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A socio-ecological adaptive approach to contaminated mega-site management: From 'control and correct' to 'coping with change'

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ABSTRACT

Mega-sites have a notable impact on surrounding ecological systems. At such sites there are substantial risks associated with complex socio-ecological interactions that are hard to characterize, let alone model and predict. While the urge to control and clean-up mega-sites (control and correct) is understandable, rather than setting a goal of cleaning up such sites, we suggest a more realistic response strategy is to address these massive and persistent sources of contamination by acknowledging their position as new features of the socio-ecological landscapes within which they are located. As it seems nearly impossible to clean up such sites, we argue for consideration of a 'coping with change' rather than a 'control and correct' approach. This strategy recognizes that the current management option for a mega-site, in light of its physical complexities and due to changing societal preferences, geochemical transformations, hydrogeology knowledge and remedial technology options may not remain optimal in future, and therefore needs to be continuously adapted, as community, ecology, technology and understanding change over time. This approach creates an opportunity to consider the relationship between a mega-site and its human and ecological environments in a different and more dynamic way.

Our proposed approach relies on iterative adaptive management to incorporate mega-site management into the overall socio-ecological systems of the site's context. This approach effectively embeds mega-site management planning in a triple bottom line and environmental sustainability structure, rather than simply using single measures of success, such as contaminant-based guidelines. Recognizing that there is probably no best solution for managing a mega-site, we present a starting point for engaging constructively with this seemingly intractable issue. Therefore, we aim to initiate discussion about a new approach to mega-site management, in which the complexity of the problems posed by mega-sites is reflected upon in its entirety. These complexities are associated with uncertainties and unknowns that have to be addressed, as they have an impact on the strategies being developed and applied. We contend that the best that can be hoped for in mega-site management is an acceptable solution for the current state of affairs, with good flexibility to modify strategies as new site conditions, remediation possibilities, community preferences and management objectives develop over time.

1. Introduction

Mega-sites are large areas with multiple contaminants and/or contaminant sources that are likely to be active over long periods. The US Environmental Protection Agency (EPA)

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defines a mega-site as any Superfund site where remedial expenditures are expected to exceed USD 50 million. Physically, the complexity of mega-sites is related to the combination of their chemical compositions and their hydrogeological configurations. However, they are also socially complex, due to both the substantial risks they pose to human and ecosystem health and the substantial costs associated with their remediation and management. They are a common legacy of industrialisation over the past 300 years. Given a global economy that continues to favour conventional industrial approaches, it is naive not to recognize the potential for ongoing mega-site creation, particularly through industrial manufacture, related resource development, and oil and mineral processing. While the field of industrial ecology concerns itself with the design of new approaches to industrial manufacturing that can inhibit the formation of new mega-sites, benefits are only likely to be realized in future decades. There also remains a pressing need to develop forward looking long-term strategies for sustainable management of the ones that cannot be avoided. Our aim with this paper is to open up a discussion about sustainable long-term management of mega-sites that is realistic about their inevitability and optimistic about the prospects for developing socio-ecologically constructive strategies for their management.

Along with their massive scale, mega-sites are both physically and socially complex. They often have irresolvable uncertainty regarding historical changes in their use and physical condition. Additionally, many mega-sites are characterised by changeable (or changing) social, economic and political contexts. The large-scale chemical production facilities in the former German Democratic Republic (GDR) were often characterised by rather careless behaviour with regard to waste disposal and handling of chemicals, which led to a significant build-up of contaminants in the subsurface. Unification of the two Germanys brought the closure of the majority of the companies at these sites and large unemployment. Since closure was politically untenable, the unified Germany had to re-establish industrial production at these sites and start the clean-up process at the same time. An example presented in this paper shows that these contexts typically influence mega-site formation, and continue to influence engineered remediation. As a result, mega-sites present unique challenges for both the scientists and the decision makers involved in their management.

Traditional scientific approaches to problem solving (see Kuhn, 1962) often fail for mega-sites. Given their spatial scale, understanding and predictions of contaminant behaviour (chemical, biological, hydrogeological) are often data-limited. In turn, conventional site management approaches oriented around controlling and cleaning up contamination are often deemed unsuitable for both economic and logistical reasons. Additionally, even if a political will exists, it is extremely challenging (or technically impractical) to select an optimum path from decision alternatives that will completely control or definitively clean up the site. Using weather patterns as an analogy, long-term decisions concerning mega-site management cannot be based on reliable and specific predictions.

We argue that new management approaches are required for mega-sites: ones that take into account both the magnitude of their scale and complexity of their physical and social conditions. Experience at the mega-site of Leuna, in eastern Germany, and others, has led us to conclude that the conventional "control and correct" approach to site management could be effectively replaced with an approach based on "coping with change" (Farrell et al., 2008; Schirmer et al., 2011). Here, we expand on that argument, taking lessons from the *re*active remediation of the Leuna site to inform our thinking about how to develop better *pro*active remediation and closure management strategies for existing and developing mega-sites. The 'coping with change' approach to mega-site management is based on a combination of three established sets of tools for thinking about and addressing environmental management challenges. The three approaches are summarized below in turn with respect to their implications for mega-site management:

1. post-normal science: deals with how to develop good quality scientific understanding for policy when the problems at hand are physically and/or socio-politically complex (Funtowicz and Ravetz, 1990, 1994);
2. adaptive management: provides suggestions about how to effectively manage complex socio-ecological systems over the long term, taking into account not only their current states but also the ways in which they may change (Holling, 1978; Gunderson and Holling, 2002); and,
3. triple bottom line (economic prosperity, environmental quality and social justice): a business ethics framework for strategic planning that considers not just markets and values but also transparency, life cycle assessment, partnership collaborations, time-perspective and corporate governance (Elkington, 1997; Lee, 1993).

As mentioned above, the US EPA defines a mega-site as a site where remedial expenditures are expected to exceed USD 50 million. This definition reflects the exceptionally high costs and points toward the long-term character of dealing with these sites. The US National Research Council (US NRC) has recently published two studies of Superfund mega-sites. Both studies highlighted a need to develop special approaches that take into account the longevity of mega-sites. One study, concerning the effectiveness of sediment dredging as a remediation technique (US NRC, 2007) concluded that a more flexible and adaptive approach was required, owing to the complexity, large spatial scale and long time frame involved in mega-site management. The second study, concerning the status of a major mining mega-site (US NRC, 2005), identified the need for "long-term support of institutional-control" with respect to "maintaining, over the long term, the integrity of remedies intended to protect human health and guard against health risks from recontamination". Similar insights are also arising from studies of mega-sites in Germany, the Netherlands, Poland and Canada (for example Heidrich et al., 2004; Malina et al., 2006; Schirmer et al., 2006; Farrell et al., 2008).

2. Intractable problems require new strategies

In addition to the environmental threat posed by mega-sites, they are often distinguished by political and social controversy regarding their operations and closure management. Conflicting interests and perspectives of policy makers, citizens, site managers, scientists and engineers increase the challenges of identifying and implementing suitable remediation strategies. One approach to trying to achieve collaboration (especially when these sites are proximal to human populations) is to consider mega-site management as a post-normal science problem.