



SOLAR DETOXIFICATION – TREATMENT OF CONTAMINATED GROUNDWATER

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Contamination from organic compounds such as benzene, toluene, ethylbenzene and xylenes (BTEX) represent a common issue in the oil and gas industry. A number of technologies have been developed and demonstrated for the treatment of groundwater contaminated with these compounds. Some of these technologies include advanced oxidation process (AOP), steam stripping, air stripping and more recently, monitored natural attenuation. Each technology has its own set of advantages and limitations. As an example, the AOP technology gained some popularity in the 1990s as a remediation technology for treating trace concentrations of organic contaminants; however, power consumption of AOP treatment plants is relatively high. This energy consumption constitutes the majority of the plant operating cost and adds to the general demand on electricity.

Recently a solar-based AOP technology was developed by a group of Canadian researchers. This solar detoxification process offers the potential for significant energy savings in the treatment of groundwater. This new technology could contribute to the reduction of the environmental footprint from oil and gas production and at the same time demonstrate an innovative approach in alternate energy source application.

Photo-oxidation involves the use of ultraviolet (UV) light plus an oxidant to generate hydroxyl radicals. The hydroxyl radicals then attack the organic compounds to initiate oxidation. There are two major oxidants that act as a source of hydroxyl radicals: hydrogen peroxide and ozone. Photochemical degradation is based on the oxidative reaction that is generated by the photolysis of the oxidant, hydrogen peroxide, in this case.

In a conventional AOP system, the oxidant absorbs UV in the 200-300 nm range and initiates the degradation process of organic contaminants. However, the solar energy that reaches earth's surface is mainly at wavelength above 300 nm due to atmospheric absorption. Since hydrogen peroxide and ozone do not absorb significantly beyond 300nm, the solar source is not suitable for these absorbers. An alternative is the injection of ferrioxalate that absorbs in the region of 250-480 nm (Safarzadeh, Bolton & Cater, 1996). Photolysis of ferrioxalate generates iron(II) which then reacts with hydrogen peroxide to produce hydroxyl radical. As in conventional AOP, hydroxyl radicals then degrade organic contaminants in the treated medium.

As hydroxyl radicals are generated, iron (II) is oxidized to iron(III). Iron (III) chelates then repeats the generation of iron (II) under irradiation. Previous research had demonstrated that photolysis of the ferrioxalate in the presence of hydrogen peroxide provides a continuous source of radicals. When conditions are correct, iron (III) chelates act as a catalyst in this process. At higher pH, ferric iron precipitates as ferric hydroxide. From previous studies, workable pH range for this process is between 4 and 5. The efficiency of the process decreases dramatically as pH goes above 5. The use of ferrioxalate enables the utilisation of approximately 18% of the incident solar radiation energy.

In the reported work, research was conducted to develop this technology further through bench-scale and field-scale work. Bench-scale test results showed excellent destruction of BTEX, MTBE and MMT contaminants. This is consistent with our earlier experience in BTEX and MTBE destruction using conventional AOP systems. A site was selected in British Columbia to conduct the field demonstration. A suitable field scale system was designed and assembled. Test equipment operated well in the field and system components performance met expectations. Groundwater at this site had trace levels of benzene and MTBE. Field-testing lasted approximately 5 weeks. Results indicated that both benzene and MTBE destruction was extremely evident and effective using this technology.

One important aspect of this work is the development of a performance prediction model based on the solar detoxification technology. Often it is desirable to perform bench-scale test in the laboratory before conducting fieldwork or implementing a full system. It would be useful to have a model that could provide some indication on performance for the field system based on bench-scale testing. To this end, a process for performance prediction was developed. A contaminant destruction model consisting of a lamp reactor sub-model and a solar sub-model was developed and tried. Once this model becomes fully validated, it will become a useful tool to assist in the commercialisation of this technology. The application and commercialization of this innovative technology will depend on the availability of a simple-to-use design tool for remediation practitioners to determine the required system size and a readily available packaged product.

The process for system design could follow the steps described below:

- (1) Bench-scale Testing: Using actual groundwater sample, study contaminant destruction under laboratory conditions. Optimal process parameters such as treatment time, pH and reagent concentrations are determined.
- (2) Solar Performance Prediction: Using the theoretical solar irradiance model, predict theoretical outdoor process time and performance.
- (3) Determine a Site-specific Sky Factor: Using the UV index for the specific site location, determine the scaling factor required to ensure complete destruction of target contaminants in the effluent. This scaling factor would help determine the physical size and treatment capacity required for the solar detox system to treat the given groundwater under real sky conditions. UV Index is widely available and historical data for a given site could be used for this determination.
- (4) Packaged System Sizing and Installation: Using the scaling factor derived from site-specific UV Index data to construct a packaged system that will adequately treat target contaminants.