

Effect Of Chemical Oxidation On Dissolved Oxygen In Remediation Of Hydrocarbon Contaminated Water In A 3-D Tropical Sand Tank

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Abstract: This paper evaluates the effect of chemical oxidation on Dissolved Oxygen (DO) in remediation of hydrocarbon contaminated groundwater in a laboratory three Dimensional (3D) sand tank model. The chosen laboratory experimental porous media material is Alluvial Sand (Owena Sand). 60 ml of unleaded gasoline was introduced as a contaminant of concern into the 3-D sand tank via the injection wells. Thereafter, samples were taken periodically for 24 days, DO was tested for Natural Attenuation, subsequently, the Owena river sand was replaced in the sand tank and the same volume of gasoline was injected again, Potassium permanganate (KMnO₄) was chosen as oxidizing agent and varies in different percentages (1.5% and 5%), water samples were taken periodically for 24 days for testing. The results of the 50 g/l KMnO₄ had more dissolved oxygen and it is obvious that the oxidizing agent shows a significant longevity in the subsurface allowing for the increment in the DO concentration, therefore, KMnO₄ solutions is viable in remediating contaminant of concern by increasing the DO.

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Keywords: alluvial Sand, unleaded gasoline, Potassium permanganate, Dissolved Oxygen.

Introduction

Dissolved Oxygen (DO) is a measure of how much oxygen dissolved in the water, DO can tell a lot about water quality. Dissolved Oxygen (DO) measurements have been frequently neglected in groundwater monitoring, this is because O₂ has often been assumed absent below the water table. Oxygen is the first electron acceptor available for biotic transformations that is quickly consumed. The presence of dissolved oxygen is an indicator of electron acceptor availability, ITR (2002). It has been known that adding oxygen to contaminant plumes promotes the aerobic biodegradation of petroleum contaminants such as gasoline. The dissolved oxygen (DO) concentration in groundwater and distribution throughout the contaminant plume can indicate contaminant movement, degradation, or plume stability. The DO concentration usually reflects its organic contaminant load (the lower the DO, the greater the contaminant concentrations).

Adding oxygen to ground water contaminated by gasoline spills or leaking underground storage tanks is a common approach for site remediation. Since the late 1980s, it has been known that adding oxygen to contaminant plumes promotes the aerobic biodegradation of petroleum contaminants such as gasoline. Remediation of groundwater contamination using in-situ chemical oxidation (ISCO) involves injecting oxidants and other amendments as required

directly into the source zone and downgradient plume. The oxidant chemicals react with the contaminant, producing innocuous substances such as carbon dioxide (CO₂), water (H₂O), and inorganic chloride. Examples of potential contaminants that are amenable to treatment by in-situ chemical oxidation (ISCO) include benzene, toluene, ethylbenzene, and isomers of xylenes (BTEX), tetrachloroethylene (PCE), trichloroethylene (TCE), dichloroethylenes, vinyl chloride (VC), MTBE (methyl-tert-butyl-ether), PAH (polyaromatic hydrocarbons) compounds, and many other organic contaminants. Remediation of subsurface contamination has proven to be problematic. Early efforts at ground water cleanup were characterized as being costly, time-consuming and ineffective (Knox *et al* 1985). Oxygen is a colourless, tasteless, odourless gas, which in its dissolved state in water, does not directly affect human health. Oxygen concentration limits have therefore usually not been specified in drinking water standards. Although D.O. can be precisely measured, concentrations are not monitored as part of many ground water quality investigations.

Dissolved oxygen concentration should be considered a critical parameter in any investigation of groundwater contamination, particularly those involving the migration of landfill leachate or mining wastes. D.O. often controns the fate of dissolved organic contaminants by constraining the types and

numbers of microorganisms present within aquifer. In turn, bacteria can either decompose or, in some cases produce organic contaminants as part of their metabolism. For example, most alkyl benzene and chlorobenzene groups are probably biodegradable in aerobic water while stable in anaerobic water. Conversely, trichloroethylene (TCE) is stable in oxygenated water while possibly biodegradable in anoxic water (Wilson and McNabb 1983).

Material and Methods

3-D Sand Tank Model

The middle chamber was filled with a tropical saturated alluvial porous medium (Owena sand), and chamber at both ends with water to maintain constant heads. Variable level overflow outlets were incorporated in the constant head reservoirs, to facilitate varying of hydraulic gradient across the porous media chamber. The experimental aquifer is 140cm long, 30cm wide and 80cm high. Sampling wells consisted of 2cm diameter nested pipes that served as multilevel monitoring wells for the collection of depth discrete groundwater samples. One of the multilevel monitoring wells was situated 30cm from the upstream chamber and the second 40cm further downstream, while the third multilevel well was

located 40cm from the downstream end of the aquifer chamber. (3 multilevel wells). Each of the nest of pipes consisted of three pipes with screened pipe end sampling ports of depths 0.30-0.35m, 0.50-0.55m and 0.70-0.75m respectively. On the discharge side of the sand tank model, five 18.75mm diameter openings were drilled to create differential hydraulic gradient; with equal head difference of 0.05m for four (4) openings. While the fifth (5th) opening was drilled on the inlet side at 0.73m height of the sand tank model (Fig.1b and Fig. 1b).



Figure 1a: 3-D Sand Tank Model. (Ojuri 2010)

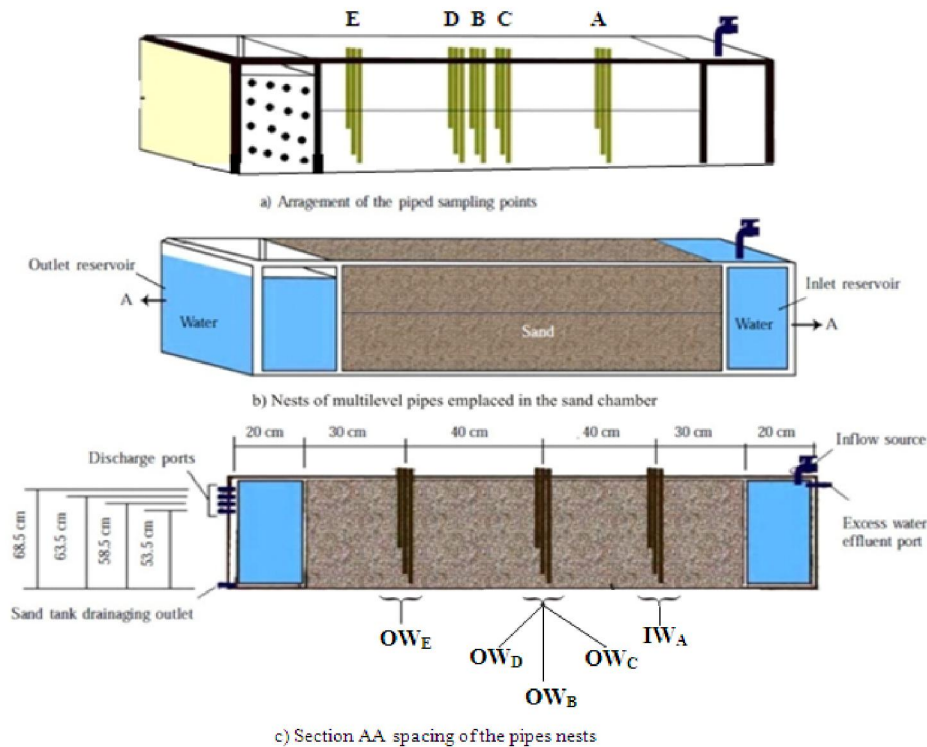


Figure 1b: Isometric and Sectional View of 3D Laboratory Sand Tank Model (Ojuri 2010)

Key:

IWA – Injection Well A
 OWB – Observation Well B

OWC – Observation Well C
 OWD – Observation Well D
 OWE – Observation Well E

A 500-gallon plastic water container was used as a source of water to the sand tank model. Water was harvested into the 500 gallon storage from the elevated roof storage tank by means of a tee connected to the discharge pipe, from the roof tank into the 500 gallon storage water source. The effective invert level of the sand tank model when it is dry, without water, is 0.95m and when it is full with the side opening on the inlet side open, the effective level of water is equal to 1.68m, (0.95 + 0.73) m. The inlet level of the source water tank is 1.80m. when the source water tank is full, the level of water in it will be 2.7m. So, the head difference between the source water when it is full and the inlet source water in the sand tank model when it is also full at 1.68m marks was 1.02m.

Portable Horiba Water Quality Checker (Mfg.No.404013)

The Water Quality Checker is a multimeter that can perform simultaneous measurement of six parameters; turbidity, salinity, dissolved oxygen, electrolytic conductivity, pH and temperature with the aid of direct-submersion sensors. This apparatus is available in the Water Resources and Environmental Engineering Laboratory in the Department of Civil and Environmental Engineering, The Federal University of Technology Akure.

Oxidants

The oxidant used for the remediation is Potassium Permanganate (KMnO₄) and this was varied in two proportions for the remediation (i.e., 15g/l and 50g/l).

Methods

Phase one

Alluvial sand was filled in the middle chamber of the sand tank model and 60 ml of unleaded gasoline was injected via the injection well A (IW_A), water was allowed to flow at a constant flow rate, samples of water were taken periodically for DO from the monitoring wells B (M), C (M), D (M) and E (M) for natural attenuation.

Phase two

After the natural attenuation testing period was over, alluvial sand was replaced fresh one and 60 ml of unleaded gasoline was introduced via injection well A and 15 g/l of KMnO₄ was injected via the Injection well A (IA_T), samples were also taken periodically for the DO, this was also repeat for the 50 g/l of KMnO₄ proportion.

Results and Discussion

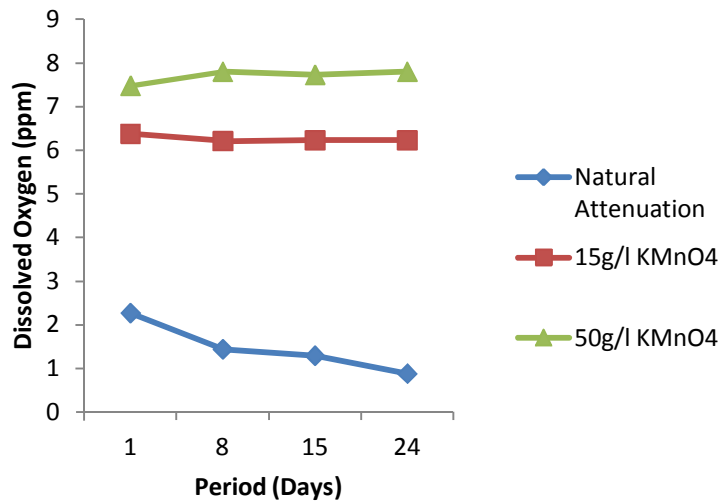


Figure 2: Dissolved Oxygen against period for Natural Attenuation, 15g/l and 50 g/l of KMnO₄

Table 1: Summary of Dissolved Oxygen after Injection of Gasoline for Natural Attenuation, 15 g/l and 50 g/l of KMnO₄ Remediation

Period (Days)	Natural Attenuation	15 g/l of KMnO ₄	50 g/l of KMnO ₄
1	2.27	6.38	7.48
8	1.44	6.21	7.80
15	1.29	6.23	7.73
24	0.88	6.23	7.80

Results of Spatial Distribution of DO for Natural Attenuation, 15 g/l and 50 g/l of KMnO₄.

The dissolved oxygen (DO) for the control (i.e., water samples collected from the laboratory aquifer model before the injection of contaminant) is 16.55ppm.

The Dissolved Oxygen (DO) for water samples at observation wells for the natural attenuation (NA) does not show much substantial increment in the dissolved oxygen (Figure 2), i.e., the depleted dissolved oxygen due to the presence of petroleum does not respond significantly to the natural attenuation. The samples remediated with varying percentage of oxidant show small increases in the DO. The DO average values of 6.38, 6.21, 6.23 and 6.23 ppm for day 1, 8, 15 and 24 respectively after the injection of 15 g/l of KMnO₄, also, the DO average values of 7.48, 7.80, 7.73 and 7.80 ppm for day 1, 8, 15 and 24 respectively after the injection of 50 g/l of KMnO₄ were observed. The DO increase from 0.88ppm after the injection of gasoline to 6.23ppm

after remediation with 15 g/l of KMnO₄ on the 24th day of remediation and 7.80ppm after remediation with 50 g/l of KMnO₄ for 24 days, hence, the percentage of increase from natural attenuation to remediation with 15 g/l of KMnO₄ gives 607 percent and 786 percent for natural attenuation to remediation with 50 g/l of KMnO₄. The results is in agreement with the research of Ola *et al.*, 2015 on the comparison of two remediating agents, the DO increased with age for KMnO₄ samples, also the DO values for the water samples remediated with 15g/l and 50 g/l of KMnO₄ is >6mg/l recommended by Rump (1999) for water of good quality.

Percentage increment of the Dissolved Oxygen during the remediating experiment for Natural Attenuation, 15g/l and 50g/l.

Comparing the percentage increment in Dissolved Oxygen between Natural Attenuation and experiment with 15 g/l of KMnO₄. At Observation Well B middle. Using the Expression below:

$$\% \text{ increment in DO} = \frac{\text{DO at 24th day of 15 g/l} - \text{DO at Natural Attenuation (24th day)}}{\text{DO at Natural Attenuation (24th day)}} \times 100$$

$$\% \text{ increment in DO} = \frac{6.23 - 0.88}{0.88} \times 100 = 607\%$$

Thus, percentage increment is 607% using 15 g/l of KMnO₄ for the remediation

$$\% \text{ increment in DO} = \frac{\text{DO at 24th day of 50 g/l} - \text{DO at Natural Attenuation (24th day)}}{\text{DO at Natural Attenuation (24th day)}}$$

$$\% \text{ increment in DO} = \frac{7.80 - 0.88}{0.88} \times 100 = 706\%$$

Thus, percentage increment is 786% using 50 g/l of KMnO₄ for the remediation.

Conclusion

Dissolved Oxygen (DO) is the amount of oxygen that is present in the water, it is probably the most significant water quality test to determine the suitability of the water. The DO increases with day with the two percentages of remediating agents, it is obvious that 50 g/l KMnO₄ had more dissolved oxygen and it is obvious that the oxidizing agent shows a significant longevity in the subsurface allowing for the increment in the DO concentration. (the longevity of an oxidant after it is applied to the subsurface is important because it affects the radius of influence by affecting the distances the oxidant can travel in subsurface and still be active).

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