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An Investigation of How Surface Coal Mining Affects Water Quality

Thesis submitted in partial fulfillment of Honors

By

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Midway Honors Scholars Program
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Abstract:

Surface coal mining has become the ideal method for extracting coal from the Appalachia Mountains. However, surface coal mining generates large amounts of waste which may decrease the water quality in central Appalachia. This research is an attempt to determine whether surface coal mining negatively impacts water quality. This research consists of a literature review in addition to an analysis of data obtained through the Virginia Department of Environmental Quality. This data was analyzed at three separate locations along the Clinch River, VA to determine trends and cycles in pH, temperature, total hardness, and chloride, sulfate and metal concentrations. After analysis of data, it was concluded surface mining did not negatively impact water quality at these three locations. In addition, more research must be done to make a more accurate, concise conclusion between water quality and surface mining.

Introduction and Background:

Vaccines refrigerated at a local clinic, traffic lights regulating the flow of traffic, and computers in a classroom all are powered by electricity. Electricity is a vital component of the American lifestyle. How is electricity so affordable and available for Americans? A vital natural resource, coal, generates enough energy to power more than 25 million American homes (<http://www.facesofcoal.org/index.php>). Coal mining has been an acceptable means of extracting the resource needed to power America for centuries, morphing from underground mining to the now popular, surface mining. The coal industry has been especially significant in central Appalachia which includes Virginia, West Virginia, Tennessee, and Kentucky, where residents are impacted economically, socially, and environmentally by coal mining. Although there are benefits to surface coal mining like electricity, the hazards to human health, safety and the degradation to the environment are slowly being recognized and brought to the public's attention. This research is an effort to understand the impact of surface coal mining on water quality and associated degradation of human health and environment.

History:

There are two types of mining underground and surface mining. In the past, in the Central Appalachia regions, underground mining was used to extract the coal from inside the mountains. However, the ridgelines of central Appalachia are comprised of peaks and low gaps, which do not allow enough area for deep mining (Kitts, 2010). Therefore a new way of mining became increasingly popular. In 1967, West Virginia became one of the first states to adopt the surface mining technique because it was a cheaper, "safer" and a

more efficient way of extracting resources (Block, Thurston, and Dang 28-29). However economical surface mining might be, it still results in land disturbances at the reclamation site and at the processing and waste disposal facilities (Block, Thurston, and Dang 28-29). The most common problem with surface mining is the mining waste, also labeled “fill material.” Throughout the history of surface coal mining, waste this has been handled in a variety of ways.

Before surface coal mining, the waste rock, or spoil was left in pile around the mined out area. In hilly areas it was common to dispose of waste by dumping it down the outslope. This led to problems in the reclamation process, made revegetation nearly impossible and in some cases led to hazardous instances such as landslides (Block, Thurston, and Dang 28-29). Today, during the mountain top removal process, the waste is placed in a valley adjacent to the mining site. This fill material buries streams that the coal companies have labeled “intermittent” because they do not sustain an ecosystem and they only carry water when it rains.

Why Surface Coal Mining

Surface mining is necessary according to Kitts, the Senior Vice President of Mining Services, “Coal is surfaced mined because that is the method necessary to recover the resource” (Kitts). Surface Mining is necessary, especially in Appalachia because of the topography of the landscape. Central Appalachia is comprised of peaks and gaps that make underground mining impossible but provide coal beneath a ridge top that may only measure 400 to 500 feet from one side of the mountain to the other (Kitts). This narrow coal seam of 400 to 500 feet, is too narrow for deep coal mining. Often, coal seams in

Appalachia are to thin or to close together for deep coal mining. Kitts goes on to explain, “Frequently, the rock overlying the coal seams higher when a mountain is broken or unconsolidated, making the roof too weak to allow safe underground mining.”

Although there is much stigma associated with surface coal mining, especially mountain top removal, coal companies do not ‘jump’ at the opportunity to surface mine. Mining companies determine if the land should surface mined according to the topography. Most mining companies use a combination of surface mining techniques including mountaintop removal, contour and area mining. Once mining companies decide to surface mine there are several economic factors to consider:

1. How many cubic yards of earth must be moved to expose the coal
2. What is the cost of moving this material
3. What is the price of coal

(Kitts)

According to Kitts, surface mining is also more productive when compared to underground mining. This was determined using the Mine Safety and Health Administration Data for the first three months of 2009, WV surface miners produced 3.99 tons per employee-hour of coal compared to the 2.94 tons per employee-hour for WV deep miners (cited in Kitts). In other words, 120 surface miners could mine 100 tons per year while 163 underground miners would be required to mine the same amount (Kitts).

It has been argued that the coal extracted from surface coal mining in central Appalachia only accounts for a small percentage of the nation’s coal productivity. However, Kitts goes on to explain why surface coal mining in central Appalachia is especially important, “In 2008 central Appalachian surface mining produced almost 131

million tons of coal” (Kitts). Of the 131 tons produced in Central Appalachia, 69 tons of it came directly from West Virginia, which sold for roughly 50 dollars per ton (Kitts, 3).

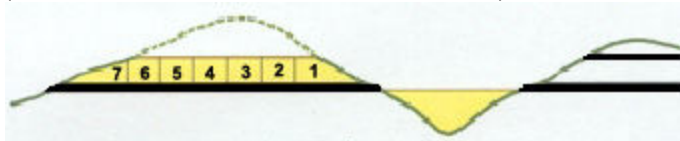
Mountaintop Removal Process

Mountaintop mining, a method of surface mining, involves the removal of the mountaintop to expose coal seams and disposing of mining overburden in adjacent valleys (<http://www.epa.gov/region03/mtntop/index.htm#what>). Surface mining, including mountaintop removal has five major steps:

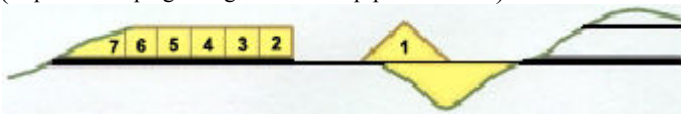
1. Layers of rock and dirt above the coal (called overburden) are removed (<http://www.epa.gov/region03/mtntop/process.htm>)



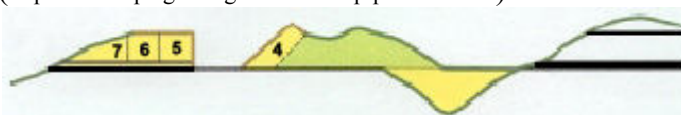
2. The upper seams of coal are removed with spoils placed in an adjacent valley (<http://www.epa.gov/region03/mtntop/process.htm>).



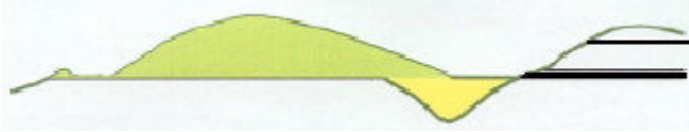
3. Draglines excavate lower layers of coal with spoils placed in spoil piles (<http://www.epa.gov/region03/mtntop/process.htm>).



4. Regrading begins as coal excavation continues (<http://www.epa.gov/region03/mtntop/process.htm>).



5. Once coal removal is complete, final regrading takes place and the area is revegetated (<http://www.epa.gov/region03/mtntop/process.>).



The surface mining process greatly disturbs the land at both the mined sites and nearby valleys where the overburden is dumped. This disturbance adversely affects human health and the health of the environment. In the instance the reclamation process is not complete or is not completed properly surface mining can accelerate erosion, pollute water, damage property, promote flooding and diminish the value of the land (Block, Thurston, and Dang 1981). To reduce or eliminate these problems, federal regulations and requirements have been set including the Surface Mining Control and Reclamation Act and the Clean Water Act.

The Surface Mining Control and Reclamation Act

The Surface Mining Control and Reclamation Act (SMCRA) regulates surface mining and reclamation activities by establishing mandatory standards. SMCRA includes purposes such as:

To establish a nationwide program to protect society and the environment from the adverse effects of surface coal mining operations. establish a nationwide program to protect society and the environment from the adverse effects of surface coal mining operations; assure that surface mining operations are not conducted where reclamation is not feasible and are conducted so as to protect the environment; assure that adequate procedures are undertaken to reclaim surface areas as contemporaneously as possible with the surface coal mining operations; strike a balance between protection of the environment and agricultural productivity and the nation's need for coal as an essential source of energy; assist the states in developing and implementing a program to achieve the purposes of the Act; promote the reclamation of mined areas left without adequate reclamation prior to August 3, 1977 (15).

SMCRA also established an Office of Surface Mining and Reclamation Enforcement, which is comprised of professionals of varying degrees of study. The office has several important positions including the director and the secretary. The director is appointed by the president and has responsibilities such as ensuring the health and safety of miners. The secretary has a plethora of responsibilities including, assisting states develop programs that meet SMCRA's criteria for surface coal mining, deciding what state areas are and are not suitable for coal mining, attempting to eliminate adverse social and environmental impacts, and administering the Abandoned Mine Reclamation Fund (Surface Mining and Reclamation Act 1993).

SMCRA also created an Abandoned Mine Reclamation fund, which is administered by the secretary. This fund should be used by coal companies to properly reclaim the land and water that was disturbed during mining practices, prevent and control water pollution, and fill voids, shafts and tunnels created during the mining process.

SMCRA was developed to improve the health of the people and the environment closest to mining activities. However, due to vagueness, loopholes have been found and problems have occurred. For example, there are general provisions for excess spoil resulting from mining in flat or rolling terrain, but there are strict, detailed standards for excess soil disposal for steep-slope or mountaintop mining. The problem is, SMCRA applies uniform regulations to mining which do not consider the difference in terrain, climate and geology (Block, Thurston, and Dang 1981).

The guidelines set by SMCRA leave numerous gaps and inadequacies in scientific data. The collection of data from specific sites over a long period of time is important to establish trends, cycles, and ranges. “ To plan and carry out a program of data collection that will effectively serve the Office of Surface Mining (OSM), coal operators, and the public, it will be necessary to consult and coordinate with other federal and state agencies regional research organizations (such as universities), mining companies and associations, and interested technically oriented individuals” (Block, Thurston, and Dang 1981). Areas where data is lacking include basin studies, watersheds, precipitation, surface and underground water.

The Clean Water Act

The Clean Water Act regulates the release of pollutants in U.S. waterways by requiring dischargers to obtain a permit before any pollutants are released. The Clean Water Act regulates “priority” pollutants including toxic pollutants, conventional pollutants (including pH and suspended molecules), unconventional pollutants and direct and indirect discharges (Federal Water Pollution Control Act). In addition to regulating pollutants the Clean Water Act established section 319, which implemented management of nonpoint water pollution. Nonpoint water pollution is different from industrial and sewage pollution because this pollution that comes from various activities without any discrete source. Pollutants are caused by rainfall and snow melting and moving over the ground (<http://www.epa.gov/agriculture/lcwa.html#Nonpoint%20Source%20Pollution>). As the runoff moves over the ground it picks up pollutants including acid drainage from

mining sites

(<http://www.epa.gov/agriculture/lcwa.html#Nonpoint%20Source%20Pollution>). It is up to each state and can be fairly expensive, to regulate water pollution and enforce the Clean Water Act, therefore federal assistance (grants) could be provided to states that could prove the need for financial assistance to complete the program.

Spruce Mine Veto

There are consequences for mining companies that do not follow the guidelines described by SMCRA and the Clean Water Act. The Obama Administration and the EPA are working toward vetoing the largest mining permit in history, Spruce Mine one of the largest mountaintop removal mining sites in Central Appalachia, located in West Virginia. “In an 84-page report with four appendices, Garvin (the EPA administrator) outlined the EPA's concerns that the nearly 2,300-acre mine would bury seven miles of headwater streams and pollute waterways downstream from the mine site” (Ward 2010). This report stated, “The Spruce Mine would "eliminate the entire suite of important physical, chemical and biological functions" of affected streams and "likely have unacceptable adverse effects" on wildlife” (Ward 2010). In a recent water quality report, it was found the Spruce Mine violated the West Virginia water quality limits for toxic selenium and is suspected of eliminating more than 70 percent of insects and aquatic life at nearby streams (Ward 2010). According to the EPA, the drainage from the mine can cause elevated levels of selenium and an increase of total dissolved solids which can negatively impact on drinking water and water dependent communities in Spruce Fork watershed.

In addition to the allegations, the Spruce Mine is a suspect in participating in pollution that caused a massive fish kill in Dunkard Creek approximately a year ago. Although the EPA needs improvement in regulating water quality as a result of mountaintop removal, it is comforting to know there is an attempt to make decisions on a case-by-case basis. Each mining company does need to be evaluated individually to insure a safe community for people and biological residents.

Environmental Impacts of Soil Disposal

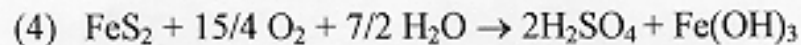
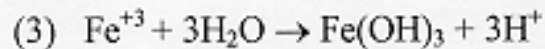
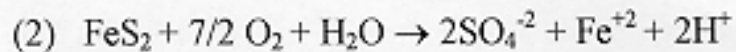
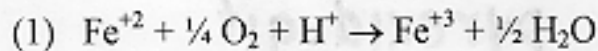
Environmental problems include surface and ground water pollution, sediment-clogged streams, acid-mine drainage, landslides, flooding, and unreclaimed or inadequately reclaimed areas. It has been suggested the runoff from spoil embankments is greater than runoff from undisturbed lands but this statement cannot be made with confidence due to the lacking data and a variety of factors that influence the rates (cited in Block, Thurston, and Dang 1981). Factors that influence the rates the water enters the soil include the permeability of the subsoil, expressed as saturated and unsaturated hydraulic conductivity, vegetal cover, the source of water, water temperature, soil structure and organic matter, and the former water content in the soil (Block, Thurston, and Dang 1981).

Surface Runoff also impacts the water quality in streams near surface mining sites. The quality of the runoff, both chemically and biologically, is strongly influenced by spoil bank. Polluted water bodies decrease the water quality and aquatic diversity. In May 2003 the Environmental Protection Agency released an

Environmental Impact Statement discussing the affects of mountaintop removal on the environment between the years 1985-2001:

724 miles of streams in Central Appalachia were buried by valley fills; another 1200 miles of streams have been impacted by valley fills; selenium was found only in those coal field streams below the valley fills; aquatic life forms downstream of the valley fills are being harmed or killed (cited in Chhotry).

Contaminated spoil bank can cause soil to become more acidic potentially causing acid mine drainage. Acid mine drainage can occur. "Acid mine drainage is produced by oxidization of sulfide minerals, mainly iron pyrite and iron disulfide" (Jennings, S., Neuman, D., Blicher, P. 2008).



Equation 1 shows the oxidation of pyrite (Todd, & Reddick, 1997). Equations 2 and 3 shows the oxidation of ferrous iron to ferric iron and the precipitation of ferric iron as ferric hydroxide (Todd, & Reddick, 1997). Equation 4 describes the complete reaction of pyrite and the formation of sulfuric acid (Todd, & Reddick, 1997).

Acid soil can be associated with natural occurrences and activities, such as mining, that can disturb the land. Activities, such as mining, can enhance and initiate the oxidation of sulfide minerals by increasing exposure to the atmosphere.

Mine tailings and waste rock, have much greater surface area than in-place geological material due to smaller grain size are more prone to generate acid mine drainage (AMD). Since large masses of sulfide minerals are exposed quickly during the mining process, the surrounding environment can often not attenuate the resulting low pH conditions [...]. Concentrations of common elements such as Cu, Zn, Al, Fe, and Mn all dramatically increase in waters that have a low Ph (Jennings, S., Neuman, D., Blicher, P. 4).

Water contaminated with AMD can have a long lasting effect on human health and aquatic life. Typically these waters have elevated metal concentrations which are toxic to most aquatic organisms leaving these water bodies devoid of most living creatures (Jennings, S., Neuman, D., Blicher, P. 2008). Water contaminated with AMD can be treated, but it is difficult and expensive. A common material, crushed limestone, can be used to neutralize the hydrogen ions, but cannot be used to eliminated heavy metals

Although laws like SMCRA and CWA work to protect communities and the environment, short cuts are taken in the reclamation process that could have devastating consequences. Many times there are reforestation issues and non-native grass is planted to ensure hurried vegetation of the reclamation site (cited in Chhotray 9). According to the EPA, “There is no evidence that native hardwood forest will...eventually re-colonize large mountain top mine sites using current reclamation methods” (cited in Chhotray). The Appalachian region is known for the large amount of biodiversity. Hunting, hiking, fishing, the scenery, along with other activities

brings tourism and money to this region. Without the mountains this popular tourism site will no longer flourish.

Effects on Human Health

Environmental problems associated with coal and coal mining have been recognized and researched however, there is little research and literature concerning human health problems associated with coal and coal mining. It has been suggested the mountaintop removal process and coal that is extracted contain harmful chemicals that can severely affect the health of Appalachia residents, most directly through the water supply. Coal contains harmful toxins such as arsenic, fluorine, selenium, and mercury (Chhotray). Mountaintop removal also generates heavy metal waste such as cadmium, mercury and nickel (Chhotray). “Thousands of families throughout Appalachia have had their wells contaminated or dewatered due to the blasting process (cited in Chhotray). Appalachia consists of rural communities that depend heavily on groundwater to supply their wells with drinking water.

Contamination of groundwater could cause heavy metal poisoning and diseases like Balkan Endemic Nephropathy (BEN), an irreversible kidney disease that has been related to the leaching of toxic organic compounds in groundwater, ingested by the local population (Chhotray). Although the origin of BEN is unknown and is more prevalent in areas such as Bulgaria and Romania, it is important to understand it is hypothesized the disease began with the contamination of wells with toxic organic compounds (Finkleman, Orem, Castranova, Tatu, Belken, Zheng, Lerch, Maharaj, and Bates 9). Many people in these areas, similar to those of Appalachia, still rely on

well water for drinking, cooking and bathing and can be exposing themselves numerous times to toxic chemicals.

Children are also greatly at risk, in a recent study conducted by the University of Kentucky it was found children in Letcher County, Kentucky, suffer from vomiting, nausea, diarrhea, shortness of breath and are more likely to be born with blue babe syndrome (cited in Chhotray). “The reason for these symptoms has been traced back to sedimentation and dissolved minerals that have drained from mine sites into nearby streams” (cited in Chhotray). The children of Letcher Country are not an exception; children attending Marsh Fork Elementary in Sundial, West Virginia regularly attend a school 400 yards downslope from a mountaintop removal site. The mining site located above the school is operated by Massey Energy and houses a the Shumate sludge impoundment where 2.8 billion gallons of toxic sludge are held back by a 385 foot earthen dam (<http://www.ilovemountains.org/memorial/c301/>).

Coal sludge is created when the coal is “washed” to remove excess soil and rock before the coal is shipped off. Coal sludge contains harmful carcinogenic chemicals as well as heavy metals such as arsenic, mercury, chromium, cadmium, boron, selenium, and nickel (<http://www.ilovemountains.org/memorial/c301/>). It is not uncommon for earthen dams to fail. In 1972 a dam failed in Buffalo Creek and again in 2000 when a Massey Energy dam failed dumping 300 million tons of sludge into Martin Country, Kentucky (<http://www.ilovemountains.org/memorial/c301/>). Should the dam fail above Marsh Fork Elementary the students would have less than 5 minutes to evacuate before the water reached 6 feet

(<http://www.ilovemountains.org/memorial/c301/>). There is no literature on coal ash at Marsh Fork Elementary but there have been comments about “black feet” and “black hands” after playing outside on the playground. The ash may be another health concern for children attending Marsh Fork Elementary.

Hazards of Heavy Metals

There are major threats to human health resulting heavy metal exposure, including exposure to cadmium, mercury, arsenic, selenium, and iron. Surface Mining generates huge amounts of waste called “fill material,” as well as “sludge” that results from cleaning coal before shipment. These waste products contaminate streams and soil and potentially contaminate water sources for communities.

According to Jarrup, “Cadmium exposure may cause kidney damage.” This damage may begin with tubular dysfunction which can be characterized by low molecular weight proteins or enzymes and may progress into severe kidney damage (Jarrup 2003). This tubular dysfunction is said to be reversible but there is no supporting data. High exposure to cadmium may be linked to decreased glomerular filtration rate, an increased risk of kidney stones (due to the increase of calcium in the urine) and chronic renal failure (Jarrup 2003). Long term exposure to high levels of cadmium may cause skeletal damage. In the 1950 cadmium contaminated water lead exposed people to itia-itia, also known as “ouch, ouch” disease was discovered in Japan (Jarrup 2003). Itia-itia disease is a combination of osteoporosis and osteomalacia and has not been common among those with low cadmium exposure. (Jarrup 2003).

Although cadmium has been identified by the IRAC as a group 1 human carcinogen, the argument is weak. (Jarrup 2003) It has been suggested cadmium exposure could increase the risk of kidney and prostate cancer, but there is both positive and negative evidence (Jarrup 2003).

Mercury is also a potential by-product of surface mining and coal “sludge” that could contaminate water sources however most of the general population is not at risk for methyl mercury exposure. It is most common for those who frequently consume fish. “Methyl mercury poisoning has a latency period of 1 month or longer after acute exposure, and main symptoms relate to nervous system damage” (Jarrup 2003). Symptoms usually begin with numbness in the hands and feet and progress into coordination difficulties, restriction of visual field, and auditory symptoms (Jarrup 2003).

The general population may also be exposed to additional metals such as, arsenic, by food or water intake. “Food is the most source, but in some areas, arsenic in drinking water is a significant source of exposure” (Jarrup 2003). Mine trailings have been known to have elevated levels of arsenic, increasing the likelihood of Appalachian residents to have been exposed to arsenic. Arsenic exposure can be characterized by the presence of arsenic in the nails, hair, blood or urine (Jarrup 2003).

Populations exposed to arsenic via drinking water show excess risk of mortality from lung, bladder, and kidney cancer, the risk increasing with increasing exposure. There is also an increased risk of skin cancer and other skin lesions, such as hyperkeratosis and pigmentation changes (Jarrup 2003).

Presently the World Health Organization concluded arsenic exposure by way of drinking water is casually related to cancer in the lungs, kidney, bladder and skin (Jarrup 2003). This assumption was based on the drinking water consisting of concentrations between 50-100 µg/l. Arsenic exposure has been associated with other diseases such as hypertension and cardiovascular disease but the evidence is lacking to support these associations (Jarrup 2003).

Another metal of concern, selenium, is often released during the mining process and could possibly end up in water supplies.

Selenium in raw coal and overburden is leached out when these materials are exposed to air and water, and the leachate can pose a significant environmental hazard. Mountaintop removal mining tends to maximize hazard because selenium-laden waste rock is disposed of as valley fill, which places this selenium source in close proximity to streams and other surface waters (Lemley 2009).

Potential selenium sources include fill material and ash as a result from surface mining ("Toxic Selenium: How Mountaintop Removal Coal Mining Threatens People and Streams" 2009). Selenium's ability to bioaccumulate makes this chemical element so dangerous. In other words, the low concentration of selenium in water could increase by several orders of magnitude by the time it reaches fish and other wildlife. Selenium exposure can lead to hair and finger nail loss, fatigue, and irritability ("Toxic Selenium: How Mountaintop Removal Coal Mining Threatens People and Streams" 2009). Long term exposure has more detrimental effects such as liver and kidney damage as well as damage to the nervous and circulatory system ("Toxic Selenium: How Mountaintop Removal Coal Mining Threatens People and Streams" 2009). According to the Safe Drinking Water Act the selenium threshold

level should be no higher than .05 parts per million ("Toxic Selenium: How Mountaintop Removal Coal Mining Threatens People and Streams" 2009).

Iron, one more metal of concern, is usually associated with acid mine drainage. Iron is a heavy metal that rarely exists in nature as an element, rather it exists as an ion, Fe⁺² or Fe⁺³. This ion readily reacts to form oxygen or sulfur containing compounds (Fawell , Lund, & Mintz 2003). The presence of iron that exceeds quantities of 40 µg/L can be detected by taste in distilled water (Fawell , Lund, & Mintz 2003).

The presence of iron gives acid mine drainage the rust color. In drinking water the unstable Fe⁺² salts are precipitated and settle out as rust colored silt (Fawell , Lund, & Mintz 2003). The amount of iron required to discolor the water varies depending on groundwater or pipe systems. For ground water the iron concentrations may be several Mg/L compared to piped systems where color may develop at iron levels of .05-.1 Mg/L (Fawell , Lund, & Mintz 2003).

Iron is an element that is essential in human nutrition. Although the minimum daily amounts vary according to age, sex and physiological status, the typical bioavailability ranges from 10-50 mg/day (Fawell , Lund, & Mintz 2003). "The average lethal dose is 200-250 mg/kg of body weight, but death has occurred following the ingestion of doses as low as 40 mg/kg of body weight (Fawell , Lund, & Mintz 2003).

The Chemistry of Acid Mine Drainage

Acid Mine Drainage starts with the reaction of pyrite with oxygen and water. This exposure oxidizes the pyrite and results in the release of hydrogen ions, therefore lowering the pH (Jennings, S., Neuman, D., Blicher, P. 2008). During the oxidation of pyrite, ferrous sulfate and sulfuric acid which can be further oxidized to increase acidity (Jennings, S., Neuman, D., Blicher, P. 2008). At the low pH sulfur oxidizing bacteria further catalyze this reaction (Jennings, S., Neuman, D., Blicher, P. 2008). The red-orange color of water affected by acid mine drainage is the result of the ferrous iron precipitating (Jennings, S., Neuman, D., Blicher, P. 2008) In addition to precipitating ferrous iron can react directly with pyrite to produce more ferrous iron and increase acidity (Jennings, S., Neuman, D., Blicher, P. 2008). It is not uncommon for other metals to form precipitates that will increase acidity.

Concisely, the demand for coal to fuel the United States is evident, with a significant portion extracted from Appalachia. Literary evidence suggests there is negative impacts, both directly and indirectly, of surface mining on the environment, human health and water quality. This research will examine the adverse effects of surface mining on water quality of the Clinch River. This research will also provide an overview of the decline of water quality from surface mining, particularly mountaintop removal, in Central Appalachia. This research will draw conclusions about the water quality and make comparisons between water quality and human health and environmental restoration.

Methodology for Data Collection and Analysis

Identification of Study Area

In order to draw conclusions about the water quality and make comparisons between water quality, human health, and environmental restoration; a content and data analysis was conducted. The research question was defined using evidence and support extracted from credible sources, including peer reviewed articles. Sources were identified which contained differences and contradictions. Evidence either did or did not support these differences and contradictions; thus redefining the thesis and making the topic more significant and interesting.

The Appalachian Mountains are a broad area of focus. Therefore this research defined an area of study, the Clinch River. This River was chosen based on the amount of available data and the close proximity with coal mining companies. Data was provided by the Virginia Department of Environmental Quality. Data was analyzed to see the trend in organic, inorganic, and metal concentrations, as well as, temperature and pH fluctuations.

Clinch River

A sample population, consisting of the Virginia portion, was examined during this research (See results). This data was retrieved from the Virginia Department of Environmental Quality. The Clinch River was chosen because this river sustains very diverse and rare mussel, fish, mammal, bird and plant populations. Many portions of the Clinch River, such as River Place (located along highway 70 Kyles Ford, TN), are used for recreation such as canoeing, fishing, rafting and picnicking. The water

quality of the Clinch River has been threaten by surface mining in the past, but today organizations such as the Nature Conservancy and the Virginia Department of Mines, Minerals and Energy are working to implement a project that will include ecological restoration and reforestation on coal mined lands.

The Virginia Department of Environmental Quality follows the water quality standards mandated by the State Water Control Law.

Description of Waters	Dissolved Oxygen (Mg/L) Daily Average	pH	Max Temperature (°C)
Mountainous Zone Waters	5.0	6.0-9.0	32

These water quality standards describe water quality requirements such as specific numerical limits for chemical, physical and biological components to ensure safe water for drinking, recreation, wildlife and aquatic life (figure 7). The water quality standards vary according to the location of the water body (figure 6) and are constantly being updated in accordance to technology and new information made available to the Water Board and DEQ. Contaminants such as arsenic, cadmium, lead, etc. are a source of concern for consumers. These contaminants may be present in the drinking water and are only categorized as acute and chronic toxicity when concentrations reach dangerous amounts. The State Water Control Board defines acute toxicity, “An adverse effect that usually occurs shortly after exposure to the pollutant” (2010). Acute toxicity is measured by lethality and or immobilization to organisms (2010). Water bodies can also be classified as chronically toxic, meaning,

“ The adverse effect is irreversible or progressive or occurs because the rate of injury is greater than the rate of repair during prolonged exposure to pollutant; including reduction in growth and reproduction” (2010). The State Water Control Board set these standards as according to the natural quality or the quality in the absence of human pollution (2010).

Results and Discussion:

Table 1.

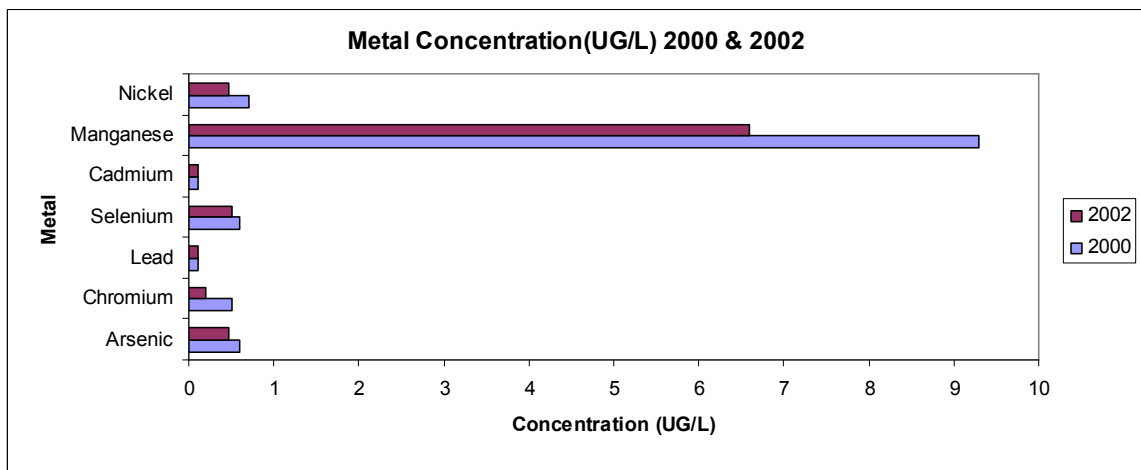
pH Measurements 1999-2008 for Route 627, VA

Date	pH
1/12/1999	8.04
1/24/2000	8.13
1/22/2001	7.86
1/28/2002	7.66
1/28/2003	8.24
1/6/2004	7.62
1/11/2005	8.18
1/17/2006	8.06
2/13/2007	8.00
2/13/2008	8.20

From January 1999 through February 2008, there are not any significant changes in the pH at Route 627. The pH fluctuates minimally between 7.6 and 8.2. The pH measurements within these limits do not violate the numerical standards set by the State Water Control Law.

Figure 1.

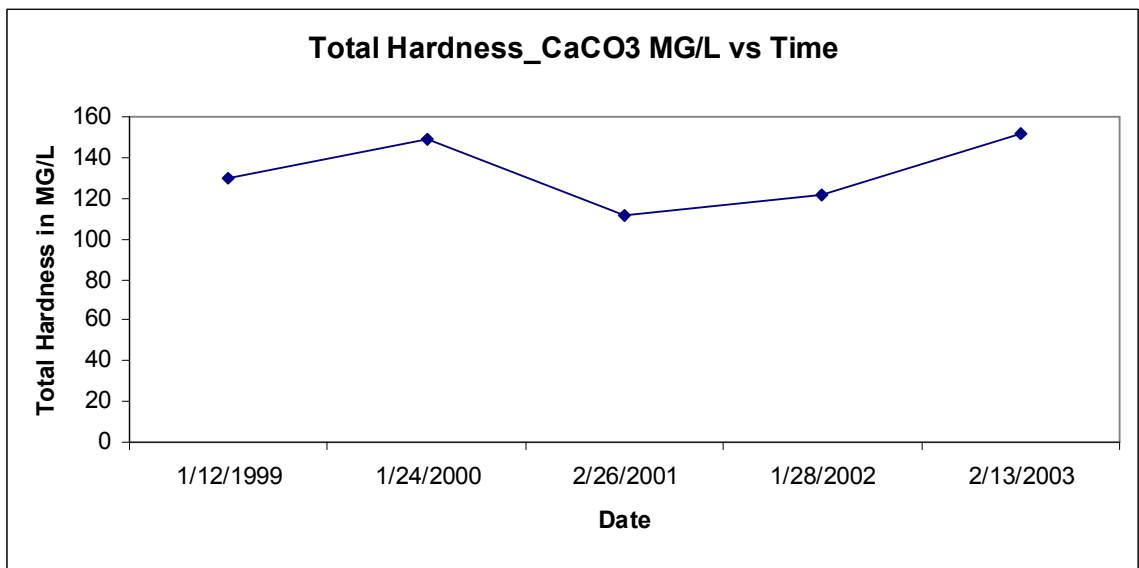
Metal Concentrations for Route 627, VA 2000-2002



When comparing metal concentrations for 2000 to 2002, most metal concentrations have decreased at Route 627. Nearly every metal concentration decreasing, with Manganese decreasing the most, from 9.3 UG/L to 6.6 UG/L and selenium decreasing the least, from .6 UG/L to .5 UG/L. Lead concentrations did not increase or decrease but stayed at a concentration of .1 UG/L. All the above concentrations are within the standards set by the State Water Control Law.

Figure 2.

Total Hardness of CaCo3 at Route 627, VA 1999-2003



From January 1999 through February 2003 the total hardness of the water at Route 627 stayed within the limits set by the State Water Control Law. The total hardness of the water fluctuated between approximately 10-30 MG/L from 1999 to 2003.

Table 2.

Sulfate Concentration at Route 627, VA 1999-2001

Date	Sulfate_MG/L
1/12/1999	23.8
1/24/2000	34.8
2/26/2001	24.3

From January 1999 through February 2001 the sulfate concentrations at Route 627 stayed within the standards set by the State Water Control Law. The fluctuation between these concentrations, approximately 10 MG/L, was not significant.

Table 3.

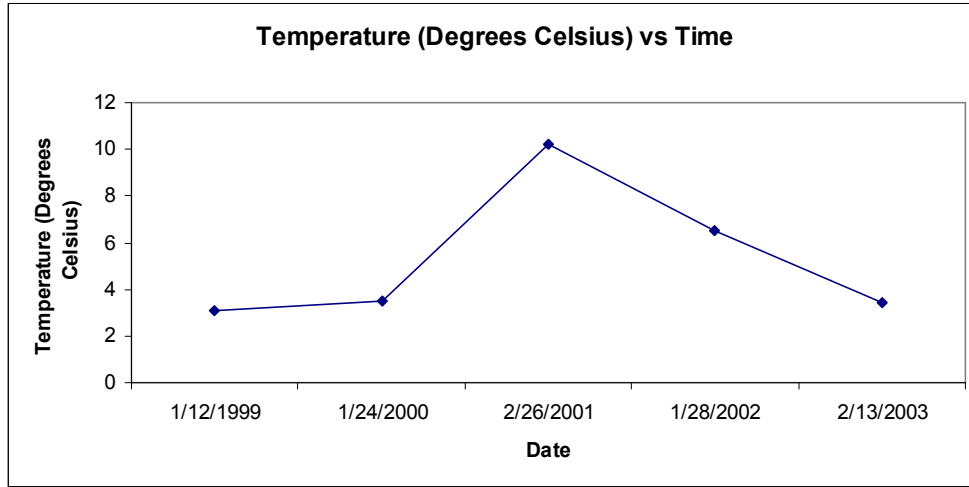
Total Chloride Concentration at Route 627, VA

Date	Chloride_MG/L
1/12/1999	9.3
1/24/2000	15.6
2/26/2001	9.4

From January 1999 to January 2000 the chloride concentration increased by approximately 4.0 MG/L. The chloride concentration decreased January 2000 to February 2001 by approximately 4.0 MG/L. These fluctuations in concentrations do not violate the standards set by the state water control law.

Figure 3.

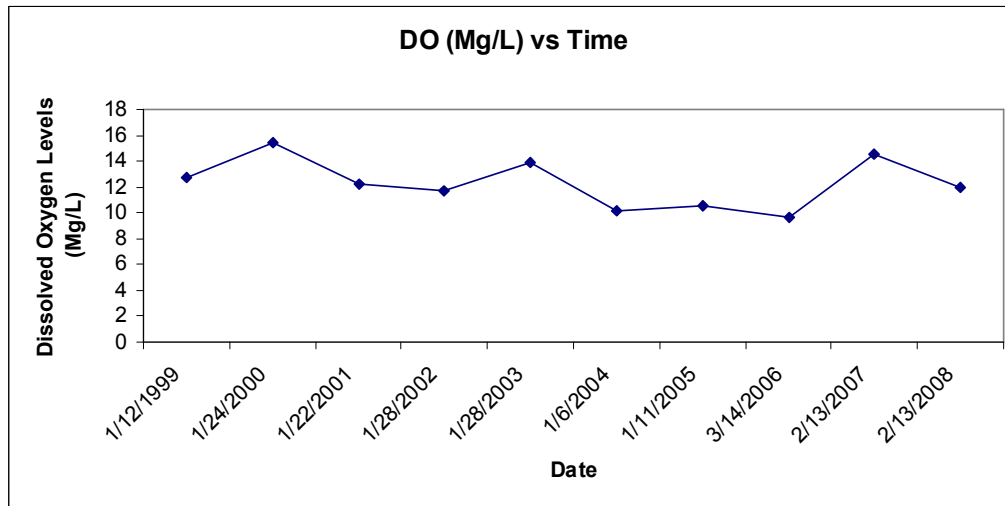
Temperature Measurements at Route 627, VA 1999-2003



The figure above shows temperature fluctuations from January 1999 to February 2003. There is an increase in temperature between the years 2000 and 2001. The temperature decreases between the years 2001, 2002 and 2003.

Figure 4.

Dissolved Oxygen Measurements at Route 627, VA



Dissolved oxygen (DO) concentrations were analyzed from January 1999 to February 2008. DO concentrations did fluctuate minimally between approximately 9.0 and 15.5. The highest DO concentration was measured in 2000 at 15.43 Mg/L and the lowest in 2008 at 9.7 Mg/L.

Table 4.

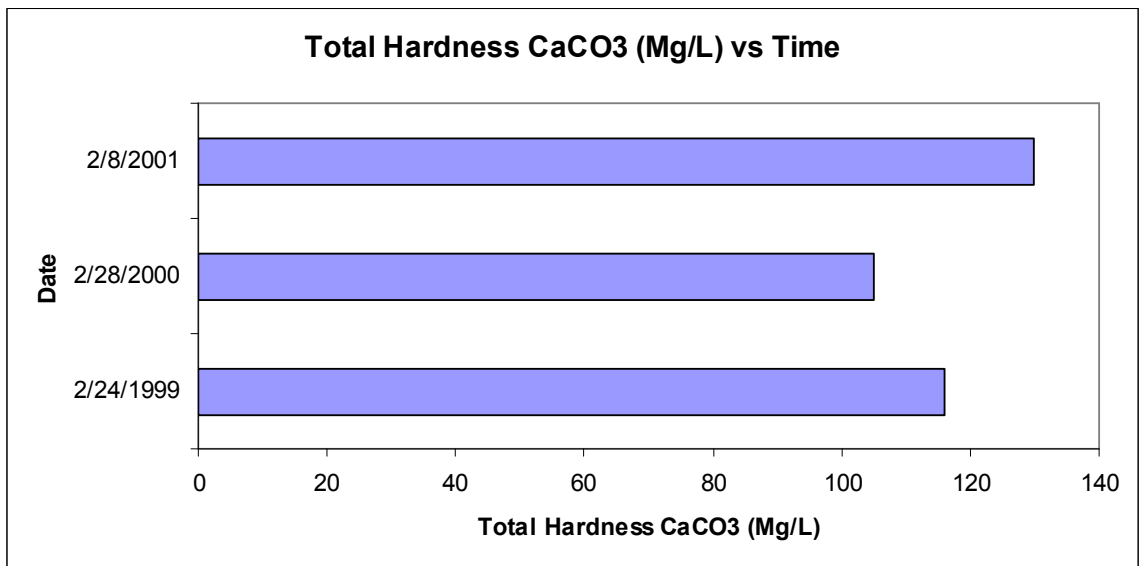
pH Measurements at Route 65, VA 1999-2001

Date	pH
2/24/1999	8.3
2/28/2000	8.08
2/8/2001	8.44

From February 1999 to February 2001 the pH measurements at Route 65, VA stayed at approximately 8.0. The pH measurements stayed within the standards set by the State Water Control Law.

Figure 5.

Total Hardness of CaCO₃ at Route 65, VA



From February 1999 to February 2001 the total hardness of the water at sampling location, Route 65, VA, decreased from 116 mg/l to 105 mg/l, then increasing to 130 mg/l.

Table 5.

Sulfate Concentration at Route 65, VA

Date	Sulfate (Mg/L)
2/24/1999	26.2
2/28/2000	23.4
2/8/2001	37.2

The sulfate concentration for Route 65, VA were compared from 1999 to 2001. The concentration showed small changes during this time period. The concentration increased by approximately 3 mg/l from 1999 to 2000 and approximately 14 mg/l from 2000 to 2001.

Table 6.

Chloride Concentration at Route 65, VA

Date	Chloride (Mg/L)
2/24/1999	6.8
2/28/2000	9.1
2/8/2001	14.1

Chloride concentrations were measured at Route 65, VA from February 1999 to February 2001. The chloride concentrations steadily increased from 6.8 mg/l to 9.1 mg/l from 1999-2000. Then increased again from 9.1 mg/l to 14.1 mg/l from 2000-2001.

Table 7.

Temperature Measurements at Route 65, VA

Date	Temperature (°C)
2/24/1999	4.7
2/20/2000	11.5
2/8/2001	7.7

The temperature measurements, in degrees Celsius, were compared for Route 65, VA from February 1999 to February 2001. The temperature more than double from 4.7 °C to 11.5 °C during the year span of 1999 to 2000, then decreased from 11.5 °C to 7.7 °C during 2000 to 2001.

Table 8.

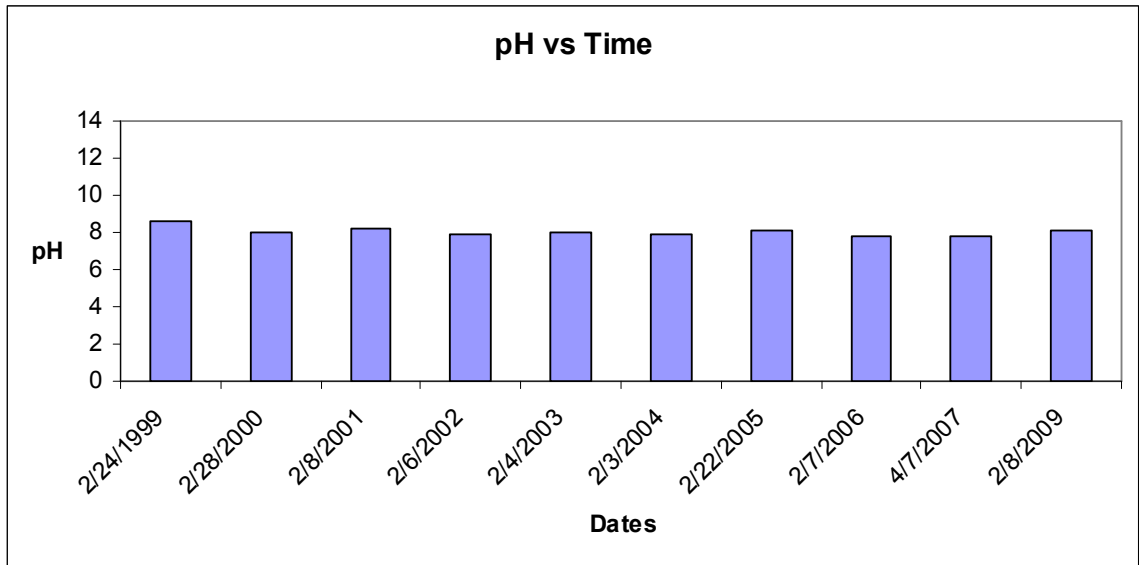
Dissolved Oxygen Levels at Route 65, VA

Date	Dissolved Oxygen (Mg/L)
2/24/1999	12.56
2/28/2000	11.96
2/8/2001	14.23

Dissolved oxygen (DO) levels were analyzed from February 1999 to February 2001 with minimal fluctuations in the concentrations. The concentrations were measured in mg/l with the highest concentration at 14.23 mg/l and the lowest at 11.96 mg/l.

Figure 6.

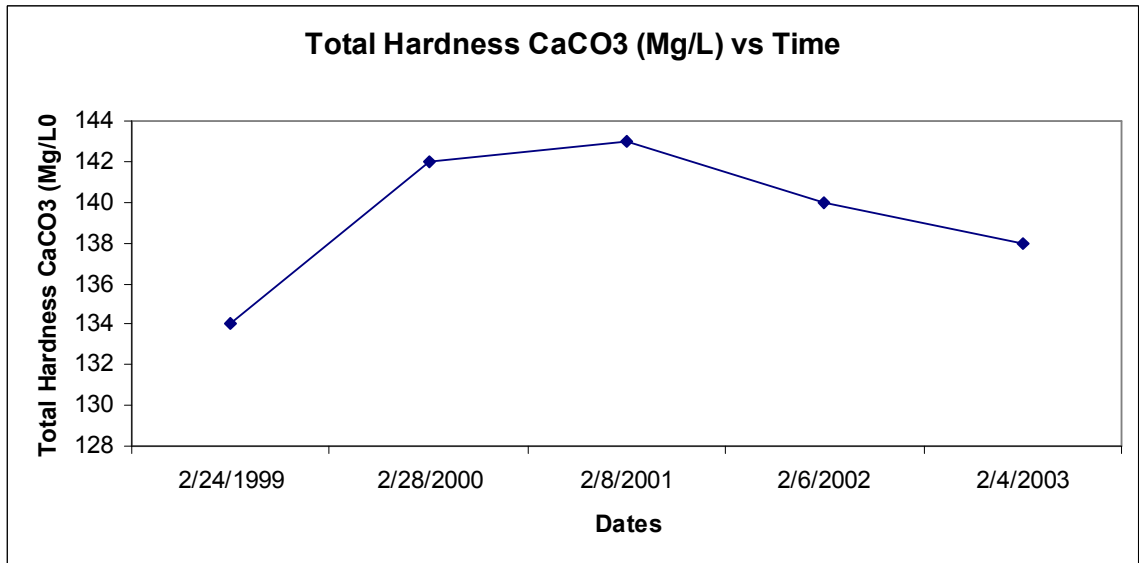
PH Measurements at Route 82, VA



pH measurements were analyzed from February 1999 to February 2009 for Route 82, VA. The pH fluctuates minimally between 7.8 and 8.6. The pH measurements for this site stay within the standards set by the State Water Control Board.

Figure 7.

Total Hardness of CaCO₃ at Route 82, VA



During the years 1999 and 2003 the total hardness of the water at the sampling site Route 82, VA the total hardness stayed within the standards set by the State Water Control Board. The highest concentration of CaCO₃ measured at 143 mg/l in 2001 and the lowest at 134 mg/l in 1999.

Table 8.

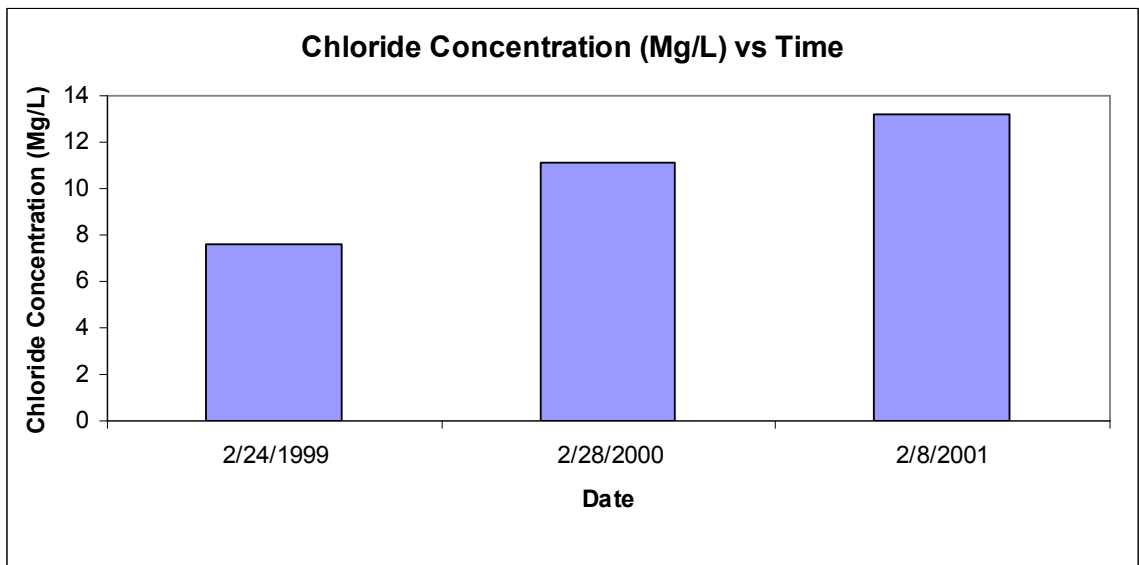
Sulfate Concentration (Mg/L) at Route 82, VA

Date	Sulfate Concentration (Mg/L)
2/24/1999	19.1
2/28/2000	22.6
2/8/2001	22.2

The sulfate concentration at Route 82, VA was measured from February 1999 to February 2001. The concentration varied with little significance during this time span.

Figure 8.

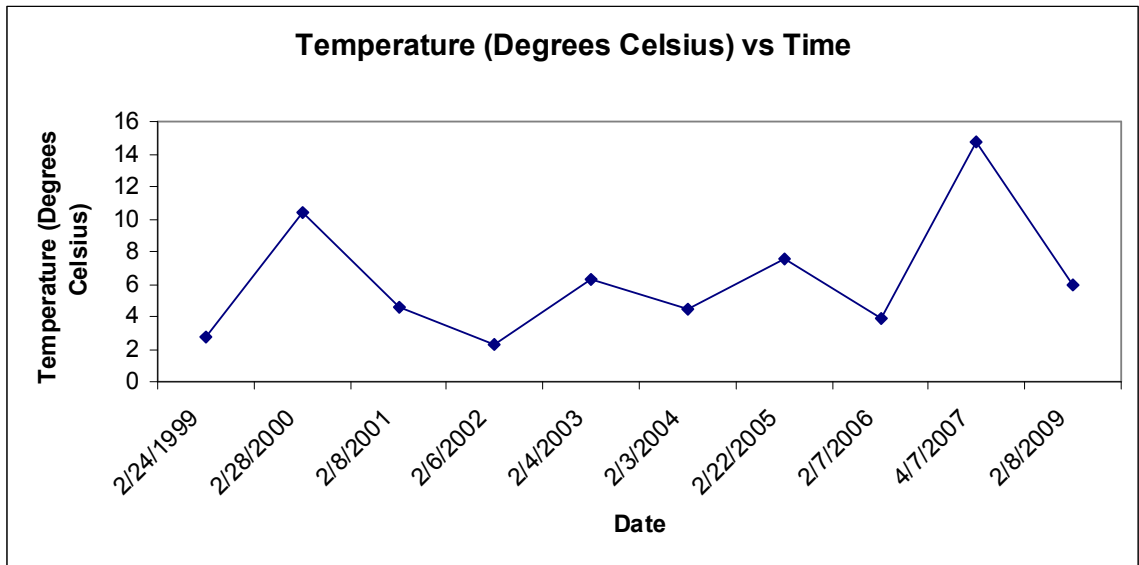
Chloride Concentration (Mg/L) at Route 82, VA



The chloride concentration at Route 82, VA increased by approximately 3 mg/l each year from February 1999 to February 2001. Although there was an observed increase, the concentrations stayed within the standards set by the State Water Control Law.

Figure 9.

Temperature Measurements at Route 82, VA



From 1999 to 2009 the temperature was measured at Route 82, VA. As shown above the temperature increased sharply from 2.8 °C to 10.4 °C during the year span of 1999 to 2000. Then again from 3.84 °C to 14.7 °C during the year span 2006 to 2007. Data for the year 2008 was not included in this analysis due to its unavailability.

Conclusion

In conclusion, the water data obtained from the Virginia Department of Environmental Quality was limited. Sampling locations such as Route 627, 65, and 82 were compared based on the quantity of data provided. These samples showed little variance in pH, temperature, chloride, sulfate, total hardness and dissolved oxygen. All pH, metal concentrations, temperature and dissolved oxygen levels stayed within the water quality standards set by the State Water Control Board

Fluctuation for pH and DO outside the parameters set by the State Water Control Board will not be considered to be violated if the source is determined natural as opposed to man-made. Temperature did fluctuate as a result of natural causes and will not be considered to be violated unless the body of water exceeds 3° C above the parameters set by the State Water Control (2010). The dissolved oxygen levels were noticeably greater than the minimum of 4, with Route 627 having the highest at 15.23 (Mg/L) and Route 82 having the lowest at 8.4 (Mg/L). The metal concentrations obtained from Route 627 did not exceed the parameters set by State Water Control.

According to the data obtained from the Virginia Department of Environmental Quality surface coal mining does not negatively impact the water at Route 65, 82, and 627. This cannot be conclusive for all water sources in close proximity to areas being surfaced mined. This conclusion would be more accurate if there was more data to compare between more water sources. Major problems during this research included obtaining the data and comparing the data. When comparing data there were often gaps in time span between data collection and record; there must be more data to

make a more accurate conclusion about surface coal mining and water quality in its entirety.

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