (770) 242-8388

tdr@piedmontdrilling.com

Continuing Education: Open

Fernbank Liaison: Miranda Gore Shealy

Phone (404) 929-6341

Miranda.Shealy@FernbankMuseum.org

Doug John

Phone (404) 929-6342

Doug.John@FernbankMuseum.org

Georgia PG Registration: Ken Simonton

Phone: 404-825-3439

kws876@gmail.com

Ginny Mauldin-Kenney,

ginny.mauldin@gmail.com

Teacher Grants: Bill Waggener

Phone (404) 354-8752

waggener80@yahoo.com

Hospitality: John Salvino, P.G.

johnsalvino@bellsouth.net

Membership: Burton Dixon

Dixonburton1@gmail.com

Social Media Coordinator: Carina O'Bara

carina_do@yahoo.com

Newsletter Editor: James Ferreira

Phone 508-878-0980

Ferreira.02767@gmail.com

Web Master: Ken Simonton

kws876@gmail.com

www.atlantageologicalsociety.org

ATLANTA GEOLOGICAL SOCIETY

www.atlantageologicalsociety.org

ANNUAL MEMBERSHIP FORM

Please print the required details and check the appropriate membership box.

DATE: _____

NAME: _____

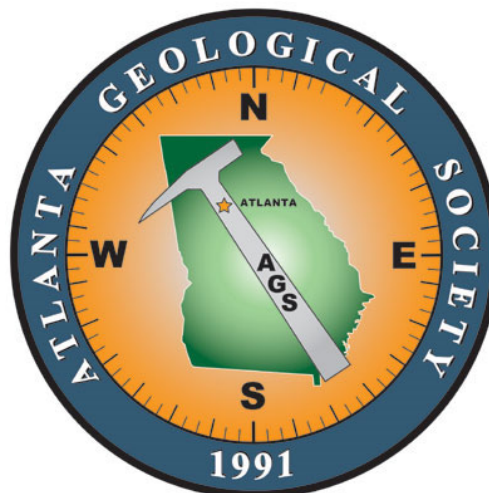
ORGANIZATION: _____

TELEPHONE (1): _____

TELEPHONE (2): _____

EMAIL (1): _____

EMAIL (2): _____



STUDENT \$10 ☐

PROFESSIONAL MEMBERSHIP \$25 ☐

CORPORATE MEMBERSHIP \$100 ☐

(Includes 4 professional members, please list names and emails below)

NAME: _____

EMAIL: _____

NAME: _____

EMAIL: _____

NAME: _____

EMAIL: _____

NAME: _____

EMAIL: _____

For further details, contact the AGS Treasurer:
John Salvino johnsalvino@bellsouth.net

Please make checks payable to the "Atlanta Geological Society" and bring them to the next meeting or remit with the completed form to:

Atlanta Geological Society, Attn: John Salvino
3073 Lexington Avenue
Woodstock, Georgia 30189

To pay electronically; click
<https://squareup.com/store/atlanta-geological-society>

CASH ☐ CHECK (CHECK NUMBER: _____)