A BIOLOGICAL APPROACH TO THE STUDY AND CONTROL OF ACID MINE POLLUTION

JOHN W. PARSONS, Tennessee Game and Fish Commission

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Coal deposits and mining operations are found in 19 counties in East Tennessee, all within the Cumberland Plateau region. Since World War II, acid coal mine pollution of streams has become a serious problem in Tennessee. The demand for coal by large industries, particularly TVA steam plants, is expected to increase the annual coal production in Tennessee from six to fourteen million tons within the next decade. The original Tennessee coal deposits were estimated at forty million tons (Safford and Killebrew 1876) and as long as there is a use for coal, mine pollution appears to be a never ending problem.

Acid mine pollution in Tennessee has destroyed more than 125 miles of fish habitat in streams which once were abundant with smallmouth black bass, *Micropterus dolomeiu dolomeiu* (Lacepede), and the Ohio muskellunge, *Esox masquinongy ohioensis* (Kirtland), and has had a profound effect on other streams. Since most of the polluted streams are located in relatively low populated areas of the plateau and flow into the alkaline reservoirs of the TVA and U. S. Army Engineer waterway systems, they prove to be more of a biological rather than a public health problem.

Coal mine pollution in Tennessee exists in two major forms: the discharge of acid water into the streams, and the existence of coal dust which is brought about either by dumping the inferior coal and shale into the stream bed or by washing the coal with water as it is mined. Of the two, acid mine pollution is by far the greater menace to our streams. The pollutant, sulphuric acid, is formed within the mines when iron pyrite, FeS_2, oxidizes in the presence of water (Anonymous 1942). This acid will remain in the water until it has become neutralized by some alkaline or basic material.

The damage to streams caused by coal mine acid is often so serious that the effects of other mining wastes may be minimized. Low grade coal and shale frequently are dumped into the streams to be washed and deposited into the pools downstream. Many pools are filled and the coal layers may be several feet in depth. In some cases, control of acid mine pollution would not be profitable from a biological standpoint without subsequent control of coal mine wastes. The washing of coal before shipment produces a similar coal mine waste pollution condition.

Where acid pollution is serious in Tennessee, the drainages are slightly acid by nature and offer little buffer action to the acid. There are several areas, however, where acid discharge is high, yet, due to the alkaline condition of the drainage, the acid has little effect on fish life. In several instances, where exposed limestone deposits exist, these highly acid streams flow underground to return to the surface in an alkaline condition. Where polluted streams are exposed to limestone deposits, a sludge, given off by the chemical change, settles on the stream bottom making conditions poor for aquatic life.

Neutralization of acid water by natural processes also presents another problem. If limestone outcroppings are present in the stream bed, heavy acid pollution of a stream often results in the erosion of the limestone until an underground flow develops. Should acid pollution later be controlled, the influence of the acid pollution will be evident during low water when stretches of the stream flow underground leaving disconnected stream sections, an undesirable condition for fish life.

The acid pollution of a stream may also have effects not generally recognized. If the water is too acid, it cannot be used for household purposes, nor will livestock drink it. Wildlife, unable to drink the acid water, is usually absent in areas near a badly polluted stream. One even more important effect is the decrease in land value.

Acid water effects fish in two ways: First, it destroys much of the fish food organisms and second, the acid coagulates the albumen in the cells of the fish gills and also decreases the permeability of the cell membranes. Since the gills then cannot function properly, the fish suffocate from a lack of oxygen. Fish that are able to live in acid pollution water usually suffer from constipation. The effects of acid pollution on fish life vary with the species of fish present and the existing chemical features of the water.

The effects of acid pollution on streams in Tennessee represent a number of contrasting conditions. The relationship between the flow of the stream and the volume of the acid discharge generally determines the degree and time of pollution. Most acid discharge from mines varies near pH 3.0. Regardless of the fluctuation of the discharge of acid water from a mine, seldom does the pH change significantly. In some mining districts the volume of acid water discharge is proportionately greater than the normal stream flow during wet weather. These streams are more severely polluted in the winter. Streams where the acid pollution is more severe during the summer are affected by mines where the acid flow is more constant. There are instances where a stream may be severely polluted during normal or high water but flow underground during low water to return to the surface in an alkaline condition. Streams of this type often have periodic fish kills which occur when the fish migrate into the unpolluted water to be killed when freshets flush large quantitites of acid water throughout the stream. A stream in Tennessee where this occurs has a similar effect on an embayment of one of the large U. S. Engineer reservoirs.

A combination of drift mines discharging acid water and a strip mine area is particularly dangerous to a stream. The drift mine flow may keep the strip mine excavations full of water. A heavy rain may flush the acid water into the stream during low water, severely affecting it and the relatively unpolluted stream below their confluence. Fish kills of this type have been in evidence in Tennessee although such flushes of acid water have been known to drive some fish downstream into unpolluted waters. Large numbers of pH readings of various streams under different conditions in Tennessee suggests that any pH of 6.5 or lower indicates an acid pollution condition.

Biologically, a study of mine pollution should include the effects of acid water on aquatic environments, those related to fish particularly. The extent of the biological study should depend upon its purpose as well as the time involved and the expenditures available. There may be some question as to the practicality of such study but those persons practicing acid pollution control can hardly apply satisfactory methods without having some idea of the acid pollution on a body of water. This would be particularly necessary in determining where and when acid pollution control could best be applied.

The effects of acid pollution on a fish population is usually so severe that the absence of fishermen could be used as a biological index. The determination of acid pollution in water is so simple by chemical means that the use of any biological index in a strict sense would not be justified. The presence of fish in some polluted streams during high water or when the acid content is low gives no indication of periodic pollution. The best understanding of the acid pollution in streams can be obtained from residents within the drainage area who have observed the fish populations and water conditions for many years.

Observations in some streams have revealed the presence of fish populations in waters heavily polluted by coal mine acid. The common creek chub, of all size groups, was found in one stream in abundance where the pH varied between 4.3 and 5.6 during the first year of observation. Later the pH decreased to 3.4 and no fish were observed or taken by scientific methods. This stream had been badly subjected to coal washing waste and most of the pools were filled with fine coal. Bottom samples indicated practically no aquatic food available to fish life. Bluegills, *Lepomis machrochirus* (Refinesque), have been found in a stream where the pH varied near 4.5. These fish, which were confined to an isolated pool caused by low water, showed amazing growth. A good population of longeared sunfish, *Lepomis megalotis megalotis* (Refinesque), was found in a stream where a fish kill had just occurred. The pH had been 5.6 or lower for several weeks. However, the sunfish were nesting and reproduction was abundant.

Such findings as these demonstrate the need for the recognition of the factors that affect fish populations in acid polluted water. Usually such peculiar animal and habitat relationships are noted but seldom analyzed under normal stream conditions. The possibility that such studies might uncover factors that influence aquatic production under any condition should not be overlooked.

The most logical approach to control acid drift mine pollution is the prevention of the formation of sulphuric acid within the mines. Since oxygen is necessary in the acid formation, the exclusion of oxygen from a mine would be a preventative measure. Mine seals, built for the purpose of discharging mine water yet blocking the passage of air into the mine, have been fairly satisfactory in pollution control but as yet cannot be used with any guarantee of success. Some mine openings may not have the features necessary for a successful sealing operation. Oftentimes air may enter the mine from some other source that is not detectable by ordinary methods.

Most of the acid pollution is caused by drift mines but strip mines also produce some acid water. Usually small lakes are formed by the excavated surface and the overflow of water is often acid. This can be eliminated by filling the excavations or dredging them so that no water will accumulate. The use of chemicals in neutralizing these acid wastes has been proven impractical (Anonymous 1942). Not only are the costs of neutralizing plants and processes prohibitive but the sludge given off by the chemical reactions present another pollution problem.

An approach to the study and control of acid coal mine pollution in Tennessee was activated by public opinion of good fish management. The author periodically inspected scores of streams in determining the seriousness and extent of acid pollution in Tennessee. Hundreds of mines were examined and all influences and conditions were evaluated. A need for acid pollution control was apparent and the

Tennessee Game and Fish Commission recently completed an acid pollution control project in a State managed wildlife area. This project was formulated with the idea of becoming familiar with the costs, problems, methods and results of sealing mines, as well as the control itself. The mines which were sealed had been long abandoned and the removal of caved-in material over and in the entrances proved a major problem. As this material was removed, care had to be taken in controlling the volume of acid effluent even though stream flow was high. Such mine drainage could not have been done during low water without endangering fish life in many miles of stream below. In the removal of the caved-in material it was found that special heavy equipment would be necessary for large scale sealing operations. This is particularly important in Tennessee where 85% of the total mine acid discharge flows from abandoned mines (Anonymous 1942).

A review of acid coal mine pollution literature and related subjects generally indicates at least some of the reasons for the lack of successful control of acid coal mine pollution. Most studies have concerned themselves with certain phases of mine pollution without considering the overall picture. Few publications offer the problems, methods, and results of acid mine pollution projects, possibly due to the lack of long time coordinated efforts and the frequency of negative results. A need was shown for a definite biological approach to the pollution problem as coordinated with all related physical and chemical influences.

The study of acid coal mine pollution and experiments of control can be carried out on a short time basis. However, acid pollution control projects should be done as a perpetual operation with considerable control at all times. Millions of dollars have been spent in the past on acid pollution projects which failed in their purpose as soon as they were discontinued.

In dealing with acid mine pollution, each stream should be investigated and, if possible, controlled individually. From a public health standpoint, the decrease of the total acid discharge into a stream drainage is the main objective. However, fish management of polluted streams must not be based on acid coal mine pollution as a whole but on each stream and the factors affecting that stream. In most cases, fisheries management of a polluted stream accomplishes objectives similar to those of public health activities. There have been attempts in the past to control acid mine pollution in areas where limestone has neutralized the acid before materially damaging the fish life. Control projects in such areas would be a depature from acid control for fish management purposes.

The records of success or failure in methods used in past mine sealing operations apparently are filed in obscurity. The results of extensive studies of mines where seals are unsatisfactory may greatly increase the possibility for more efficient sealing operations. The author has used newly fallen snow and frost in locating an opening into mines. Few factors that affect the success or failure of a mine sealing operation have been determined. The fact that biological factors may have an effect on the formation of sulphuric acid in coal mines should be further investigated.

Investigations of the source of acid discharge should be done on a seasonal basis since the extent of acid discharge may vary with the rainfall. Not all mines discharging acid necessarily need be controlled but it is important to decide where the control is needed.

Who is responsible for the control of acid coal mine pollution and how it can be financed are important questions. Unless unexpected influences arise, it appears that each state must accept the responsibility for the acid pollution and its control within its boundaries. However, cooperation between state and federal agencies and intra-state cooperation is extremely important. Federal aid through the Dingell-Johnson bill is another important consideration.

Within each state, I believe that any great degree of mine pollution control can be gained only by full cooperation between the mine pollution control agency or department with the mine owners, plus legislative action that provides for funds, legal authority, and anti-pollution laws specific to coal mine pollution that can be sensibly enforced. Each mine operator should be required to register an operating mine at the county in which he operates and report when the mine is abandoned. A minimum tax should be levied so that the owners could not mine a few tons of coal a year just to keep the mine from being designated as abandoned. A mine not operated for a year presumably would be considered abandoned, unless the case was properly appealed. The control agency should have the authority to seal any mine once it was declared abandoned by the proper authorities, or in the case of a strip mine to dredge or fill.

Tennessee and several other states have laws that enforce the mine owner to pump all water for the working areas in coal mines to a stream or runoff area so that working conditions in the mines will be more satisfactory. Laws of this type would have to be adjusted to pollution control, particularly where parts of active mines could be sealed to eliminate acid formation in worked out sections.

The tendency in the past has been for various departments and agencies to throw the responsiblities of coal mine pollution on other authoriative organizations. Those who are held responsible have not now the tools nor the objective approach to carry out a sustained coal mine pollution control effort. It is time for Conservationists to assume responsibility and take action on the study and control of coal mine pollution.

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APPENDICES

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