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Article

Putting Corporate Social Responsibility to Work in Mining Communities: Exploring Community Needs for Central Appalachian Wastewater Treatment

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Abstract: Due to the finite nature of non-renewable mineral and energy resources such as coal, resource extraction is inherently unsustainable; however, mining and related activities can contribute to sustainable development. Indeed, the principles of corporate social responsibility (CSR) require that mine operators design and conduct their activities in ways that provide for net positive impacts on surrounding communities and environments. In Central Appalachia, there appears to be a particularly ripe opportunity for the coal industry to put CSR to work: participation in sustainable solutions to the long-standing problem of inadequately treated wastewater discharges—which not only represent a potential human health hazard, but also contribute to the relatively high incidence of bacterial impairments in surface waters in the region. In this paper, we outline the underlying factors of this problem and the advantages of industry-aided solutions in a region where limited economic and technical resources are not always aligned with social and environmental needs. We also suggest a framework for problem-solving, which necessarily involves all interested stakeholders, and identify the primary challenges that must be overcome in pursuit of sustainable solutions.

Keywords: mining; water quality; sustainable development; human health; socio-environmental justice; bacterial contamination

1. Introduction

Sustainable development was formally defined by the Brundtland Commission in 1987 as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" and has since taken on subtly different meanings in different contexts. In fact, since this ground-breaking inception, the term has come to encapsulate many different meanings to different stakeholder groups; some more complete than the original, and some more convoluted [1]. To many, sustainable development is a balancing act; it attempts to provide benefits to society without adversely impacting the environment or economy [2]. In the business sense, "Corporate Social Responsibility" (CSR) pertains to a commitment to corporate action that results in net positive impacts in realms outside of those focused on purely financial drivers for the corporation, e.g., social, socio-economic and socio-environmental development. Importantly, both sustainable development and CSR suggest that industry members have an obligation to respect and contribute to the communities in which they operate. For the mining industry, this expectation has become particularly clear in recent decades as global attitudes towards mineral extraction have shifted. Local communities, the public at large, government entities, and investors are demanding transparency, accountability, and a measurable commitment to best practices and continuous improvement [3,4].

To meet these demands and ensure that mining projects are better aligned with the principles of sustainable development, the past two decades have seen significant efforts to produce guidance and tools for mine operators, as highlighted by the work products of a number of international organizations such as the Global Mining Institute (a meeting of global mining companies in 1998) and the International Council on Mining and Metals (founded in 2001). Many of these efforts have focused specifically on the aim of ensuring that resource projects are developed in a manner consistent with gaining and maintaining a *social license* to do business, which necessarily hinges on stakeholder engagement and education, particularly within local communities, and industry commitment to transparency in information exchange and timely conflict resolution [4]. The Mining, Minerals and Sustainable Development (MMSD) Project. identified the most significant challenges faced by the global mining industry [5], and its North American branch then used those challenges as guideposts to develop a framework for the assessment of mining projects within the context of sustainable development. The MMSD was created via a collaboration of the World Business Council for Sustainable Development and the International Institute for Environment and Development and is largely funded by a mixture of government organizations, international agencies, private foundations, and corporate donors. In the report *Seven Questions to Sustainability: How to Assess the Contribution of Mining and Minerals Activities*, a framework is provided to evaluate, and ultimately enhance, contributions of current and proposed projects across local to global scales, using seven broad guiding questions provided in Table 1 [6]. Affirmative responses to any of the questions may signal positive contributions of CSR activities, though those associated with "people," "environment", and "traditional and non-market activities" are likely to be the most tangible.

Table 1. The Seven Questions to Sustainability [7].

Question Category	Issue Addressed
Engagement	Are engagement processes in place and working effectively?
People	Will people's well-being be maintained or improved?
Environment	Is the integrity of the environment assured over the long term?
Economy	Is the economic viability of the project or operation assured, and will the economy of the community and beyond be better off as a result?
Traditional and Non-Market Activities	Are traditional and non-market activities in the community and surrounding area accounted for in a way that is acceptable to the local people?
Institutional Arrangements and Governance	Are rules, incentives, programs and capacities in place to address project or operational consequences?
Synthesis and Continued Learning	Does a full synthesis show that the net result will be positive or negative in the long term, and will there be periodic reassessments?

Efforts to implement sustainable development practices by mining companies have achieved varying levels of success and impact; scale and corporate motives and commitment often play a part in defining ultimate outcomes. While CSR is frequently a part of national discussion of resource extraction practices in developed countries like Canada [8] and Australia [9], the concept of CSR is gaining traction in developing countries across Africa [10] and South America [11] as well. Past or ongoing examples are available from all corners of the globe, with deliberate corporate interventions ranging from small infrastructure projects, to environmental improvement and management efforts [12], to specific high-priority community health-related projects [13,14], to full-scale community development [15,16] or even attempts toward conflict resolution in war-torn nations such as Angola [17]. Regardless of scale and the particular community or environmental need addressed, one parallel between all success stories is a strong commitment to community engagement and at least some degree of social license. Genuine community engagement requires open, honest and regular communication with stakeholders in order to gain an appreciation and understanding of local needs and problems—and also involvement of local people in the development and implementation of community-approved solutions.

In this vein, calls for more inclusive approaches to decision-making and problem solving have been tendered with emphasis on meaningful public participation in questions of ecosystem valuation, post-mining land use, and community development [18] in Central Appalachia. To address community problems, environmental and sociological characteristics must be defined, which will allow the specific needs of regional communities to be outlined. By necessity, this includes a determination of stakeholders and their relationships to each other. Finally, the available resources in the region have to be identified and aligned towards desired solutions to community issues. Using this crucial suite of information, solutions can be pursued within a framework of sustainable development. The goal of this paper is to explore the processes by which sustainable development and CSR principles could potentially lead to resolutions to a common community and environmental problem in Central Appalachia: inadequate residential wastewater treatment and associated impacts on water resources. The issue of inadequately treated sewage discharges in Central Appalachia is a complex one. In highly developed nations, basic sanitation problems are somewhat surprising, and indeed publicly available information in citable documents is scarce. Over several years of dialogue with local residents, public health officials, regulators, and industry representatives, we have gained evidence that sewage discharges are more than an anecdotal concern of a diverse group of stakeholders in this region. In reality, the scope and challenges associated with solutions represent a complicated interplay of history, politics, and economics that make the problem perhaps even more complex than in developing countries. The goal of this paper is not to highlight specific cases of sewage discharges in Central Appalachia, but rather to broadly discuss the issue within the context of CSR and to present a common-sense approach to finding mutually beneficial solutions where regional stakeholders can cooperate and coordinate efficient use of limited available resources. Within this context, this discussion aims to add to the global dialogue on the critical nature of public-private partnerships in sustainable development.

2. Mining CSR in Central Appalachia

2.1. Unique Opportunities for Community Solutions

Appalachia broadly refers to a cultural region in the eastern U.S. (US) which the Appalachian Regional Commission (ARC) geographically defines to include 420 counties in thirteen states ranging from New York in the north to Alabama and Mississippi in the south [19]. The "Central" Appalachian region, which generally includes Kentucky, Maryland, Ohio, Pennsylvania, Virginia, and West Virginia (Figure 1) accounts for the majority of the fossil energy production (*i.e.*, coal and natural gas) in greater Appalachia, and is currently at the center of several debates on related issues of environmental and social justice [20,21]. In many ways Appalachia is a historical microcosm of the United States throughout its turbulent history; Appalachia has struggled with inequality between established residents and migrant workers, it was divided during the American Civil War, and it was the first region of the U.S. to struggle with deindustrialization. Given its long history of conflict and the widespread natural resource extraction activities in this region, issues related to coal mining can be particularly controversial and emotional for various regional stakeholders. In general, coal operators and related corporations in Central Appalachia tend to be U.S.-based, while the broader U.S. coal industry includes some multinational corporations such as BHP Billiton and Rio Tinto [22].

Although the Central Appalachian region consists of many areas with significant natural resources in the form of coal and natural gas, economic growth in these communities generally lags behind the national average and has for decades. In fact, a unique federal agency called the Appalachian Regional Commission was created by an act of Congress in 1965 and has sought to stimulate the economy in the region since that time. The most recent economic report on the region published by the ARC indicated that Central Appalachia significantly trailed the national average in terms of employment, personal income, income per capita, investment income, and proprietor average income [23]. As detailed by Glasmeier and Farrigan [24], billions of investment dollars by the federal government over several decades have not succeeded in lifting all isolated communities of Central Appalachia out of poverty. A significant reason for the apparent disparity between resource richness and economic depression is often that the land where the wealth of resources is located is owned by outside parties. These entities then lease the land to mining and gas operators who then remove the resources for profit. Jobs in this region are strongly linked to natural resource extraction industries and are heavily influenced by state and national energy policies. These links make the job market in Central Appalachia an entity constantly in flux [24]. Regardless, resource extraction remains a mainstay of the regional economy with more than one third of US coal production occurring in Central Appalachia, employing over 60,000 people in the larger Appalachian region [22].

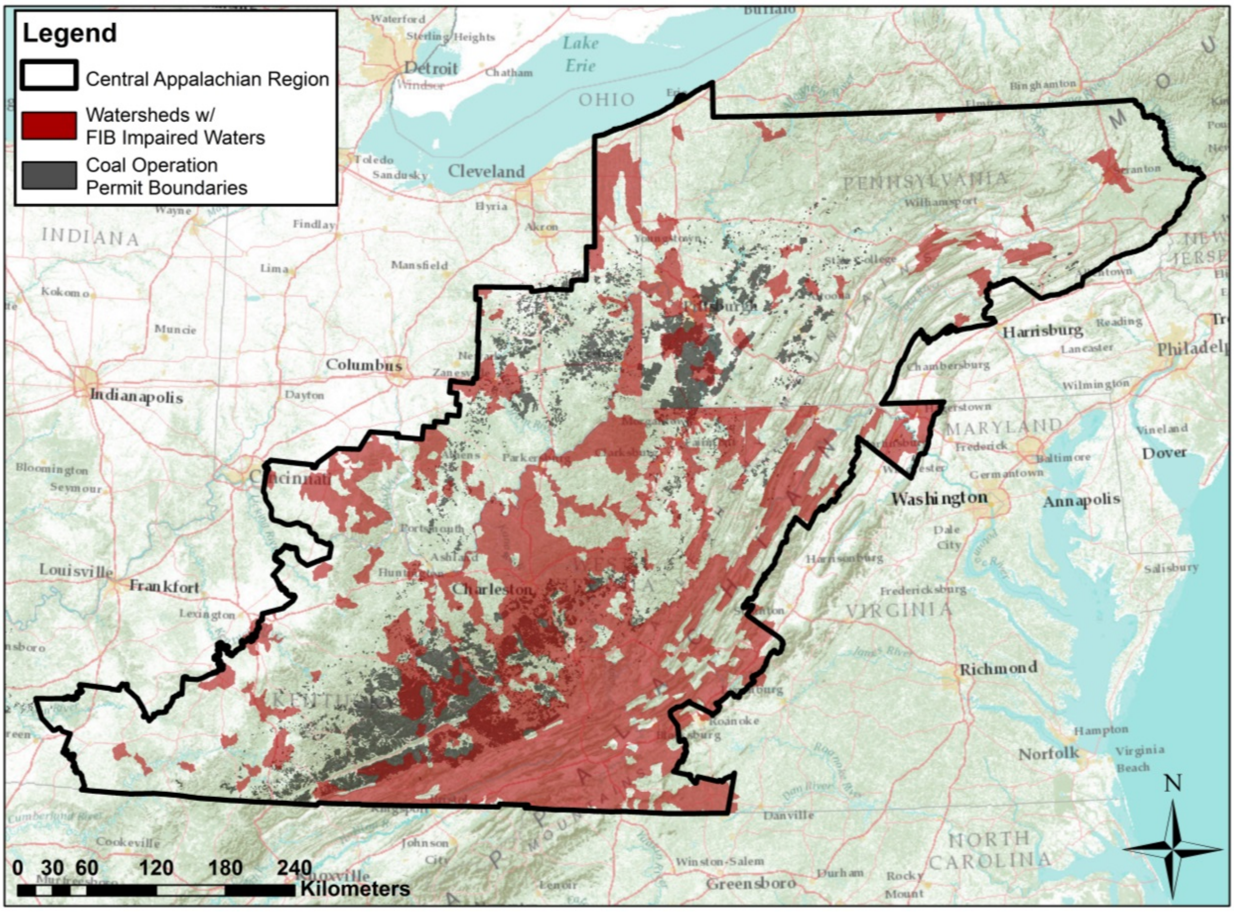

Figure 1. Central Appalachian Region Political Boundaries and Mining Extents (including historical mining extents, current permit boundaries, refuse sites, and valley fills in grey) and FIB-impacted watershed areas. (Data collected from Pennsylvania Spatial Data Access, Ohio Geographic Information Management Systems, West Virginia Department of Environmental Protection, Virginia DMME, and the Kentucky Geological Survey).

In some states, the total area impacted by past and present coal mining operations is extensive, with current estimates indicating that over 30,000 km^2 have been disturbed at some point in Central Appalachia alone. Figure 1 provides the regional boundaries overlaid with a compilation of mining activity extents (*i.e.*, permit boundaries, refuse sites, and valley fills), illustrating the significant geographic influence of the mining industry. However, as a consequence of this expansive presence (along with its temporal stability as both an economic player and community member), the mining industry is also a potentially important contributor of both financial and technical resources when addressing local sustainability issues. Employees of local coal mine operations are often local citizens with intimate knowledge of community social groups and attitudes, as well as local concerns. Thus, it could be argued that the mining industry may be a significant agent for change in a region that is undoubtedly in need of new models and drivers for sustainable growth and development.

Many examples of industry support for general infrastructure improvements exist globally; sustainable development and CSR approaches allow the mining industry to contribute to specific community issues such as provision of clean drinking water [14], healthcare [13], and economic development coupled with environmental and cultural preservation [12]. In larger-scale efforts, CSR contributions become synonymous with full-scale community development, and mining operations actually lead efforts to build roads, provide electricity, and install basic sewer and water service in local regions [15,25]. For the purposes of this discussion, sewerage and sewer service are synonymous, while sewage, refers to the actual household waste itself. Beyond the benefits these efforts provide in opportunities for building public-private partnerships, acquiring and maintaining social license, and improving the standard of living for whole communities, they can also be a form of political risk management in conflict-prone regions of the world when successful [17].

In particular regions of the United States, similar dynamics relative to these international examples are common. Without a strong centralized municipality or tax base, infrastructure needs often outpace local funding. In Central Appalachia and other rural areas (where mining operations are often located), infrastructure maintenance is in some cases shifting from a centralized municipality-driven paradigm to a county-wide effort [26] with an emphasis on public-private partnerships or corporate dollars as a partial funding source. In West Virginia, there is a state-mandated process whereby a coal severance tax provides funding for county-level infrastructure maintenance [27]. Although a legal driver, not CSR, is behind these funds, it does demonstrate recognition of corporate responsibility to give back to the communities by state government. In more localized examples, large-scale sewer service improvements have been proposed in Nevada [28,29] and small-scale package plants have been installed in southwestern Virginia [30] via carefully orchestrated efforts between governmental organizations, private industry, NGOs, and community organizations. The case of sewerage in Central Appalachia is of particular concern because of potential related public and ecosystem health concerns.

2.2. The Specific Case of Bacterial Surface Water Impairments in Central Appalachia

Many communities in Central Appalachia have evolved from former "coal camps" in narrow mountain hollows along streams. This geographic isolation, coupled with the chronically depressed socio-economic status of the region, has resulted in an often underappreciated problem: lack of proper sewerage for household waste. Many of the rural counties in the area are comprised of isolated communities without a sufficiently large central municipality to organize widespread infrastructure efforts. Under such conditions, it is not surprising that centralized or advanced wastewater treatment systems are not always present or even plausible for all residences. While historical precedent (*i.e.*, the justification that "it's always been this way") or a lack of understanding regarding potential consequences may contribute to the prevalence of this deficiency, inadequate water and sanitation issues in the U.S. are often largely economic and/or political. These issues most often plague minority populations or economically distressed populations centered in poor urban areas or rural areas such as

Central Appalachia [31,32]. In many Central Appalachian communities, residents are aware of the problem but lack the resources to take any effective action.

In many cases in small rural Central Appalachian communities, septic tanks are installed in an attempt to treat sewage; however, soils in the region are notoriously thin and often inadequate for proper septic system functioning. Housing density within narrow "hollows" can also render appropriate siting of drain fields difficult. Even adequately installed septic systems can contaminate local water resources, since near-surface groundwater flows through karst geological strata and may interact with septic system drain fields [33,34]. In some cases, partially treated water from septic tanks or "grey water" (*i.e.*, water from residential activities like washing dishes) is discharged into trenches that run into streams. And in the worst-case scenario, no treatment approach exists at all and residential waste, including wastewater from toilets, is piped directly to a creek or stream—a practice known as "straight-piping".

The process of straight-piping may be one of many contributors to bacterial loadings of pathogen indicators (*E. coli*, fecal coliforms, and *enterococci*) in Central Appalachia, and in terms of immediate human health implications is likely the most concerning. Although generally non-pathogenic themselves, the presence of indicator organisms is associated with contamination by mammalian fecal material and exposure is linked to health risk [35]. Exposure to waters containing high concentrations of coliform or enterococci bacteria have been linked with an elevated risk of gastroenteritis, respiratory infections, and skin infections in humans [36]. In addition to the general health risks themselves, the exposure to waterborne illnesses is an economic stressor; hospitalization and out-patient care for these diseases cost over $800 million annually in the US, not including lost work time and productivity [37] Common sources of pathogen loadings to receiving waters include wastewater discharges (both from municipal treatment facilities and individual households), wildlife, domestic animals, and runoff from manure-amended agricultural soils [38,39]. Recent research has indicated that these impairments occur in mainly forested watersheds with low population densities (rural watersheds) and not much agriculture in Central Appalachia [40]. Because development is dense near stream beds, this fact seems to indicate that straight-piping may be a significant contaminant source in cases of bacterial impairment.

From a regulatory perspective, primary water quality concerns in Central Appalachia focus on the abundance and diversity of stream macro-invertebrates (the bottom of the macro-scale food chain in streams), which are often used as a proxy for the general degradation of stream ecology [41,42]. The assumption is that if the base of the food chain is healthy, the upper level organisms will also thrive. The RBPs also detail protocols for examining fish populations as well as periphyton (algae). This emphasis began in 1986 with an initial EPA study of surface water monitoring methods, which recommended a future emphasis on biological monitoring. In 1989 the Assessment and Watershed Protection Division of the EPA developed rapid bioassessment protocols (RBPs) designed to provide cost-effective biological data [43]. Today, several states have developed their own specific methods of RBP assessment as understanding of benthic ecology and water quality continues to evolve. It is critical to note that these assessments only determine the quality of the benthic communities present, and often require additional data to determine the causes of any observed impairment. While untreated residential discharges may certainly contribute to macro-invertebrate stress [44] as well as human health risks [35] and associated costs [37], they currently receive relatively little attention. As in other regions of the US, regulatory efforts are generally focused on large discharges (e.g., industrial, commercial and municipal point sources).

In Central Appalachia, a very significant number of those discharges are in close proximity to ongoing coal mining activities, which means that the mining industry has a significant role to play in regional water quality management. Clearly, mine operators are not directly contributing to bacterial loadings to receiving waters in this region, but their widespread presence and needs for water-related permits present a heretofore untapped opportunity for sustainable solutions. GIS data was collected from the states of Central Appalachia and analyzed via a formalized approach in a previous study [40] where stream impairment layers and coal mining permit boundaries were compared through spatial analysis. Figure 2 represents a purely illustrative example using data from the West Virginia Department of Environmental Protection (impaired streams) and the West Virginia Natural Resource Analysis Center (permit boundaries). Figure 2 shows FIB impairments in a specific area of West Virginia (in red) and different impact scenarios of mining industry participation in mitigation (in yellow) on a direct drainage level, a watershed level, and a community level (assuming a 10 and 25 km radius from a mine permit boundary to simulate community variability). Calculations associated with the specific area shown in Figure 2 indicate that roughly 11 km of stream could be addressed on a drainage basis, 52 km on the watershed basis, and almost 114 (10 km radius) to 620 (25 km radius) km on a "community" basis. Figure creation and calculations were based on analysis using ArcMap (ESRI Products, Redlands, CA, USA, www.esri.com). Stream mileage calculations were performed using GIS to determine the cumulative stream miles based on mitigation level. Direct-drainage and watershed level mitigation potential was calculated by summing impaired stream miles within the boundary of the permit area and watershed boundary, respectively. Community-level mitigation potential was calculated by creating 10 km and 25 km radii around the mining permit boundary in GIS and summing impaired stream miles within the potential sphere of influence. These calculations clearly assume that all impairments could be successfully addressed by some intervention involving mining operation participation. Based on a similar assumption, a previous study showed that throughout the Central Appalachian region, mining operations could at least attempt interventions for roughly 77% of all bacterial impairments [40].

While the example analysis above is hypothetical, though based on real water impairment and mine location data, it illustrates the magnitude of potential impacts that might be realized if the mining industry was incentivized to contribute to sustainable development of the region by improving human health and environmental quality. Historically, sustainable development has not been a direct aim of the mining industry, but globally the trend towards corporate social responsibility (CSR) and sustainable development has pushed the industry to consider new paradigms [4]. While application of these new paradigms may be less complicated in developing economies, opportunities in developed economies such as the U.S. should not be overlooked. It should be noted that CSR efforts toward infrastructure are likely to be much simpler in less complex regulatory environments such as those in still developing economies. Infrastructure implementation projects in developed economies are likely to be more costly and fraught with bureaucratic hurdles; however, these activities may be more necessary to earn the necessary support of local communities, broader public opinion, and regulatory officials charged with protecting the environmental quality of the region.

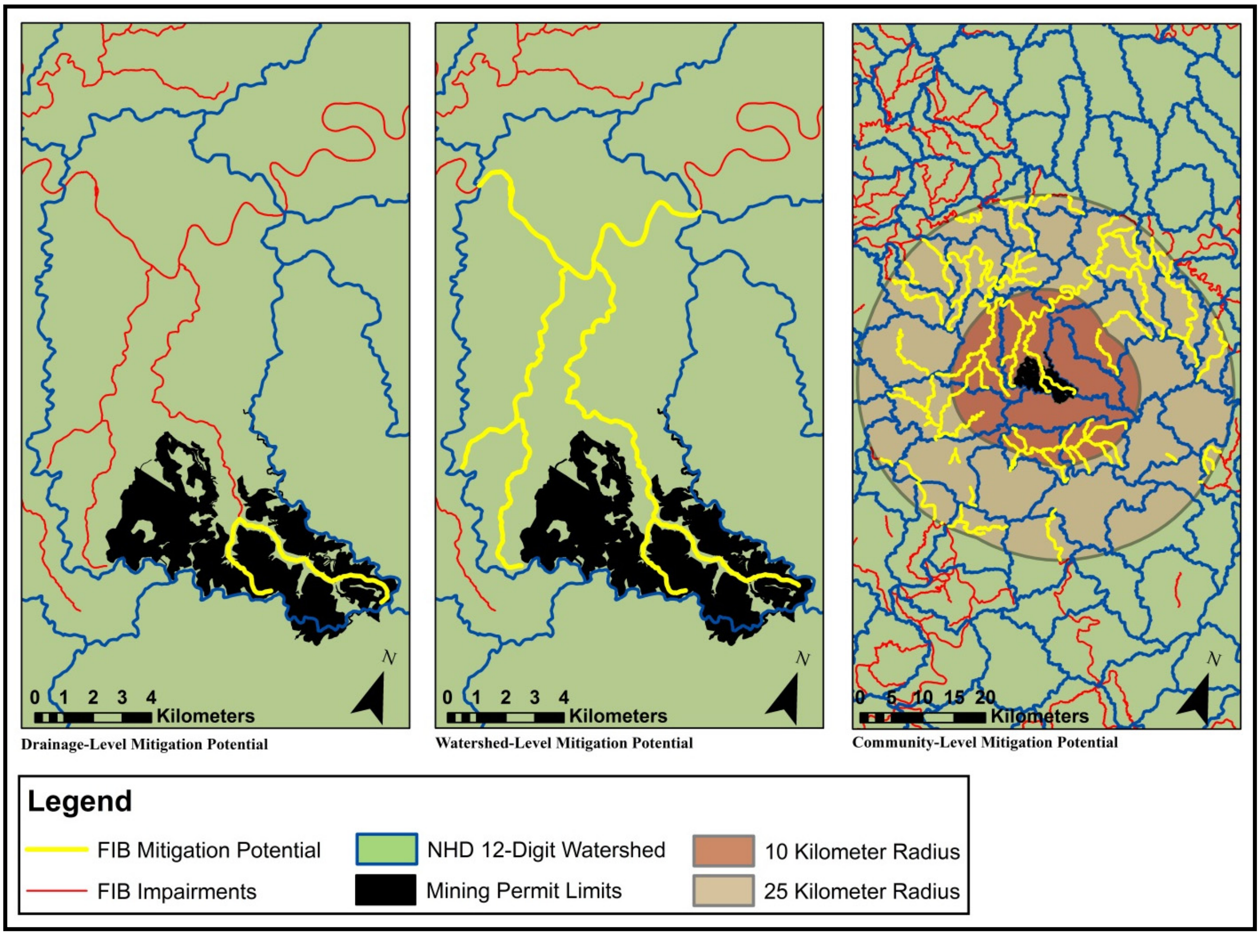

Figure 2. Permit, Watershed, and Community Level Mitigation Impacts from Mining Operations.

2.3. The Need for Resource Alignment

In Central Appalachia, opportunities do seem to exist for addressing some community issues like bacterial surface water impairments. By proceeding with a sustainable development-driven approach, mining operations can contribute to the maintenance of their social license to operate in the region. For the purposes of this discussion, "social license" is used synonymously with the term "license to operate," which refers to the permission granted by local community members to nearby coal operators to pursue resource extraction activities [3]. Social license can exist on two levels: the community social license, which represents those living in close proximity to resource extraction activities, and the public opinion social license, which refers to a national or global attitude towards resource extraction activities. The process of building this social license includes an inventory of resources, which requires all stakeholder groups in the community to evaluate their own potential contributions towards a broadly acceptable and mutually beneficial solution. Resource extraction in Central Appalachia is often controversial and can, along with the socio-economic characteristics of the region, lead to conflict or stalemate amongst varying stakeholder groups over perceived conflicting priorities. Aside from the mining industry and oppositional groups, other stakeholders of importance in the region include community residents, non-profit advocacy groups, federal and state regulatory agencies, public service organizations, and local governments. Using the sewerage issues in some areas of Central Appalachia as a hypothetical focus, each of these groups brings important resources to the table to address this problem, but no single group appears to have the necessary means to implement a long-term solution. The issue of sewage-related bacterial impairments in local water resources is an environmental health concern, and mine operators are already often the primary players in regional water quality management—*i.e.*, in terms of their legal obligations to receive and comply with permits.

With such complex social and political relationships in the region, a first step towards an analysis of sustainable solutions to bacterial impairments is to identify available resources. Figure 3 illustrates these stakeholder groups (derived from general literature review, interactions with local officials, and field experience), the obstacles that hinder them from implementing solutions and their "sustainability capital" (*i.e.*, the resources they bring to the table). In Figure 3, "community industries" refer to local natural resource extraction operators (whether it be coal, natural gas, or otherwise), while NGOs may refer to community based or nationally based NGOs. Similarly, regulatory agencies are comprised of multiple scales: local, state and federal regulatory agencies all hold sway on community-level activities. Social license is used here as defined above, while "funding" refers to the financial ability to pay the cost of infrastructure project realization from conceptual design phases through construction and maintenance stages "Scientific Community" represents researchers and academics who may contribute funding and expertise to projects through grants, field research, and laboratory analysis.

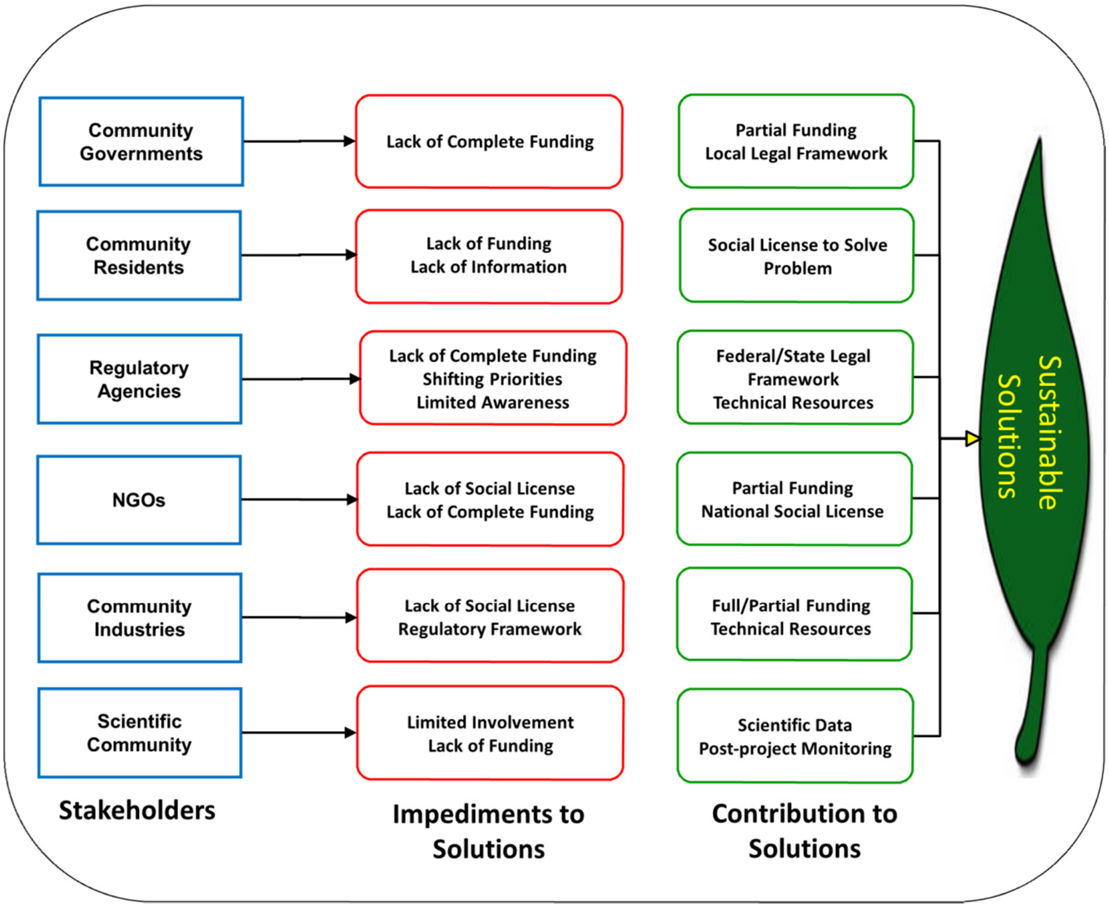

Figure 3. Stakeholders, Impediments, and Sustainability Capital in Central Appalachia.

One of the main resources necessary for implementing any solution, whatever it may be, is social license, financial resources, and a federal, state, and local legal framework that not only allows the mining industry to participate in problem-solving, but provides incentives such that participation is the most attractive option. Tangible incentives are particularly important because of the relatively large initial capital investment that is necessary for infrastructure improvements in these communities. Currently, legal language does exist that would allow mining operators to apply mitigation efforts to sewerage improvements or to pay in-lieu mitigations fees (fees in place of direct actions) in some cases. [45]. However, this alternate avenue is often only available when no other state or local government has "affirmative obligation" on which to act and sufficient ambient water quality monitoring exists to officially classify streams as impaired. In other words, if an agency such as a state EPA or local municipality have legal obligation to address impairments, it is difficult (if not impossible) for industries to contribute to solutions, even if governmental resources and/or motivation appears insufficient. Few permits have been approved using this type of broad mitigation planning, so industry-aided solutions to these sewerage issues continue to elude motivated stakeholder groups in local communities.

Although the process remains complex, Figure 3 suggests that the necessary components for developing and implementing solutions to sewerage issues in Central Appalachia do presently exist. It is worth noting, however, that within each of these very broadly defined stakeholder groups exist multiple sub-groups, some of which are in regular opposition or lack clear means of productive communication. Example issues illustrative of the complexity of stakeholder inter-relationships and potential burden of responsibility include:

- Stream impairments should be addressed by TMDL implementation in accordance with 303(d) impairment listings, but what happens when the private citizens responsible for discharges do not have the means to reduce contaminant discharges (e.g., insuffficent finances to re-design sewage treatment systems)? (TMDL: Total Maximum Daily Loads are plans designed to reduce pollutant loads in impaired water bodies to levels acceptable to standards detailed in section 303-d and 305-b of the Clean Water Act of 1972 [46] and subsequent EPA technical bulletins [47,48]; states are required to assess water bodies based on their designated use and report on those assessments under section 305-b. When waters are assessed as 'impaired' they are added to the 303-d list.)
- Assuming initial capital investment in sewerage improvements are provided by industry, can the system be maintained without a local government entity to take responsibility?
- Can local residents afford to pay a sewer bill or tax to provide maintenance funding?
- Is *E. coli* presence in their streams sufficiently concerning that paying such a fee would be acceptable to these residents?
- What further research/outreach is required to evaluate residents' willingness to pay and the worth of indivudal benefits?
- Are there sufficient downstream human and ecological health issues related to straight-piping such that a legal framework for industry involvement in solutions will be acceptable to regulators?

While the scientific, financial, and logistical elements of this issue are challenging, the most complex aspect of implementing community solutions to bacterial impairments is likely improving communication across stakeholder groups. Communication between external groups and dialogue internal to these groups can be an issue. In some cases, sub-groups are isolated from each other (e.g., various NGOs or community groups that may operate within the region.) Even within governmental organizations, responsibilities are split between federal agencies, state agencies, and local entities, which can create a complicated bureaucracy that impedes the communication process [18]. Conflicts between and within various groups can often stand in the way of progress. Between individual groups, the most obvious conflicts are related to fundamental differences in values and agendas. For example, some environmental and citizen advocate groups are rooted in opposition to coal mining in Central Appalachia [49], which is inherently at odds with the interests of the regional mining industry. For some community members, particular advocacy groups and NGOs are seen as "outsiders" attempting to foist non-local values and priorities on the local region [50]; meanwhile, grassroots advocacy groups may espouse a more nuanced perspective. In the case of outsider NGOs, these groups may represent the voice of a broader outside public opinion, but not have community social license to represent local or regional interests. Regardless of the ultimate goal (e.g., clean water), easing friction between such groups is fundamental to the development of sustainable solutions since stakeholder cooperation is an imperative for effectively addressing community problems.

As shown in Figure 3, it is clear that social license is not a one-dimensional entity, but more of a hierarchical structure comprised of community, state, and national levels. Not only must social license be maintained with those in close proximity to projects and activities (*i.e.*, local communities), but also in the court of public opinion at various scales. Although industry efforts might be supported by local residents, if NGOs sway public opinion on a state or national scale, political support for these community-approved projects and activities can be endangered. Therefore, the idea of social license does not only apply in a narrow sense to a local project, but also to the conduct of an industrial entity on a larger scale.

2.4. Putting Corporate Social Responsibility to Work

Assuming, in this hypothetical case, the end goal is a broadly acceptable solution that provides adequate sewerage and improves surface water quality, a first step is delineation of a regulatory framework that incentivizes local industry to participate, specifically in providing initial capital investments and technical assistance. A legal framework that "allows" for mine-related water permits to theoretically include sewerage improvements currently exists [45]; however, it has not been successfully utilized largely due to conflicting regulatory priorities at the government level, lack of historical precedent (*i.e.*, successful past projects), or general lack of knowledge about this permitting possibility within the industry. Further incentives may be necessary to garner buy-in from both the industry perspective as well as the federal regulators' point of view. In a recent court decision in Pennsylvania, courts upheld EPA's "holistic watershed approach" to addressing nutrients in the Chesapeake Bay watershed via TMDLs that include upstream states that do not directly border the Bay. While this TMDL includes all geographical parties that make up the Chesapeake Bay watershed area, it focuses on a single pollutant (nutrients) rather than a suite of water quality impacts [51]; the next logical step from a geographically inclusive watershed approach focused on a single pollutant is one that analyzes multiple pollutants and prioritizes water quality impacts in a manner that maximizes holistic watershed improvement. For bacterial impairments in Central Appalachia, this means that a future holistic approach may eventually be developed for multiple pollutants where those causing the most ecological harm are prioritized, opening the door for sewerage projects to regularly be included in the permitting process. Independent peer-reviewed research providing direct evidence of downstream environmental effects and human health risks related to regular sewage discharge would be supportive of these aims. A successful framework would require clear guidelines for acceptable solutions; specific accompanying water quality credits for those contributing to these solutions; and detailed strategies to encourage long-term participation by local residents in solution design and monitoring. Rejected attempts to operate within this framework would require clear explanation of their failings so that the process would not be perceived as a dead end within the mining industry.

Once a clear legal pathway for industry involvement exists, the next step towards solving local sewerage problems is communicating the human and environmental hazards associated with inadequate wastewater treatment to local residents effectively. Because community stakeholder participation is so important in the solution process, guidelines have been developed outlining the creation of community communication strategies and plans for environmental and health risks [52]. Collaboration involving local residents and other stakeholders will only occur once the community is sufficiently aware of the costs of inaction and relative benefits of proposed solutions.

The specifics of the community and the geographical layout of the homes will require different solutions; potential methods include the piping of untreated sewage to a proximate municipal treatment facility, the installation of a local package plant (and supporting sewer lines), or the development of a constructed wetland for grey water filtering (following septic tank pre-treatment). In terms of capital investment, all of these options are likely more costly relative to the financial resources of a single small Appalachian community, but may be a worthwhile investment for local industry members—provided that some sort of "credit" is awarded to reflect resultant improvements downstream (e.g., a company may be incentivized by the opportunity to earn credit towards mitigating impacts of their own water discharges). After installation, results should be monitored by independent groups such that the benefits of each solution implementation are clear, thus perpetuating the social license of such solution processes. Further, initial projects should be monitored by independent scientists so that the effects of each solution can be both identified and quantified.

Given these issues, would the hypothetical implementation of wastewater treatment infrastructure to replace straight-piping in Appalachia be considered a contribution to sustainable development? Reviewed loosely within the framework proposed by *Seven Questions to Sustainability*, the process appears theoretically sound based on all seven criteria: (1) engagement among stakeholders is enhanced by bringing parties that do not normally communicate together to solve community issues, perhaps in the process also airing and resolving other inter-group frictions; (2) the well-being of residents is undoubtedly improved as potentially harmful bacteria and pathogens (as well as chemicals associated with household waste) would be removed from recreational waters in close proximity to their homes; (3) although observational evidence is presently scant, common sense would indicate that the environment would likely be enhanced by the removal of raw sewage discharge; (4) economic benefit is added to the community by removing health care costs associated with waterborne illnesses as well as the capital cost of new infrastructure; (5) traditional and non-market activities, including recreational activities such as fishing, hiking, and swimming, would be enhanced by improvements in water quality; (6) implementation and operation of wastewater treatment infrastructure using a transparent and inclusive approach, satisfies the category of "Institutional Arrangements and Governance"; and (7) implementation of these solutions, and the monitoring of downstream human and ecological outcomes, contributes to synthesis and continued learning. New knowledge about the effects of sewage on the environment and the benefits of its removal can be studied in areas where these projects are installed, and will likely provide insight into efforts to improve water and sanitation access both locally and globally [32].

As a practical application, the success of this framework depends on managers of local mine operations or corporations. As new mining permits are sought, a manager can assemble a team for community outreach as well as regulatory compliance. The first team could identify community leaders through which local communities can be engaged; would these communities be amenable to local mining taking place? Would community members find value in industry-led efforts at providing them with modern sewerage options? With community support in place, a manager must address regulatory and government stakeholders. Communication with regulators and local governments can build support for such efforts, as well as determine the likelihood of such mitigation efforts to be accepted by the necessary permitting agencies. By communicating with these parties, efforts can move forward with legal support as well as community support. Two final steps are crucial in the broader public image-building process: communicating with NGOs that would support such efforts and researchers (either industry or academic) who could quantify the benefits of such efforts. With stakeholder support in place, permit application can proceed and project design and construction can as well. At the end of infrastructure improvement implementation, managers can communicate their successful results to shareholders and the broader public, illustrating community-building, local government support, processes by which regulators approved such projects, and scientifically-backed results of infrastructure improvement projects.

3. Conclusions

A unique opportunity exists in Central Appalachia for industry to assist in the improvement of surface water quality. Given the potential human health and ecological impacts of sewage-related bacterial impairments, immediate and serious attention should be given to any possible mechanisms for mitigation. Under current regulatory paradigms, contributions from industry via the construction of package plants, constructed wetlands, or general sewerage improvements are not impossible, but the pathway to associated mitigation credit related to accompanying water quality improvement is unclear at best. Further development of a framework in which mine operators can fund and participate in solutions to these sewerage issues while receiving appropriate regulatory recognition, is not only necessary to make them a reality, but is an opportunity for communication development within local communities and a potential contribution to broader regional sustainable development. Formalizing new paradigms in developed economies is likely to be a protracted effort as the success of individual projects is likely to be affected by local, state, and federal governments in addition to global energy markets and attitudes towards carbon-based energy sources. While the environmental aspects of mining are often a topic of contentious debate, all stakeholders likely agree that untreated sewage has no place in community recreational waters. Resultant understanding of the impacts of successful sanitation improvements will provide useful scientific information for the broader scientific community. To support this paradigm of using public-private partnerships to address local community needs, further research is needed to quantify the financial benefits afforded local communities by such projects, the efficiency of different methods of community-scale wastewater treatment solutions, as well as the environmental benefits of removing untreated sewage from Central Appalachian streams. If solutions to inadequate residential wastewater treatment could be implemented using the principles of CSR and sustainable development, projects in Central Appalachia could join a diverse array of case studies coming from localities across the globe that demonstrate that the mining industry is stepping forward into a new era of community engagement and improvement.

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Author Contributions

Nicholas Cook synthesized the maps, text, analysis, and figures in this paper. Emily Sarver and Leigh-Anne Krometis were principal investigators and provided text, guidance, and editing to this paper.

Conflicts of Interest

The authors declare no conflict of interest.

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