Environmental Pollution 197 (2015) 55–61

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Damage cost of the Dan River coal ash spill

A. Dennis Lemly

215 Sapona Road, Lexington, NC 27295, USA

ARTICLE INFO

Article history:
Received 24 August 2014
Received in revised form
19 November 2014
Accepted 30 November 2014
Available online

Keywords:
Coal ash
Dan River
Duke Energy
Fish
Wildlife
Selenium
Copper

ABSTRACT

The recent coal ash spill on the Dan River in North Carolina, USA has caused several negative effects on the environment and the public. In this analysis, I report a monetized value for these effects after the first 6 months following the spill. The combined cost of ecological damage, recreational impacts, effects on human health and consumptive use, and esthetic value losses totals $295,485,000. Because the environmental impact and associated economic costs of riverine coal ash spills can be long-term, on the order of years or even decades, this 6-month assessment should be viewed as a short-term preview. The total cumulative damage cost from the Dan River coal ash spill could go much higher.

Published by Elsevier Ltd.

1. Introduction

On February 2, 2014 two large stormwater drainpipes (36″ and 48″ diameter) underlying a coal ash disposal impoundment at Duke Energy's Dan River Plant collapsed, spilling approximately 39,000 tons of coal ash (Duke Energy revised figure, originally estimated at 82,000 tons) and about 27 million gallons of untreated ash wastewater into the Dan River at Eden, North Carolina (Duke Energy, 2014; NCDENR, 2014, Fig. 1). This event was the third largest coal ash spill ever recorded in the USA (Waterkeeper Alliance, 2014).

The volume of ash and wastewater, and its rapid release, overwhelmed the river's natural flow. The spill coated the river banks and left ash deposits on the river bottom several feet thick in some places, and changed the chemistry of the entire flow of the river due to poisonous metals and trace elements such as selenium, arsenic, and copper. Within days, the US Fish and Wildlife Service detected floating ash and benthic ash deposits at the mouth of Kerr Reservoir in Virginia, some 70 miles downstream (USFWS, 2014). The North Carolina Department of Environment and Natural Resources called the spill “an environmental disaster” (Zucchino, 2014).

In addition to chemical hazards from waterborne toxins, the physical habitat degradation (blanketing and smothering) caused by coal ash deposited after a spill is extremely damaging to benthic animals like mussels, clams, insects, snails, worms, crayfish, frogs, toads, salamanders, turtles, etc. A portion of the more mobile species such as fish may be able to escape the initial “ash tsunami” by moving long distances up or downstream (in the Dan River, only downstream movement is possible due to a large weir dam just upstream of the spill site), but this doesn't really prevent damage to the greater animal community. Some fish will stay and ingest toxic ash and be chemically poisoned (Tuberty, 2009). Many will leave, which causes mass exodus of populations and severe disruption of the natural ecosystem balance (Arcadis, 2012). The ash deposits will persist and some of their contaminants will move up the benthic food chain into fish and wildlife (Ruhl et al., 2010; Arcadis, 2012). In addition to direct impacts on animals and their habitat, there is a cascade effect of the ecological damage that influences human-related factors such as recreation, public health, consumptive uses, and property values. The environmental damage from coal ash spills into rivers can be catastrophic and the effects can be long-lasting. Research shows that when a riverine aquatic ecosystem is severely damaged from coal ash pollution, it may never fully recover to its “pre-pollution” biological condition and ecological balance. For example, a spill of smaller size in 1967 on the Clinch River in VA resulted in destruction of benthic communities and displacement of resident fish populations for over 70 miles (Lemly

E-mail address: lemlyad@wfu.edu.

http://dx.doi.org/10.1016/j.envpol.2014.11.027
0269-7491/Published by Elsevier Ltd.

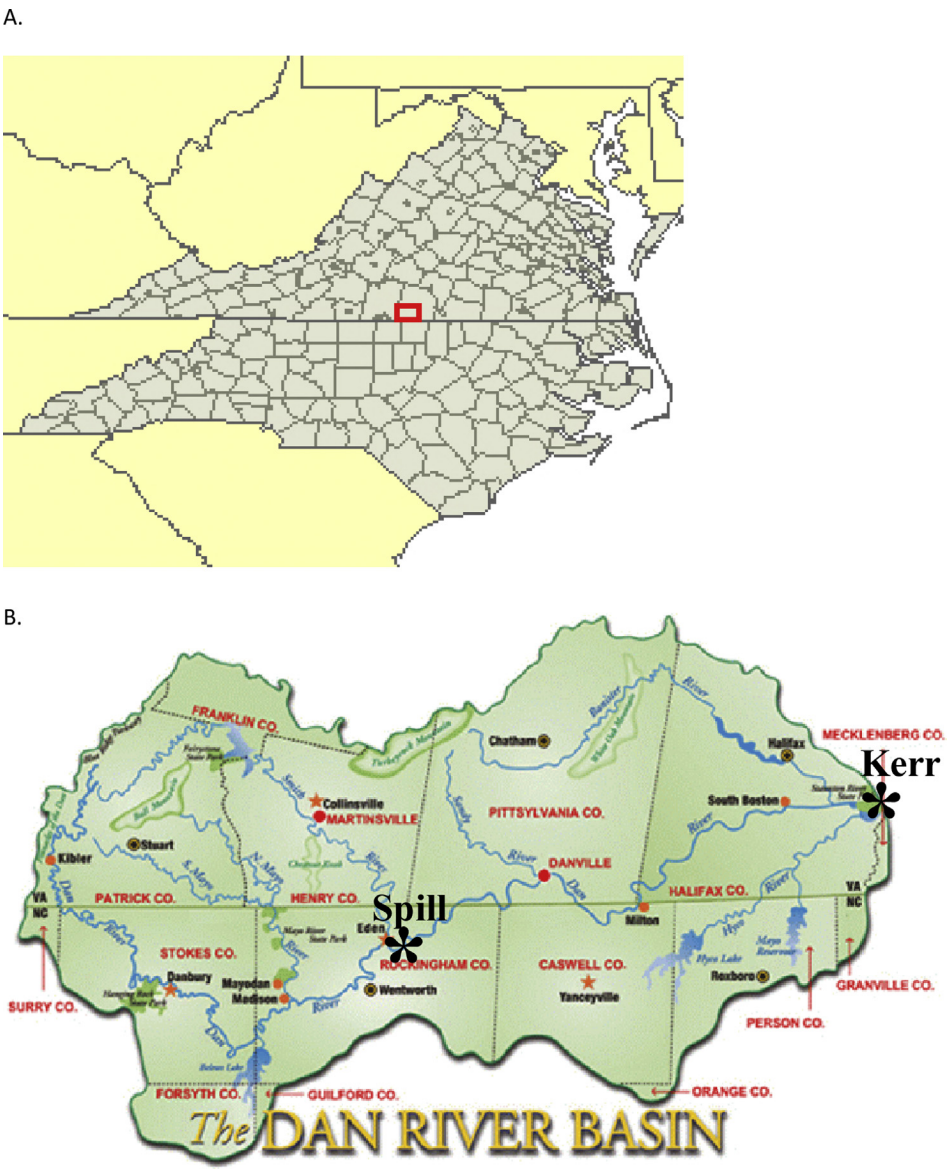

Fig. 1. A. Location of the Dan River coal ash spill zone, which spans the North Carolina–Virginia border and extends from Eden, NC to Kerr Reservoir, VA. About 10 miles of the spill zone are in NC and about 60 miles are in VA. B. Watershed of the Dan River basin showing spill site near Eden, NC and mouth of Kerr Reservoir in VA.

and Skorupa, 2012a, 2012b). Natural recovery coupled with extensive restoration efforts (stocking) for endangered and threatened mussels carried out by the US Fish and Wildlife Service have not been able to restore the native river fauna to its pre-pollution condition after more than 30 years (Jones et al., 2000). Other examples of extensive, long-term damage of coal ash spills on water quality and river fauna include the Delaware River, PA and the Emory River, TN (Arcadis, 2012; Carriker et al., 2013; Lemly and Skorupa, 2012a, 2012b; Ruhl et al., 2010).

The type of pollution and associated fish and wildlife impacts that have taken place in the Dan River due to coal ash results in diminished natural resource values that have both short-term and long-term negative economic effects at the local, state, and regional levels (Kopp and Smith, 1993; King, 1998). These values include (1) ecological costs (poisoning and blanketing/smothering of animals, displacement of animals, destruction of aquatic habitat and ecosystem function, associated animal replacement and aquatic habitat restoration costs), (2) sport/recreational costs (impacts to fishing, camping, hiking, boating, swimming, and associated costs including outfitters, guides, licenses, food, clothing, tackle/gear, bait, gasoline, vehicles, and other provisions), (3) human health and consumptive use costs (food value of poisoned or displaced edible fish, human health risks from elevated pollutants in edible fish, physical stress and anxiety), (4) property damage costs (lost/depreciated real estate values of waterfront property due to pollution), and (5) esthetic costs (inherent value of a clean and healthy ecosystem to non-users/recreators). Spatial extent of the damage and duration in time both add substantially to these costs.

2. Damage cost of the Dan River spill after 6 months

The cost calculations presented here were derived based on valuation parameters established by NC State Statute for fish and wildlife replacement, US Fish and Wildlife Service Natural Resource Damage Assessment principles and procedures, and case examples taken from the scientific and technical literature (Lemly and

Skorupa, 2012a, 2012b; NOAA, 2013). Because a large part of the environmental impact and associated economic costs of riverine coal ash spills can be long-term, i.e., on the order of years or even decades, this 6-month assessment should be viewed as a short-term preview of what is potentially a much larger total cumulative damage cost from the Dan River coal ash spill.

3. Damage element one – ecological impacts

3.1. Physically and chemically altered benthic aquatic habitat

Coal ash that spilled into the Dan River coated the bottom for a distance of 70 miles, according to the US Fish and Wildlife Service and US Environmental Protection Agency (USFWS, 2014; USEPA, 2014). Deposits ranged from several feet deep near the spill site, to 5 inches at 2 miles downstream, 2 inches at 9 miles downstream, and one-half inch at 62 miles downstream. It is possible to analyze the nature of ash deposits themselves to ascertain the degree of habitat degradation that took place in the first 6 months. It is useful to also draw upon information from regional coal ash spills that have been extensively investigated for years. For example, there is a voluminous literature from the 2008 Kingston TN coal ash spill which shows that ash deposits such as those in the Dan River physically disrupt ecosystem structure and function, chemically poison and displace aquatic animals, and significantly degrade aquatic habitat (Arcadis, 2012; Carriker et al., 2013). Monetization of damage in the form of degraded aquatic habitat can be done according to guidelines for valuation of mixed freshwater habitats set out by King (1998). King's procedure uses a "willingness to pay" framework (i.e., what state and federal agencies acting on behalf of the public have been willing to spend or have spent by permit seekers to attempt to restore aquatic and wetland habitat). Given that 39,000 tons of coal ash was spilled into the Dan River, at a weight of approximately 62 lbs per cubic foot, or 1674 lb per cubic yard, this translates to a volume of 46,594 cubic yards of coal ash spilled. This, in turn, translates to a volume of coal ash capable of blanketing the river bottom to a depth of 2 inches over an area of 52,000 acres, or one-half inch over an area of 208,000 acres. Two inches of coal ash can eliminate much of the benthic fauna (insects, snails, mussels, clams, toad and frog tadpoles, salamanders, etc.) following a spill event and one-half inch severely disrupts population balance and ecosystem function (Arcadis, 2012; Carriker et al., 2013; Lemly and Skorupa, 2012b). The US Fish and Wildlife Service measured river bottom ash depths of 2 inches at nine miles downstream, and one-half inch at 62 miles downstream (USFWS, 2014). This benthic habitat is physically and chemically altered (degraded) to the point that it no longer supports the full complement or health of animals and it poses long-term hazards to fish and wildlife. For example, USEPA has documented sediment selenium concentrations exceeding chronic toxic threshold levels (threshold = 2.0 mg/kg or parts-per-million, Lemly, 1993, 2002; measured levels = 3.8–7.4 mg/kg) throughout the Dan River from February through their latest sampling results for June 4–July 2 (USEPA, 2014). Selenium bioaccumulation from sediments into aquatic food chains is a major route of exposure that can cause long-term dietary toxicity to fish and wildlife (Lemly, 2002). USEPA also found that sediment ecological hazard trigger levels were exceeded for arsenic and barium. Collectively, the ash deposition and contaminant levels translate to approximately 1878 acres of polluted aquatic habitat (using 250 ft as average river width measured from satellite imagery × 62 miles of river). Applying these numbers, the environmental damage cost due to physical and chemical degradation of aquatic habitat would be $97,656,000 using King's valuation guideline of $52,000 per acre (1997 dollars) for mixed aquatic habitats (which is conservative because inflation-adjusted cost in 2014 dollars is $77,220 per acre). It should be noted that this is an "instantaneous valuation", that is, the initial environmental degradation cost. As time passes and additional monitoring information comes in, there may be a need to add a "duration of impact" factor in order to fully assess total cost. This is termed "cumulative damage", and it may increase total damage cost significantly. At this time, it is reasonable and conservative to only consider the $97 million that constitutes instantaneous valuation.

3.2. Acute and chronic poisoning of fish and wildlife

The acute (96 h or less), or short-term toxicity of coal ash contaminants and ash on aquatic life in the Dan River is difficult to assess directly because no toxicity studies were undertaken in the days following the spill event. Investigations to assess chronic (weeks, months, years), or long-term biological impacts in the Dan River are underway but are incomplete and unreported at this time. Initial efforts by the electric utility were focused on stopping the spill, and by state and federal agencies on measuring water and sediment concentrations of pollutants for human health concerns since the Dan River is a public water supply for the City of Danville, VA. There was no comprehensive response to do a rapid assessment and inventory of fish and wildlife killed. However, there were numerous news accounts of dead fish, turtles, clams, and mussels that were attributed to the spill, which included photographic documentation by local citizens (e.g. Coyle, 2014; Daily Kos, 2014). These reports, although not substantiated with scientific investigation, were probably accurate. When asked if these dead animals were killed by coal ash, a U.S. Fish and Wildlife Service biologist said "We don't know at this point. Is it possible? Sure" (Ward, 2014). In a spill of this magnitude, it is almost certain that there were significant acute toxic impacts due to a combination of chemical poisoning and "ash asphyxiation", or smothering. These effects were well documented at other riverine coal ash sites which have been extensively investigated (Arcadis, 2012; Lemly and Skorupa, 2012a, 2012b; Carriker et al., 2013). Thus, although substantial acute impacts likely occurred, it is not currently possible to verify the anecdotal reports scientifically, quantify the damage in terms of numbers killed, or monetize the resultant value. To date, only water and sediment testing results have been released by USEPA and NCDENR (USEPA, 2014; NCDENR, 2014). No results of their fish and shellfish tissue analyses for coal ash pollutants have been posted. The Virginia Department of Environmental Quality has not released any details for water, sediment, or animal tissue (VDEQ, 2014). Examination of fish and invertebrate tissue data will be necessary to evaluate chronic toxicity by comparing tissue concentrations of contaminants such as selenium and arsenic with diagnostic toxic effect levels published in the scientific literature. That is not possible at this time. However, an examination of the aquatic chemistry analyses by USEPA and NCDENR reveals at least one important acute toxicity factor. Concentrations of waterborne copper spiked above toxic levels for aquatic life for several days following the spill, over a distance of at least 10 miles (to the NC–VA border). NCDENR and USEPA measured levels of 7.5–46 ug/L in the Dan River (parts-per-billion; NCDENR, 2014; USEPA, 2014). The USEPA water quality criterion to protect aquatic life from acute toxicity from copper is 2.3 ug/L (USEPA, 2007). This is the maximum acceptable amount for short-term exposure (48–96 h). The toxicity database used by USEPA to formulate this number indicates that concentrations of 7.5–46 ug/L are sufficient to kill 50% of a variety of aquatic animals within a 48–96 h window of exposure (USEPA, 2007). Sensitive organisms that would be poisoned include worms, snails, clams, mussels, crustaceans (e.g., amphipods, crayfish) toads, and fish (minnows, darters, trout). Elevated copper

quickly impacts the health and integrity of a riverine ecosystem. In particular, mussels and clams killed from acute copper toxicity would not be swept away by current as would fish and other free-swimming animals, and would leave a marker in the form of shells on the bottom. It is quite likely that the spike in the concentrations of copper were responsible for the evident dead mussels and clams whose shells were piled up along the shoreline a few days following the spill. The associated damage cost can be determined by applying an integrative method that uses on-site chemical and physical measurements (water and sediment) coupled with reference diagnostic toxicological data to develop a community impact profile, a procedure that has been used by federal agencies investigating oil spills (e.g., NOAA, 2013). Thus, rather than attempting to value each species or taxonomic group individually, the animal community representing a specific habitat type, in this case a southern riverine community, is considered as a whole and the resultant damage cost reflects the aggregate impact of pollution on the entire community using known toxicity profiles. With at least 7 taxonomic groups ranging from worms to fish experiencing acute copper poisoning in the Dan River, the community impact profile is high. It is reasonable to set the direct damage cost to animals at the same level as was done for their habitat in the previous item. Therefore, using an average of 250 feet for river width × 10 miles = 303 acres × $52,000 per acre = $15,756,000 in damage due to acute copper poisoning of aquatic life (which is conservative because inflation-adjusted cost in 2014 dollars is $77,220 per acre). Water copper concentrations were reported by NCDENR only to the NC–VA border due to jurisdictional limits and VDEQ has not released detailed data. However, with toxic concentrations present at the border, it is nearly certain that toxic concentrations also appeared for some distance downstream in VA. Therefore, this damage cost number will increase if VDEQ data show that water concentrations of copper spiked to toxic levels in Virginia, which constitutes by far the longest stretch of polluted river (about 60 miles). One of the big unknowns at this time is the extent to which the federally endangered James Spinymussel (*Pleurobema collina*) and Roanoke Logperch (*Percina rex*) were poisoned, as well as other state and federal threatened aquatic species of fish and shellfish. Under penalties set out in the federal Endangered Species Act each individual killed carries a damage value of $3500 (NOAA, 2001).

Acute Toxicity Damage Cost = $15,756,000 (likely to increase).

Chronic Toxicity Damage Cost = yet to be determined.

Total Fish and Wildlife Poisoning Cost = $15,756,000.

3.3. Displacement of fish

Many fish species are highly mobile and can move quickly over considerable distances to avoid rapid, detrimental changes in water quality, especially in response to physical gill irritants such as coal ash. When this happens, local evacuation and even “extirpation” may occur, which essentially removes a large part of the resident fish life. This happened during the 2008 Kingston TN ash spill (Arcadis, 2012). A displaced fish is no different than a chemically poisoned fish in terms of the removal of its inherent ecosystem and human values. Therefore, a displaced fish carries the same damage value as a fish killed directly by coal ash contaminants, which currently carries an average replacement cost of $8.25 per individual (inflation-adjusted to 2014 dollars) by NC Statute (NCAC, 1993).

The reach of the Dan River affected by the coal ash spill supported a diverse and abundant assemblage of fish, comprising at least 30 species (Lee et al., 1980; Menhinick, 1991). It is empirically and intuitively obvious from other riverine ash spills that a large number of fish attempted to escape the ash “tsunami” by fleeing the area, probably on the order of hundreds-of-thousands, at a minimum. It is likely that several million dollars of replacement cost was incurred from this impact. However, there is no quantitative fish population sampling data to verify the extent or severity of this fish exodus. Therefore, it is not possible to place a dollar cost on it. This is a serious data gap in the early stages of biological assessment of coal ash impacts in the Dan River. It would still be possible to make a long-term assessment by conducting comprehensive upstream–downstream comparisons of fish populations near the spill site.

Total 6-month Ecological Damage Cost = $113,412,000.

4. Damage element two – recreational impacts

From the time of the spill, recreational use of the Dan River decreased. This is evidenced by news reports and interviews with local individuals and businesses (e.g., News-Record 2014, Catanoso, 2014a; Visit-NC, 2014), and by the impacts due to issuance of a Recreational Water Advisory and Fish and Shellfish Consumption Advisory for the Dan River spill zone by the North Carolina Department of Health and Human Services on February 14 (NCDHHS, 2014a). These advisories recommended no direct water contact and no consumption of fish and shellfish. This effectively labeled the river as a “high hazard” location for major popular recreational activities such as fishing, swimming, tubing, kayaking, camping, and boating, and would have significantly reduced recreational usage by the public. State and area tourism authorities and city mayors were quick to point out that the Dan River was free of coal ash upstream of the spill, and encouraged the public to use those areas in an attempt to stem the evident reduction in tourism and recreational usage (e.g., Braun, 2014; Mollerus, 2014; Visit-NC, 2014; Wilson, 2014). This publicity effort apparently worked, as recreational use of upstream locations was relatively unaffected (e.g., Jeannot, 2014).

There is historically a very high public usage of the Dan River in what is now the spill zone for recreation and consumptive uses, resulting in hundreds of thousands of public use days per month during peak seasons along the 70 mile stretch of river (DRBA, 2014). Any restriction or impairment of this usage constitutes a significant negative cost impact to the local economy and prevents public enjoyment of a wide variety of popular outdoor activities. Although NCDHHS recommended lifting the Recreational Water Advisory on

Table 1
Estimated recreational losses on the Dan River from Eden, North Carolina to Kerr Reservoir, Virginia due to the February 2 spill of coal ash from Duke Energy's Dan river plant.

Time period	Total recreator/Angler days lost[a]
February 2–28	9550
March 1–31	15,200
April 1–30	22,600
May 1–24	23,900
May 25–31	36,500
June 1–30	28,800
July 1–7	49,200
July 8–31	24,300
Total	210,050

[a] Estimated as 30% of total usage for fishing, swimming, tubing, canoeing, kayaking, camping, hiking, and boating.

July 22, it recommended that the Fish and Shellfish Consumption Advisory remain in place (NCDHHS, 2014b). Thus, at the time of this assessment, there has been 6 months of negative recreational and consumptive use impact on the Dan River, which encompassed perhaps the two heaviest usage periods for the river – the Memorial Day holiday week in May and the July 4th Independence Day holiday week. Negative impacts downstream of the spill were noted in February and continued in May and July, while upstream impacts were far less pronounced (Table 1, Catanoso, 2014a; Visit-NC, 2014; Smith, 2014).

Another significant negative recreational impact occurred because a popular city park on the river at Danville, VA was closed by Duke Energy from mid-May through late July and used as a staging area for dredging operations to remove about 2500 tons of ash from behind Schoolfield Dam. This closure spanned both the Memorial Day and Independence Day holiday weeks – two of the peak public usage periods for camping, boating, swimming, and hiking (GoDanRiver, 2014).

Recreational costs were calculated using a flat rate of $150 per recreator/angler day lost, averaged from literature reported values that range from $100–250 per day, depending on location (Lemly and Skorupa, 2012a, 2012b). Lost recreator/angler days were determined using accounts of past usage levels (pre-pollution) that included the Memorial Day and July 4th Holidays (DRBA, 2014). The days lost was estimated to be 30% of usage because not all recreation stopped on the Dan River despite the warnings issued by NCDHHS and closure of Abreu-Grogan Park due to dredging by Duke Energy. This should contribute to a conservative damage cost calculation for recreational impacts. Because the spill occurred in early February, recreational use would have been relatively low at that time due to cold weather, but would have ramped up substantially in April and peaked over the Memorial Day and July 4th holiday weeks.

The total 6 month damage cost of recreational impacts is calculated as $150 × 210,050 = $31,507,500.

5. Damage element three – human health and consumptive use

The hazard of coal ash to human health from eating contaminated fish or shellfish is clear from the consumption advisory for the Dan River issued by NCDHHS (NCDHHS 2014a). The hazard to human health from coal ash pollutants through direct contact with water is evident from the NCDHHS Recreational Water Advisory (NCDHHS 2014a). The damage cost from water contact is mostly captured in the lost recreational usage figure given above, as it includes those activities which would expose humans to direct exposure and accidental ingestion (fishing, swimming, canoeing, kayaking, etc.). However, that number is conservative because only 30% of total usage days were used for the calculation. Nevertheless, no additional cost will be applied here or calculated in this Damage Element for direct water contact.

Consumptive used damage costs reflect the value of uneaten fish and shellfish that would have been consumed, but were not due to lost angler days, contaminated animals, and consumption restriction advisories. The costs associated with animals containing a hazardous concentration of pollutants and resultant consumption restriction advisories cannot be calculated at this time because no tissue analysis results have been posted by USEPA, NCDENR, or VDEQ. Therefore, the consumptive use cost is incomplete. A partial damage valuation can be determined by estimating the lost angler days and multiplying that number times the value of one fish/shellfish meal per day, assuming one fish/shellfish meal is captured per day for the "fishing trip" at a value of $7.50 per meal (Lemly and Skorupa, 2012a, 2012b). The number of lost angler days is estimated by applying a percentage, that is, angler use comprises approximately 80% of total usage during "cold months" (November–March) and 30% of total usage during "warm months" (April–October). A seasonal differential in relative usage is well known for the Dan River (DRBA, 2014; Visit-NC, 2014; Wilson, 2014).

Applying these percentages to the numbers in Table 1 yields the following: lost angler days = 7640 for February, 12,160 for March, 6780 for April, 18,120 for May, 8640 for June, and 22,050 for July. This totals 75,390 lost angler days, and 75,390 meals at $7.50 per meal = $565,425.

Additional health costs were added to account for the stress and anxiety of knowing the river ecosystem is polluted, fish and wildlife are poisoned, and public health is threatened. This procedure uses the "willingness to pay" formula set out by Corrigan et al. (2007). It assumes that 20% of the population living within 30 miles of the polluted site experiences such effects and that they are valued at $100 per individual. A perimeter distance of 30 miles and a response percentage of 20% is overly conservative for the Dan River spill because an intense negative response and outcry by as much as 90% of the public reverberated for at least 100 miles (to Raleigh, NC, Richmond, VA, Blacksburg, VA, and Hickory NC; e.g., Catanoso, 2014b; Sbraccia, 2014; Wireback, 2014) and was captured by national media (e.g., Zucchino, 2014). Therefore, a distance of 50 miles is used here as the response perimeter and 50% is used as the affected percentage. DRBA (2014) states that there are approximately 1.5 million people living within a 1-h drive of the river, which is typically about 50 miles on rural highways. Half this amount, or 750,000 × $100 = $75,000,000 in health damage cost.

Total 6-month damage cost for health and consumptive use = $75,565,425.

6. Damage element four – property damage and real estate values

The damage cost of coal ash spills on property values can be assessed through comparative market valuations before and after spill events, and by realtor comparisons of market prices of "equivalent properties" for waterfront parcels or acreages in a spill zone versus reference locations. This has not been done yet along the Dan River. The results of such an investigation would be valuable and essential for compiling a complete long-term cost determination of the Dan River spill. Property devaluation from water pollution is a gradual process that follows the progression of information on the extent and severity of a pollution event and news of how long the pollution is expected to persist. It may take some time for the market to reflect what is coming to pass on the Dan River. However, given that 6 months have elapsed since the coal ash spill, and news coverage has been extensive, knowledge of the issue by those in the real estate market (both buyers and sellers) should be considerable. Therefore, it is reasonable to expect that a market analysis by realtors involved in selling land and homes along the Dan River would reveal important trends in relative pricing and values of waterfront river properties.

7. Damage element five – esthetic values

Esthetic valuation is an important part of the damage cost of pollution impacts on the aquatic environment. It does not directly

measure habitat degradation, poisoned animals, or human health effects. Rather, it captures the essence of the inherent value of a healthy ecosystem and what it means to the "greater good" of a healthy environment to our society and our planet. Esthetic values were given a high priority in a recent report used in support of efforts to designate the Dan River as a Virginia Scenic River (Pittsylvania County, 2012). The Dan River coal ash spill has sparked intense public outcry and coalesced a very strong esthetic value response at the local, state, and regional levels (e.g., Catanoso, 2014b; Sbraccia, 2014; Wireback, 2014). Consequently, negative impacts on esthetic perceptions are a key component of damage costs resulting from the pollution event of February 2nd. The basis for calculating esthetic values is the same as for stress and anxiety impacts in Damage Element Three, that is, by applying a "willingness to pay" formula (Corrigan et al., 2007) to measure the intrinsic value to non-sportsmen/recreators assuming that 20% of the population living within 30 miles of the polluted site believe degradation of individual non-use values equals $100 or more for scenic and posterity considerations. The strength and intensity of response to the Dan River spill justifies using modified parameters (50 miles and 50%), the same as was done for human health. This results in the following calculation: 750,000 people × $100 = $75,000,000 for 6 month damage cost for esthetic value.

8. Conclusions

A 6-month damage cost analysis for the Dan River coal ash spill breaks down as follows: Ecological Impacts = $113,412,000; Recreational Impacts = $31,507,500; Human Health and Consumptive Use = $75,565,500; Property Damage and Real Estate Values = Not Calculated; Esthetic Values = $75,000,000. The grand total 6-month damage cost is $295,485,000. This total will likely increase substantially as additional information on poisoning and chemical contamination of fish and wildlife becomes available as well as long-term impacts on public health, recreational use, and property values. Dan River now becomes Case 24 in the long history of major environmental pollution episodes caused by surface impounded coal ash, dating back to 1967, and costing over $3 billion in damage based on scientific investigation of less than 5% of those impoundments (Lemly and Skorupa, 2012a; Lemly, 2014a). In North Carolina alone, the total damage cost from coal ash stands at $1,989,673,417 after study of only 5 of 14 Duke Energy power plant sites. The multiple components of damage and high cost of the Dan River spill illustrate the pressing need to discontinue surface impoundment disposal of coal ash – the environmental and economic impacts are far too great. It is clearly evident from the history of lax coal ash management and regulatory control policies in North Carolina and other states, the USEPA needs to issue and enforce rigorous national regulations that phase out and eliminate existing coal ash impoundments and prevent construction of new ones (Lemly, 2014b). No surface coal ash impoundments means no disastrous spills like the Dan River. The opportunity for USEPA to act prudently and effectively is upon us – a regulatory decision from that agency is due this December. The NC State Legislature recently enacted a law that attempts to address pollution issues at 33 Duke Energy coal ash ponds in NC (McGuireWoods, 2014). It proposes removal and lined-landfilling of the ash from a small percentage of ponds (4 of 33), while also including the option of leaving ash in-place at the other 29 ponds. Although this law is viewed by some as a landmark step for other states to follow, in my opinion, it only addresses the tip of the iceburg in that it does not require comprehensive ecological assessment and environmental remediation at all sites, which have been shown and acknowledged by the State of NC to be polluting groundwater and/or surface waters of the State for years (Western North Carolina Alliance, 2013).

References

Arcadis, 2012. Kingston Ash Recovery Project Non-time Critical Removal Action River System – Baseline Ecological Risk Assessment (BERA). Document Number EPA-AO-050. Available on the Internet at: http://www.epakingstontva.com/Phase%203%20Documents/BERA/Appendix%20I%20BERA/App%20I%20BERA.pdf.

Braun, A.D., February 21, 2014. Rockingham officials encourage tourism despite Dan River spill. Triad Bus. J. Available on the Internet at: http://www.bizjournals.com/triad/blog/morning-edition/2014/02/rockingham-officials-encourage-tourism.html.

Carriker, N.E., Young, S., Baker, T.F., Stack, M., Jones, D., Cagley, A.M., 2013. A Long-term Monitoring Plan for the Kingston Ash Spill. Tennessee Valley Authority Report. Available on the Internet at: http://www.flyash.info/2013/167-Carriker-2013.pdf.

Catanoso, J., 2014a. Jobs Go First, Then Recreation? Duke Energy's N.C. Coal Ash Spill Spoils the Garden in Eden. National Geographic News Watch. February 24, 2014. Available on the Internet at: http://newswatch.nationalgeographic.com/2014/02/24/jobs-go-first-then-recreation-duke-energys-n-c-coal-ash-spill-spoils-the-garden-in-eden/.

Catanoso, J., 2014b. Public Outcry over Duke Energy Coal Ash Spill Puts Pressure on NC Regulators. National Public Radio. March 5, 2014. Available on the Internet at: http://wfdd.org/post/public-outcry-over-duke-energy-coal-ash-spill-puts-pressure-nc-regulators.

Corrigan, J.R., Egan, K., Downing, J., 2007. Aesthetic values of lakes and rivers. In: Likens, G.E. (Ed.), Encyclopedia of Inland Waters. Academic Press.

Coyle, C., 2014. Dead Mussels, Clams Piling up Downstream of Dan River Coal Ash Spill. Fox 8 News. Available on the Internet at: http://myfox8.com/2014/03/05/dead-mussels-clams-piling-up-downstream-of-dan-river-coal-ash-spill/.

Daily Kos, 2014. Bed of Dan River is Poisoned by Coal Ash for 70 Miles: Turtles Emerging and Dying. Daily Kos. Available on the Internet at: http://www.dailykos.com/story/2014/02/19/1278762/-Bed-of-Dan-River-is-Poisoned-by-CoalAsh-for-70-Miles-Turtles-Emerging-Dying#.

DRBA (Dan River Basin Association), 2014. Internet website. http://www.danriver.org/.

Duke Energy, 2014. Dan River Response. Duke Energy. Available on the Internet at: http://www.duke-energy.com/dan-river/.

GoDanRiver, 2014. Danville park Reopens after Coal ash Clean-up. Available on the Internet at: http://www.godanriver.com/news/coal-ash/danville-park-reopens-after-coal-ash-clean-up/article_8d5098f4-18e6-11e4-a606-001a4bcf6878.html.

Jeannot, D., June 25, 2014. Tourism is up for the Dan River. WXII News. Available on the Internet at: http://www.wxii12.com/news/local-news/piedmont/Tourism-is-up-for-the-Dan-River/26663792.

Jones, J.W., Patterson, M.A., Good, C.R., DiVittorio, A., Neves, R.J., 2000. A Survey to Evaluate the Status of Freshwater Mussel Populations in the Upper Clinch River, Virginia. Final Report to U.S.. Fish and Wildlife Service, Abingdon, VA.

King, D., 1998. The dollar value of wetlands. Natl. Wetl. Newsl. 20, 7–11. Available on the Internet at: http://kingeconomics.com/pubs/King%20Value%20of%20Wetlands%20paper.pdf.

Kopp, R.J., Smith, V.K., 1993. Valuing Natural Assets: the Economics of Natural Resource Damage Assessment. Resources for the Future, Washington, DC.

Lee, D.S., Platania, S.P., Burgess, G.H., 1980. Atlas of North American Freshwater Fishes. North Carolina Biological Survey, Raleigh, NC.

Lemly, A.D., 1993. Guidelines for evaluating selenium data from aquatic monitoring and assessment studies. Environ. Monit. Assess. 28, 83–100.

Lemly, A.D., 2002. Selenium Assessment in Aquatic Ecosystems: a Guide for Hazard Evaluation and Water Quality Criteria. Springer-Verlag, New York.

Lemly, A.D., Skorupa, J.P., 2012a. Wildlife and the coal waste policy debate: proposed rules for coal waste disposal ignore lessons from 45 years of wildlife poisoning. Environ. Sci. Technol. 46, 8595–8600. Available on the Internet at: http://pubs.acs.org.

Lemly, A.D., Skorupa, J.P., 2012b. Environmental Damage from Coal Combustion Waste in the US: the Cost of Poisoned Fish and Wildlife. Supporting Information Document for Lemly and Skorupa 2012a, available on the Internet at: http://pubs.acs.org.

Lemly, A.D., 2014a. Teratogenic effects and monetary cost of selenium poisoning of fish in Lake Sutton, North Carolina. Ecotoxicol. Environ. Saf. 104, 160–167.

Lemly, A.D., 2014b. An urgent need for an EPA standard for disposal of coal ash. Environ. Pollut. 191, 253–255.

McGuireWoods, 2014. North Carolina's First-in-the-Nation Coal Ash Law Takes Effect. September 22. Available on the Internet at: http://www.mcguirewoods.com/Client-Resources/Alerts/2014/9/North-Carolinas-First-in-the-Nation-Coal-Ash-Law.aspxr22.

Menhinick, E.F., 1991. The Freshwater Fishes of North Carolina. Larkin Publishers and Distributors, New York.

Mollerus, M., 2014. NC Tourism Season Launches at Dan River: Is it Sanitary? WFMYnews 2. May 20. Available on the Internet at: http://www.wfmynews2.com/story/news/local/good-morning-show/2014/05/20/north-carolina-tourism-season-launches-at-dan-river-after-duke-energy-spill/9316523/.

NCAC (North Carolina Administrative Code), 1993. Replacement Cost of Wildlife Resources – Fish, 15A NCAC 10C . 0215. Available on the Internet at: http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environment%20and%20natural%20resources/chapter%2010%20-%20wildlife%20resources%20and%20water%20safety/subchapter%20c/15a%20ncac%2010c%20.0215.pdf.

NCDENR (North Carolina Department of Environment and Natural Resources), 2014. Dan River Coal Ash Spill. Available on the Internet at: http://portal.ncdenr.org/web/guest/dan-river-spill.

NCDHHS (North Carolina Department of Health and Human Services), 2014a. DHHS Issues Health Advisories for Dan River Area. Available on the Internet at: http://www.ncdhhs.gov/pressrel/2014/2014-02-12_dan_river_spill.htm.

NCDHHS (North Carolina Department of Health and Human Services), 2014b. DHHS Revises Health Advisories for the Dan River Area. Available on the Internet at: http://www.ncdhhs.gov/pressrel/2014/2014-07-22_revised_dan_river.htm.

NOAA (National Oceanic and Atmospheric Administration), 2001. Endangered Species Act Penalty Schedule. Available on the Internet at: http://www.gc.noaa.gov/schedules/6-ESA/EnadangeredSpeciesAct.pdf.

NOAA (National Oceanic and Atmospheric Administration), 2013. Draft Damage Assessment and Restoration Plan/Environmental Assessment – Tank Barge DBL 152 Oil Spill. Available on the Internet at: http://www.darrp.noaa.gov/southeast/dbl152/pdf/2404 DBL_152_DRAFT_DARP_EA 3_18_13 (final http://www.darrp.noaa.gov/southeast/dbl152/pdf/2404%20DBL_152_DRAFT_DARP_EA%203_18_13%20(final).pdf.

Pittsylvania County, 2012. Dan Scenic River Report. Available on the Internet at: http://www.dcr.virginia.gov/recreational_planning/documents/srreportdan.pdf.

Ruhl, L., Vengosh, A., Dwyer, G.S., Hsu-Kim, H., Deonarine, A., 2010. Environmental impacts of the coal ash spill in Kingston, Tennessee: an 18 month survey. Environ. Sci. Technol. 44, 9272–9278. Available on the Internet at: http://pubs.acs.org.

Sbraccia, S., March 19, 2014. Poll: 90% of Voters Aware of Dan River Coal Ash Spill. WCNC News. Available on the Internet at: http://www.wncn.com/story/24896401/poll-90-of-voters-aware-dan-river-coal-ash-spill.

Smith, D., 2014. Dan River Coal Spill and Cleanup Not Slowing River Activity. Available on the Internet at: http://www.wfmynews2.com/story/news/local/2014/07/05/dan-river-july-2014/12258777/.

Tuberty, S., 2009. Preliminary Summary Report From Water, Sediment, and Fish Samples Collected at the TVA Ash Spill by Appalachian State University, Appalachian Voices, Tennessee Aquarium, and Wake Forest University. Available on the Internet at: http://appvoices.org/resources/AppVoices_TVA_Ash_Spill_Report_May15.pdf.

USEPA (United States Environmental Protection Agency), 2014. EPA Response to Release of Coal Ash into the Dan River. Available on the Internet at: http://epa.gov/region4/duke-energy/index.html.

USEPA (United States Environmental Protection Agency), 2007. Aquatic Life Criteria – Copper. 2007 Update. Available on the Internet at: http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/copper/index.cfm.

USFWS (United States Fish and Wildlife Service), 2014. U.S. Fish and Wildlife Service Continuing to Help in Dan River Coal Ash Spill. News Release – Southeast Region. Available on the Internet at: http://www.fws.gov/southeast/news/2014/012.html.

VDEQ (Virginia Department of Environmental Quality), 2014. Dan River Coal Ash Spill. Internet website available at http://www.deq.virginia.gov/ConnectWithDEQ/EnvironmentalInformation/DanRiverCoalAshSpill.aspx.

Visit-NC, 2014. Tourism Kickoff Highlights Safe Areas to Enjoy the Dan River. Available on the Internet at: http://visit-nc.com/tourism-kickoff-highlights-safe-areas-to-enjoy-the-dan-river/.

Ward, J., March 19, 2014. Government Biologists Uncertain about Coal Ash Effects on Dan River Marine Life. WDBJ7 News. Available on the Internet at: http://www.wdbj7.com/news/local/government-biologists-uncertain-about-coal-ash-effects-on-dan-river-marine-life/25059980.

Waterkeeper Alliance, 2014. Duke Energy Responsible for Third Worst Coal Spill in US History. Available on the Internet at: http://waterkeeper.org/2014/02/04/third-worst-coal-spill-in-us-history/.

Western North Carolina Alliance, 2013. Groups in Court to Stop Groundwater Contamination from Toxic Coal Ash Waste. January 8. Available on the Internet at: http://wnca.org/groups-in-court-to-stop-groundwater-contamination-from-toxic-coal-ash-waste/.

Wilson, J., May 21, 2014. N.C. Tourism officials: don't let coal ash fears keep you off the Dan River. Charlotte Bus. J. Available on the Internet at: http://www.bizjournals.com/charlotte/news/2014/05/21/n-c-tourism-officials-dont-let-coal-ash-fears-keep.html.

Wireback, T., March 25, 2014. Poll Finds Voters Worried by Coal Ash, Dan River Spill. Greensboro News-Record. Available on the Internet at: http://www.news-record.com/news/article_a033d77c-b43e-11e3-a726-0017a43b2370.html.

Zucchino, D., March 3, 2014. Duke Energy Receives 5 More Citations Weeks after Coal Ash Spill. Los Angeles Times. Available on the Internet at: http://articles.latimes.com/2014/mar/03/nation/la-na-nn-nc-coal-ash-spill-20140303.