DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

Agriculture and Natural Resources

FSA9528

What Is Water Quality?

Mike Daniels
Professor
Water Quality and
Nutrient Management

Thad Scott
Assistant Professor
Crop, Soil and
Environmental Sciences

Brian Haggard
Director
Arkansas Water
Resources Center

Andrew Sharpley
Professor
Crop, Soil and
Environmental Sciences

Tommy Daniel
Professor
Crop, Soil and
Environmental Sciences

ARKANSAS WATER RESOURCES CENTER

Arkansas Is Our Campus

Visit our web site at:
https://www.uaex.uada.edu

Introduction

The term *water quality* describes a broad spectrum of items related to how we identify water concerns and how we collectively address them. Thus, the term water quality can be confusing and mean different things to different people.

The most widely used definition of water quality is "the chemical, physical and biological characteristics of water, usually in respect to its suitability for a designated use." As we all know, water has many uses, such as for recreation, drinking, fisheries, agriculture and industry. Each of these designated uses has different defined chemical, physical and biological standards necessary to support that use. For example, we expect higher standards for water we drink and swim in compared to that used in agriculture and industry.

Water quality standards are put in place to protect the various designated uses of a waterbody. Waterbodies are then monitored by states to ensure that these standards are being met and that a waterbody supports its designated uses.

When water quality assessment reveals that a waterbody does not support its designated uses, then it is considered impaired by the United States Environmental Protection Agency (EPA). Impairments result from two major categories of water pollution: point source or nonpoint source pollution. Point source pollution originates in effluent that is discharged regularly (such as daily) from industrial and municipal wastewater treatment plants through permanent conduits such as pipes or ditches. Nonpoint source pollution originates from diffuse sources scattered across the landscape and is delivered to waterbodies during runoff-producing precipitation events. It may include pollutants derived from residential, agricultural, forested and urban areas (Figure 1). Common nonpoint source pollutants include sediment, plant nutrients, pesticides and organic compounds. Rainfall runoff events transport materials into waters even in undisturbed natural sites.

Figure 1. As the area of a watershed in forest increases relative to agricultural and urban land uses, the concentration of nutrients in streams at base flow tends to decrease.

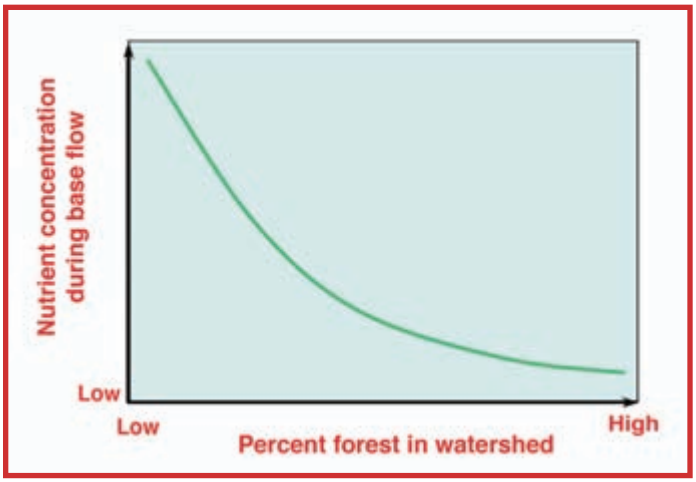

Figure 2. Effect of land use on accelerated eutrophication.

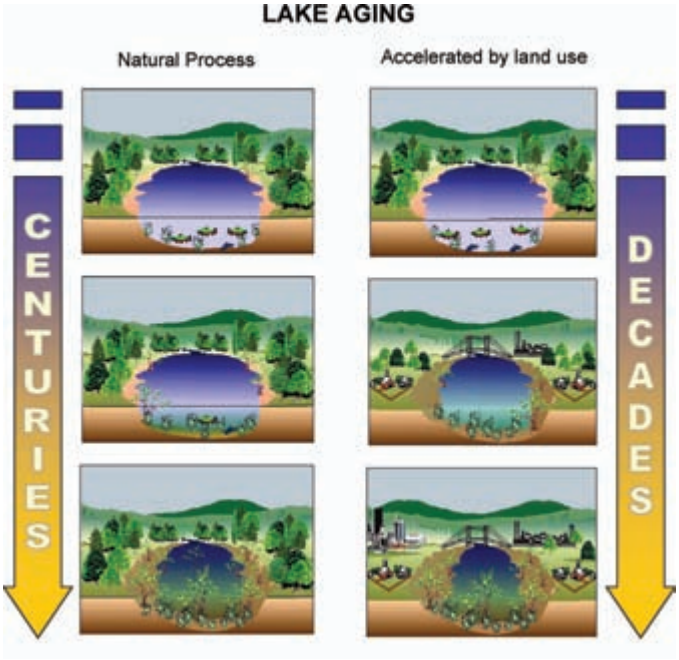

Figure 3. An example of the variability of nonpoint source pollution.

Areas in red near the stream channel have a greater potential to contribute phosphorus to the stream channel (blue line) than fields further from the stream. Most of the landscape or watershed is at risk for nitrogen loss in leaching to groundwater.

Human activities however, can increase the amount of sediment and nutrients entering waterways and introduce new contaminants such as pesticides (Figure 2).

Nonpoint source pollution is harder to identify than point source pollution because of its diffuse nature. The amount of runoff volumes as well as physical, chemical and biological constituents in runoff can vary greatly among storm events and specific watershed characteristics (Figure 3). This makes it harder to determine the impact of nonpoint sources on water quality and thus harder to control.

With the enabling of the Clean Water Act in 1972, EPA began to control point source pollution by regulations through the National Pollution Discharge Elimination System (NPDES) program. Under these rules, point sources must obtain a NPDES permit from the Arkansas Department of Environmental Quality (ADEQ) (http://www.adeq.state.ar.us/water/branch_permits/individual permits/faqs.htm, 2008) to discharge industrial or municipal wastewater. At a minimum, this permit requires point sources to accurately report their discharge of certain water pollutants and, in many cases, limit pollutant discharges to an allowable level. NPDES permits are available for public viewing at the web site mentioned above.

After 15 years of administering the NPDES program, nationwide water quality monitoring revealed that many waterbodies were still not meeting their water quality standards for a given designated use. In 1987, Congress reauthorized the Clean Water Act to place increased emphasis on nonpoint source pollution, which focused much more on nonpoint sources including agriculture. Due to its diffuse nature and delivery during episodic rainfall events, progress towards reducing nonpoint source pollution has been slower in nature than for point sources.

How Are Water Quality Concerns Determined?

In some cases, water quality concerns can arise quickly from public complaints about odor or taste, outbreak of water-borne illnesses or widespread death of aquatic species such as fish kills. Because many water quality concerns do not have such obvious or dramatic consequences, it may not be readily apparent that there is a problem. Instead, many important water quality parameters are routinely monitored and compared with water quality standards adopted for these parameters (Figure 4). Water quality standards are adopted by states to protect various designated uses and are often specific to ecoregions within the state. Ecoregions are simply areas of the state with topographic and geologic similarities (see Table 3 for details). Routine monitoring allows states to assess whether or not water quality standards, and ultimately designated uses, are being met for a particular waterbody.

Figure 4. Examples of water quality monitoring.

Monitoring

The Arkansas Department of Environmental Quality (ADEQ) and the United States Geological Survey (USGS) conduct extensive monitoring in Arkansas (Figure 5). The University of Arkansas Water Resources Center also monitors water quality through the nonpoint source pollution program administered through the Arkansas Natural Resources Commission (ANRC). Water samples are often analyzed for constituents such as dissolved oxygen, pH, ion composition, suspended solids, nutrients, pathogens, metals, oils and pesticides. Additionally, sediment and fish tissue are often collected and analyzed for metals and some organic pollutants (Table 1). Physical measurements of general conditions such as temperature, flow, color, turbidity (clarity of water related to suspended solids) and the condition of stream banks and lake shores are also collected. Biological monitoring is conducted to determine health of aquatic systems. Biological assessments often include the abundance and diversity of aquatic plant and animal life as well the ability of test organisms to survive in sample water.

Figure 5. Location of Ambient Water Quality Monitoring Stations in Arkansas *(Courtesy of ADEQ)*.

Monitoring can be conducted at regular sites on a continuous basis ("fixed station" monitoring); at selected sites on an "as needed" basis or to answer specific questions (intensive surveys); on a temporary or seasonal basis (for example, during the summer at swimming beaches); or on an emergency basis (such as after a spill). Monitoring can be conducted for many purposes, such as:

1. Characterize waters and identify changes or trends in water quality over time.
2. Identify specific existing or emerging water quality problems.
3. Assess the usefulness or attainability of water quality standards.
4. Gather information to design specific pollution prevention or remediation programs.
5. Determine whether program goals, such as compliance with pollution regulations or implementation of effective pollution control actions, are being met.
6. Response to emergencies, such as spills and floods.

Table 1. Water quality parameters routinely measured in Arkansas' ambient water monitoring program.

Physical and Biochemical			
• Air Temperature • Nonfilterable Residue	• Water Temperature • Dissolved Oxygen	• Turbidity • 5-Day Biochemical Oxygen Demand	• Filterable Residue
Radioactive			
• Beryllium	• Cobalt	• Barium	• Vanadium
Heavy Metals			
• Nickel • Zinc	• Copper • Cadmium	• Lead • Chromium	• Iron
Chemical			
• pH • Sodium • Boron	• Total Hardness • Calcium	• Chlorides • Magnesium	• Sulfates • Manganese
Nutrients			
• Ammonia Nitrogen • Nitrate+Nitrate Nitrogen		• Total Phosphorus • Ortho-Phosphorus	• Potassium

What Is the "Designated Use" Approach?

Under the Clean Water Act, EPA requires states to specify appropriate water uses based on the value of the waterbody for public water supply; for protection of fish, shellfish and wildlife; and for recreational, agricultural, industrial and navigational purposes. Designated uses are influenced by the suitability of a waterbody for the uses based on the physical, chemical and biological characteristics of the waterbody, its geographical setting and scenic qualities, and social and economic considerations. The Arkansas Department of Environmental Quality (ADEQ) has established nine strictly defined designated use categories for waterbodies in the state (Table 2). Details of these designated uses and their implementation are described in State Regulation 2 (http://www.adeq.state.ar.us/regs/files/reg02 final 071125.pdf, 2007).

Where Can I Find Water Quality Standards in Arkansas?

Water quality standards in Arkansas that are assigned to protect the designated uses of waterbodies are also specified in State Regulation 2. Standards in Arkansas are dependent on three items: 1) water quality criteria as set forth in Section 304(a) of the Clean Water Act, 2) the designated uses and 3) the ecoregion where the stream or waterbody is located (Figures 6 and 7). The ecoregion concept is important for establishing water quality criteria because aquatic life supported by streams, lakes and

Figure 6. The designated stream ecoregions in Arkansas for distinguishing water quality standards *(Courtesy of ADEQ)*.

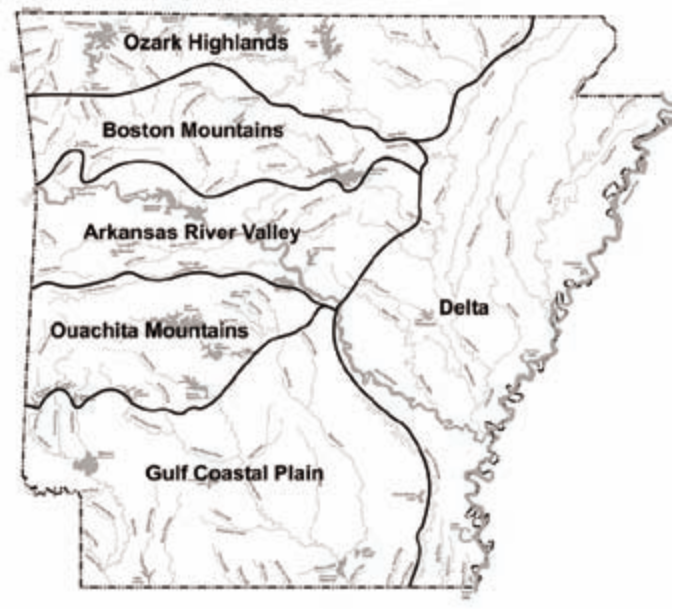

Table 2. Designated uses of waterbodies in Arkansas as set forth in State Regulation 2.

Extraordinary Resource Waters	This beneficial use is a combination of the chemical, physical and biological characteristics of a waterbody and its watershed which is characterized by scenic beauty, aesthetics, scientific values, broad scope recreation potential and intangible social values.
Ecologically Sensitive Waterbody	This beneficial use identifies segments known to provide habitat within the existing range of threatened, endangered or endemic species of aquatic or semi-aquatic life forms.
Natural and Scenic Waterways	This beneficial use identifies segments which have been legislatively adopted into a state or federal system.
Primary Contact Recreation (Swimmable)	This beneficial use designates waters where full body contact is involved. Any streams with watersheds of greater than 10 square miles are designated for full body contact. All streams with watersheds less than 10 square miles may be designated for primary contact recreation after site verification.
Secondary Contact Recreation (Wadeable)	This beneficial use designates waters where secondary activities like boating, fishing or wading are involved.
Fisheries (Fishable)	This beneficial use provides for the protection and propagation of fish, shellfish and other forms of aquatic life.
Domestic Water Supply	This beneficial use designates water which will be protected for use in public and private water supplies. Conditioning or treatment may be necessary prior to use.
Industrial Water Supply	This beneficial use designates water which will be protected for use as process or cooling water. Quality criteria may vary with the specific type of process involved and the water supply may require prior treatment or conditioning.
Agricultural Water Supply	This beneficial use designates waters which will be protected for irrigation of crops and/or consumption by livestock.

(Source: The Arkansas Department of Environmental Quality)

Figure 7. The Environmental Protection Agency's (EPA) ecoregions. Arkansas' ecoregions are based on this national designation.

wetlands can vary greatly depending on climate, topography, hydrology, geology and many other factors. The ecoregion approach allows standards to reflect natural differences that exist in these parameters throughout our state (Table 3).

Water quality standards in Arkansas are based on extensive and historic data collection of the physical, chemical and biological characteristics of least-disturbed streams, or reference streams, within one of the seven ecoregions. According to ADEQ: "Specific criteria to protect the designated uses of each waterbody were developed from the intensive ecoregion studies, an abundance of historical data, numerous additional scientific data and considerable public and other governmental agency input" (http://www.adeq.state.ar.us/water/branch_planning/pdfs/WQ05-07-01.pdf, 2008).

Standards may be reflected as: 1) numerical values, 2) narrative limitations or 3) prohibitions on physical alterations of certain waters. In Arkansas, most standards are numerical (Table 3). However, standards for nitrogen and phosphorus are narrative in nature because nutrient concentrations in streams do not always correlate directly with stream impairments. Impairment of a waterbody from excess nutrients is dependent on characteristics unique to each natural waterbody such as stream flow, residence time, stream gradient, substrate type, canopy, riparian vegetation and season of the year.

Thus, nutrient standards are narrative in nature and focus on whether the measured nutrient concentrations are stimulating algal growth to the point of impairment. Other parameters that are better indicators of excessive algal growth include water clarity, periphyton or phytoplankton biomass and production, dissolved oxygen concentrations and many others that are used in conjunction with nutrient data to determine if an impairment exists. However, many states are moving toward adoption of numeric nutrient criteria at the recommendation of EPA (http://www.epa.gov/waterscience/criteria/nutrient/strategy/index.html). At this time, the state of Arkansas is considering the development of numeric nutrient criteria for some specific waterbodies.

How Are Impairments Determined and Reported?

Section 305(b) of the Clean Water Act requires the states to perform a comprehensive water quality assessment and submit an assessment report to Congress every two years. Arkansas relies on its water quality monitoring data to compile its assessment report. In its latest report from 2004

Table 3. Selected water quality standards by stream ecoregion in Arkansas for watershed contributing areas of less than 10 square miles.

Water Quality Parameter	Stream Ecoregion						
	Ozark Highlands	Boston Mountains	Arkansas River Valley	Ouachita Mountains	Typical Gulf Coast	Least Altered Delta	Channel Altered Delta
Maximum Allowable Temperature (Degrees F) from man-induced causes	84.2	87.8	87.8	86	89.6	86	89.6
Turbidity (NTU)[1] Base Flow / All Flow[2]	10 / 17	10 / 19	21 / 40	10 / 18	21 / 32	45 / 84	75 / 250
Dissolved Oxygen: (mg/L) Primary Season / Critical Season[3]	6 / 2	6 / 2	5 / 2	6 / 2	5 / 2	5 / 2	5 / 2
Total Dissolved Solids (mg/L)	250	95.3	112.3	142	138	411.3	411.3

[1] NTU – Nephelometric Turbidity Unit – Based on comparison of the intensity of light scattered by a sample of water with the intensity of light scattered by a standard reference suspension.

[2] Turbidity when the stream sample is taken at base flow and when a sample is averaged across all flows including samples taken at storm flows.

[3] Primary season refers to the period of year when water temperatures are 71.6°F or below. In Arkansas, this generally ranges from mid-September to mid-May. Critical season refers to the period of year when water temperatures are 71.6°F or above. In Arkansas, this generally ranges from mid-May to mid-September.

(http://www.adeq.state.ar.us/water/branch_planning/pdfs/WQ05-07-01.pdf, 2008), over 9,000 miles of the state's 89,000 miles were assessed. Of the assessed miles, 83 percent meet their designated uses.

The waterbodies that do not meet their designated uses are listed as impaired according to Section 303(d) of the Clean Water Act (http://www.adeq.state.ar.us/water/branch_planning/pdfs/303d_list_2008.pdf, 2008). Arkansas utilizes a scientifically defensible process for determining impairments: 1) monitoring the ambient water quality conditions, 2) determining the designated uses for that waterbody and 3) comparing ambient water quality data to established state water quality standards established for each designated use in each ecoregion of Arkansas.

How Are Causes and Sources of Impairments Determined?

Once an impairment has been established, the Clean Water Act requires states to report a cause and source. For example, a body of water may not meet turbidity standards due to suspended sediment (the cause) from soil erosion in agricultural fields (the source). Causes are determined through direct monitoring. If the cause originates from point sources, then often it is easy to identify. If the cause is from nonpoint sources, then it may be difficult to determine the source for many reasons, such as multiple source contribution or variable watershed characteristics. Because of this, nonpoint sources are often identified by indirect methods such as:

1. Simple visual "windshield" surveys of the landscape within the watershed.
2. Land use analysis using digital satellite images and computer software known as Geographic Information Systems (GIS).
3. Watershed computer models that simulate pollutant losses from the landscape given a set of climatic, topographic and hydrological considerations.

Indirect techniques are used because they often may be more practical; however, they can be characterized by a large degree of uncertainty in predicting sources, quantifying loads and evaluating mitigation strategies. Determining the source of nonpoint source pollution within a watershed is commonly the most challenging scientific aspect of developing and implementing effective solutions to watershed and water quality issues.

Can Monitoring Distinguish Between Sources of Pollution?

Most water quality measurements at fixed locations within a stream usually reflect the concentration (mass of constituent per unit volume of water) of constituents that have been integrated or mixed by the stream from multiple sources. This

makes it difficult to distinguish the contributions from individual sources at a fixed monitoring station. The difficulty increases due to highly dynamic chemical and biological processes that take place within streams due to changes in stream flow characteristics, water temperature and other factors. Nevertheless, well-designed water quality monitoring strategies can be useful for identifying sources, or at least source areas, of pollution. Monitoring projects must be developed according to a strict understanding of the hydrologic characteristics of a stream or river network.

In Conclusion

The importance of good quality water that supports designated uses will continue to increase in the future. **Understanding the process of determining water quality and defining issues is fundamental to developing effective solutions to protecting our water resources.** Only a small percentage of Arkansas' streams have been assessed in the manner described in this fact sheet. Of those assessed, only a small percentage of waters are considered impaired. Overall, the state of Arkansas and its residents still enjoy good quality water. However, water is a resource that should not be taken for granted. The difficulty and cost of remediating impaired water is far more challenging and costly than preventing degradation to and protection of our state's water. Even if cost-effective and practical remediation strategies are available, it often takes years for implementation to reverse degradation and recover from impairments.

For more information about how you can help protect water quality, please contact your local county Extension office or the University of Arkansas Division of Agriculture's Water Resources Center.

Printed by University of Arkansas Cooperative Extension Service Printing Services.

DR. MIKE DANIELS is a professor - water quality and nutrient management with the University of Arkansas Division of Agriculture in Little Rock. **THAD SCOTT** is an assistant professor, **ANDREW SHARPLEY** is a professor and **TOMMY DANIEL** is a professor with the Crop, Soil and Environmental Sciences department at the University of Arkansas in Fayetteville. **BRIAN HAGGARD** is the director of the Arkansas Water Resources Center at the University of Arkansas in Fayetteville.

FSA9528-PD-4-09N