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The State of Research on the Prevention and Sustainable Remediation of Contaminated Sites

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In a world where energy demands are ever increasing, it is becoming overwhelmingly apparent that the current methods of development for convention sources are a point of political contention on both the domestic and global stage. This also applies to any new source of energy as they are scrutinized, not only for their ability to reduce our reliance on more conventional sources of energy, but also for their environmental impact to our natural resources such as soil, water and air. These resources form the very basis of our existence, with the need for their conservation, along with better stewardship, becoming more and more apparent as shortages are reported worldwide. As societies grow and resources are developed this has been accompanied by the loss of large areas of land and potable water sources through the disposal, either accidental or intentional, of such contaminants as hydrocarbons, dry cleaning fluids and industrial waste.

In the past, without an understanding of the potential for harm, large volumes of hazardous materials were dumped or buried, with the impacts identified only years or decades, later. The expenses associated with cleaning up these hazardous sites, using standard remediation techniques is prohibitive and has led to many companies simply "walking away" from the problem. As a result, extensive research is underway into methods with the potential to not only restore these resources, but to do so in an affordable manner. Bioremediation is one such mitigation procedure under review that has various and diverse applications. While many definitions refer to the use of microorganisms to degrade waste or by-products, phytoremediation is gaining prominence by employing indigenous plants and fungi, such as sedges, cattails and mushrooms, to treat a contaminant.

As a natural, low cost, long term and self-sustaining process, it holds the promise of rehabilitation for long abandoned, contaminated lands and the potential to obtain approval for a new procedure that might otherwise be rejected. With an increase in agricultural and industrial discharge, mine drainage and especially, municipal sewage, the scientific community has looked to the creation of man-made wetlands as an alternate source of treatment [1,2]. Proper implementation of these wetlands will result in Biomimicry, a process that requires a multi-faceted approach based on a thorough understanding of the parameters involved [3]. Seen as replicating nature on a local scale, continued research is necessary to delve into the complex, biological interactions involved while ensuring development of the optimum long term solution. Principal to this is the need to understand how a contaminant will interact with the environment to which it is exposed. Once understood, procedures can be designed and implemented to reduce the contaminant(s) of concern to acceptable levels.

The fate and transport of hazardous materials in the environment has long been studied by academia worldwide, as a means of defining the principals of how they move through and between, the various medium (air, soil, groundwater, etc). Dating as far back as 1856, Henry Darcy conducted experiments relating to fluid flow through a permeable medium, experiments that led to the law that now bears his name. Further developments have proven and refined, the concepts that now underlie the field of hydrogeology. The computer model, is commonly employed is to simulate the movement of a liquid or contaminant (water, oil, etc.) through a given medium. For a long time the speed and memory capabilities of the computers available restricted the number of independent variables that could be considered and hence the complexity of the model, limiting its use as a predictive tool. This has changed with major advances in computing power that have allowed the implementation of increasingly complex mathematical equations. The calibration of these models forms the basis for their predictive capabilities and is an important area of ongoing research. Whereas, previously the acceptable method was to infer the best possible parameters in an attempt to reproduce an observed behaviour, a more feasible and accurate, method is to use optimization routines to determine these parameters [4].

Current research focuses on the improvement of these models as predictive tools. The numerical, analytical and statistical models that are employed provide answers to the stability of a contaminant plume, its spatial distribution and more importantly, its capacity for adverse impacts to the environment and local communities. As a means of evaluating the potential for human and ecological risks, it is unparalleled in its ability to guide remedial decision making. Whenever a project is undertaken, whether for current development or the remediation of a previously contaminated site, research into potential, negative impacts is crucial to its success and acceptance by the general public. For this reason, methods that conserve or improve environmental quality while minimizing costs are more likely to move forward.

One such conservation method gaining prominence is the incorporation of Sustainable Development into projects [5], particularly those with the potential for adverse impacts. The World Commission on Environment and Development [6] has defined Sustainable Development as, "meeting the needs of the present without compromising the ability of future generations to meet their own needs". One important area, currently under investigation, is the impact to water bodies and the local ecosystem, as a result of water diversion [7].

Whenever possible, sustainable development should incorporate the three pillars of social equity, economics and the environment. This requires the input from a diverse team of experts, capable of

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understanding the complex parameters that make up even the simplest of systems [1].

Continued research into areas such as bioremediation, soil contamination, sustainable development and waste water treatment, is necessary, forming the foundation for continued growth and development of economies on a local, national and global scale.

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