ENVIRONMENTAL FORENSIC INVESTIGATION OF POLLUTED GROUNDWATER SITES

by

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CERTIFICATE

This is to certify that the thesis entitled "**Environmental Forensic Investigation of Polluted Groundwater Sites**" being submitted by **Mr. George K. Varghese**, to the **Indian Institute of Technology Delhi**, for the award of **Doctor of Philosophy** in Civil Engineering is a record of the bonafide research work carried out by him under my supervision and guidance. He has fulfilled the requirements for the submission of this thesis, which, to the best of my knowledge, has reached the requisite standard.

The material contained in the thesis has not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

This research is aimed at developing a computer based environmental forensic tool for tracking the pollutant source in the event of a groundwater pollution incident. The source tracking problem considered in the research is one, where there is no manifest evidence on the ground regarding the location of the source. Such cases arise in situations like an abandoned chemical dump that has been covered up.

Since the tool is intended for forensic applications, the legal requirements from such a scientific tool had to be investigated. It was also important to know the legal provisions for dealing with environmental crimes to know the scope of such a tool. The common law legal system generally and the Indian legal system specifically, was analyzed for this.

It was seen that, in India, the environmental redress mechanism had been predominantly criminal in nature. This had the disadvantage that, in many cases, the culprits walked free because of the very stringent evidentiary requirements put for criminal conviction. But, there was a shift from this approach recently. The Government notified the National Green Tribunal Act 2010, which is a civil liability statute for dealing with environmental cases.

This Act gives an opportunity for the victims of pollution to claim monitory compensation for the damages they suffer on account of pollution. More importantly, it is now sufficient to prove the polluter's responsibility with a preponderance of evidence and not with a certainty that is beyond all reasonable doubts as required for criminal conviction.

It was thus clear that there was a scope for a scientific tool that tracks down the polluters in the event of groundwater pollution. Further, it was seen that, scientific tools had to stand the legal scrutiny if it were to be considered as evidence in courts. The Daubert guidelines were found to be standard in this regard in many of the common law judicial systems, including India.

Thus the computer based forensic tool was developed incorporating the legal provisions. The tool used a method of forward simulation followed by optimization for identifying the source of pollution. It is an efficient implementation of a trial and error procedure, where the trials each time are governed by some optimizing criteria. The forward model used in the tool was MT3DMS and the optimization technique used was Genetic Algorithm.

The tool was developed for running in multi-core high end machines with Linux support. The coding was done in C++ 11.

The tool was run for some test problems and its performance was evaluated. It was seen that the model tracked down the unknown pollutant source for a combined error (model and observation) of up to 10% with a confidence of 95% using 8 concentration observation locations and 180 days of observation. It was also seen that concentrations distributed temporally can be replaced by lesser number of observations distributed spatially for the same degree of performance.

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