Growing Fish in High TDS Low Chloride Treated Mine Water

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Introduction

The recent flurry of water quality information regarding the Dunkard Creek disaster has inspired the writing of this article to share relevant information that may help all stakeholders better understand the variety of parameters under which some game species may thrive. Of the many parameters that impact fish health, total dissolved solids (TDS) has been in the spotlight due to the high levels found in certain West Virginia streams and creeks influenced by coal mining and recently drilling in the Marcellus shale. This article is limited in scope to the specific water quality parameters where the research was conducted.

Arkwright Mine and WVU Aquaculture Site

The Arkwright mine reservoir pond was built in the mid-1970's by Consol Energy after the clean water act was passed by congress. It has been used to concentrate iron precipitate from treated mine water for over 30 years and is monitored by the West Virginia Dept. of Environmental Protection (WVDEP) under a National Pollution Discharge Elimination System (NPDES) permit. Water from the Arkwright mine is pumped through the water treatment plant where the treatment process occurs. The steps in cleaning the acid mine water are:

1) Pump the water from the underground mine to the treatment facility.
2) Aerate the water to oxidize the iron which causes precipitation of ferric (Fe^{+3}) ions.
3) Add $Ca(OH)_2$ (hydrated lime) to increase the pH and fully precipitate the iron.
4) Aerate the water again, and allow precipitate to settle on pond bottom.
5) Water is discharged from the settling pond and used for fish production.

The flowing water (raceway) system for production of fish was installed at a location near Arnettesville. Investigators working at this site quickly determined that this water source is suitable for production of trout on a seasonal basis (Semmens and Miller 2003). The increased ionic strength of treated mine water actually helps the rainbow trout tolerate metals that might otherwise be detrimental (Tierney, Viadero, and Semmens 2004). Rainbow Trout grown in mine water at this site did not have significantly increased stress response or contaminant levels compared to control fish (Danley and Mazik 2004). Productivity of trout grown in treated mine water was similar to that of fish grown in other commercial operations and was consistent with predictions made using existing computer models.

Thousands of pounds of fish have been grown in this treated mine water since 2000. The facility is not a fish hatchery in that fish are not spawned and fingerlings are not produced. All fish are stocked as fingerlings and grown to a harvestable size. Initially only trout were grown, but other species have since been stocked in the system. These fish species include: rainbow, brook, and brown trout; hybrid striped bass, striped bass, largemouth bass, hybrid bluegill, channel catfish and yellow perch. Various strains of rainbow trout performed best on a seasonal basis when water temperatures were below 20˚C. One strain reputed to be more thermally tolerant survived and grew through the summer when water temperature approached 26 ˚C. Hybrid striped bass and striped bass survived and grew well in the system, presumably due to the level of dissolved solids in the water, particularly calcium (~430 mg/l). Yellow perch grew as expected and survived well. Largemouth bass, and hybrid bluegill did not grow or survive as well as expected. Catfish survived and grew well in summer months. Catfish >20 cm total length survived winter better than small catfish (<15 cm). It is apparent that the primary limiting factor to production of most species is water temperature. Warm water species (bass, catfish, bluegill) have only 4 months of warm temperatures. A solid waste collector has been used for the past few years to reduce the environmental impact by recycling the solid waste as a soil amendment. It is also noteworthy that mature trout grown in the system have released eggs and milt. WVU aquaculture research results can be found at: http://aquaculture.davis.wvu.edu/

Discussion

Total dissolved solids can be defined as the quantity of all dissolved material in water. By definition it is a catch-all term. TDS provides a qualitative measure of the dissolved ions but does not provide insight into specific water quality issues such as ion relationships, elevated hardness or salty taste. TDS is commonly calculated by measuring the conductivity of the water. Conductivity is the ability of water to transmit an electrical current. The units for conductivity are commonly reported as micromhos per centimeter (mhos/cm) or microsiemens per centimeter (µS/cm). These units are interchangeable. Due to the many different units used in reporting conductivity and total dissolved solids, it is easy to become confused. It should be noted that 1000 microsiemens (µS) is equal to 1 millisiemens (mS). For TDS units, 1 mg/l is the same as 1 part per million (ppm). In general when conductivity is high TDS is also high, however, a linear relationship does not exist. With saline waters, a general comparison can be made using the formula: TDS (ppm) = conductivity (µS/cm) x 0.67.

Water with high levels of TDS or conductivity is often referred to as "salty" even though the sodium (Na^+) and chloride (Cl^-) levels (NaCl = salt) may be relatively low. One important difference between well water from the Marcellus shale, (an ancient seabed) and treated acid mine drainage water, is that Marcellus shale water is very high in soluble chloride salts, and most acid mine water is not. Sulfates are often the most common dissolved substance in acid mine water. Regulating TDS levels may be necessary but it may be better to regulate the specific ions (e.g. chloride) that can cause biological problems in the river systems by providing an environment suitable for invasive species which can disrupt an ecosystem (like in Dunkard Creek). Common dissolved solids in water include phosphates, nitrates, sulfates, calcium, bicarbonate, iron, and magnesium, as well as sodium and chloride. These substances are essential to aquatic life and affect the flow of materials into and out of the cells (osmoregulation) in aquatic animals. When any of these substances are lacking, or more commonly found in excess, the process of life can become unbalanced or stressed. They can also modify the habitat that results in allowing new species to thrive.

Using distilled water as one extreme and typical sea water as the other extreme, Table 1 compares the conductivity (µS/cm), TDS, pH, and chloride (mg/l) from a variety of water sources. All of the various sources of water tend to have biologically acceptable pH ranges.

Table 1. Comparison of water conductivity, TDS, pH, Cl^-, and SO_4^{-2} from different water sources.

Parameter	**Distilled water**	**U.S. River water**	**Treated Mine water-Arkwright**	**Dunkard Creek '09**	**Typical seawater**
Conductivity µS/cm	0.5-3.0	50 - 1500	5,400 – 7,200	2000-9000	43,000
TDS (* calculated)	0	50-500*	4100 - 4975	1362-8676*	34,500
Typical pH	7.0	6.5-7.5	7.7-8.2	7.2-8.1	8
Chloride mg/l	0	1-90	115 - 116	95-295	19,000
Sulfate mg/l	0	1-80	3200- 3800	1752-5380	2,700

Fish farmers have learned that salt is one of the most effective chemicals used to raise fish. It is commonly applied to fresh water at concentrations of 0.1 to 0.3 percent (1,000 to 3,000 ppm) to improve mucus production (to resist disease) in fish during and after handling or transport. Salt is also an effective parasite control agent for most freshwater fish. A one to three percent solution works well as a short bath for parasite treatment. Salt has proven effective in preventing and treating brown blood disease at up to 20 ppm. Although the FDA has not approved salt as a "drug" it remains one of the most inexpensive and effective treatments in the aquaculture industry. The aquaculture research at WVU does not address the impact TDS levels may have on biodiversity of benthic invertebrates, which are critical in any healthy stream ecosystem.

Conclusion

As regulations that focus on total dissolved solids (or conductivity) are being considered for protection of West Virginia streams, it is important that lawmakers and stakeholders understand the diversity of substances that comprise total dissolved solids and the relative (unquantified) risk presented by high TDS from waters of different sources. Because TDS is a measurement of everything dissolved in the water, the devil (toxic or disproportionate levels of ions) can be in the details, or not.

The abundant supply of treated mine water in West Virginia will increase in the future (Donovan and Leavitt 2004). West Virginia University has shown that this resource can be used to raise healthy game fish for stocking public waters and for human consumption. Results from flesh analysis have shown that these fish are safe to eat and provide a healthy form of protein for consumption (Tierney 2002). The Maryland Department of Natural Resources has successfully used treated mine water from the Mettiki mine for raising trout to stock public streams in the Eastern Maryland region since 1994. The West Virginia DNR successfully stocked tagged hybrid striped bass, raised in the high TDS low chloride waters of the Arkwright mine treated water, into the Morgantown pool of the Monongalia River. Production facilities for trout or other species, located on mine water treatment sites, could provide economical and sustainable fish production. This production could be used for local consumption as well as for stocking local streams for improved recreational opportunities.