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# AERATION TO IMPROVE THE WATER QUALITY AND HYDRAULIC FUNCTIONS OF SEPTIC SYSTEM LEACHFIELDS

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## INTRODUCTION

Conventional septic systems are designed primarily for effective removal of solids in the tank and quick dispersal of tank effluent in the associated leachfield. The removal of nutrients and pathogens takes place with passage of effluent through leachfield soil, but is not a primary design concern. As such, the capacity of these systems for improving the quality of effluent water is generally limited. Increasing concern with contamination of ground and surface waters by failing or improperly installed septic systems has led water managers and regulatory agencies to promote on-site wastewater treatment technologies that lower emissions of pathogens and nutrients. With nearly one-quarter of households in the United States relying on onsite wastewater treatment systems (OWTS) for treatment of domestic wastewater (United States Census Bureau, 2003), development of such technologies has the potential to have a significant, positive impact on the quality of water resources.

Among the technologies that have emerged in the last few years to address these issues is leachfield aeration. The system (known as the SoilAir™ System) was developed and patented for rejuvenation of - and enhanced treatment by - failed septic system leachfields (Potts, 2000). It has been approved for use in a number of states, with over 100 systems installed in ten states in the past nine years. This paper describes the components and functioning of a typical SoilAir™ system, field observations of effects on hydraulic and water quality functions, and pilot-scale assessment of the effects of aeration on nutrient and pathogen removal under various conditions.

## SYSTEM DESCRIPTION

Soil gas samples collected from leachfields are generally depleted of oxygen and considerably enriched in carbon dioxide, methane and hydrogen sulfide relative to atmospheric levels. This is largely a function of the microbial oxygen demand exceeding the available oxygen supply, which in turn limits microbial processes that remove organic compounds and nutrients from septic tank effluent. This can translate into hydraulic failure as a result of excessive accumulation of organic materials in the biomat, at the soil/water interface.

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The SoilAir™ system typically supplies air at supra-atmospheric pressure to both the leachfield and the surrounding soil. The oxygen supplied by this process eliminates and prevents an oxygen deficit from developing in the vicinity of the leachfield by meeting and/or exceeding the biological oxygen demand of the soil and wastewater, which is exerted by the activities of microorganisms. When the system is operated, oxygen levels in and around the leachfield are no longer limiting, biomat production is controlled, ponding is reduced and treatment efficiency improves. The effects are similar to resting a trench to rejuvenate it, but the process is more efficient and requires less time.

Oxygen concentrations in the soil adjacent to a leachfield aerated with the system are typically in excess of 20%. This is over 20,000 times more oxygen than can be supplied by injecting air into water, as is performed in typical wastewater treatment processes. Increasing the oxygen concentration accelerates oxygen-limited microbial processes, such as organic matter decomposition. The removal of accumulated sludge/biosolids from aerobic treatment plants, and the subsequent land application/composting to break it down under conditions where oxygen is readily available is a typical example of the positive effect of increased oxygen availability on organic matter breakdown.

SoilAir™ systems can be installed on both gravity and pump-based septic systems (Fig. 1). On a gravity system, a level sensor is installed in or adjacent to the septic tank, with an air backflow preventer directly downstream of it. With a pump-based system, a level sensor is installed in the pump station to control the system. A blower is connected to the piping between the septic tank or pump station and the leachfield. While air is supplied to the leachfield, water accumulates in the septic tank or pump station until the level sensor activates and turns off the blower. Once the blower is off, a dose of wastewater is allowed to flow to the leachfield. Aeration starts again at a set time after dosing.

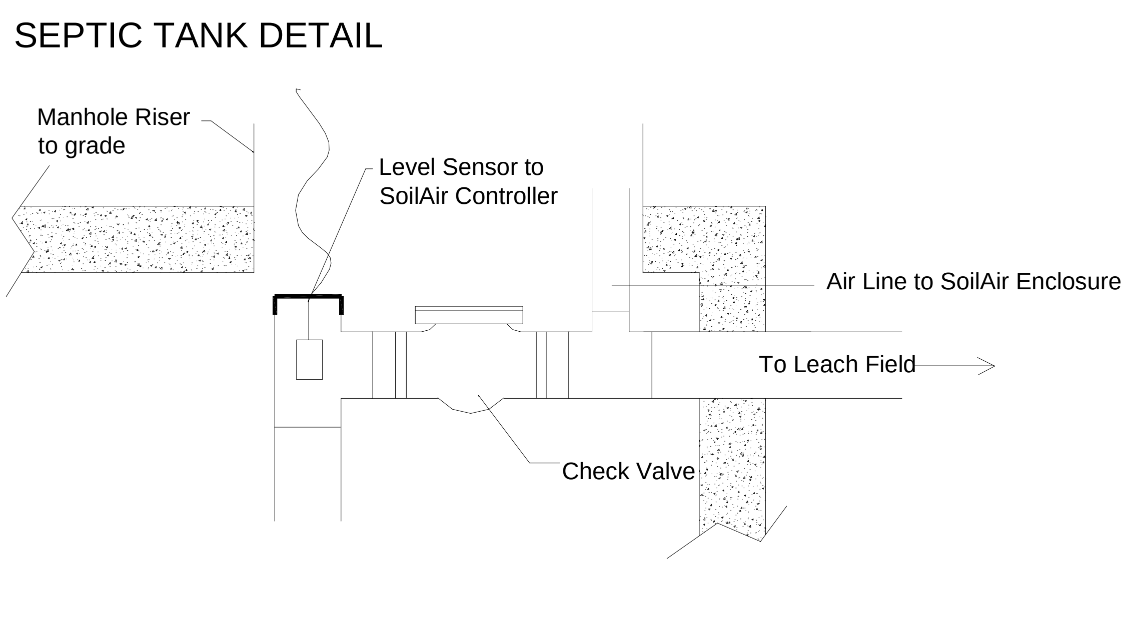


**Fig. 1. Detail of SoilAir™ system connection in a septic system, showing placement of wastewater level sensor, check valve, and aeration line.**

In addition to a simple, programmable timer, the system can be equipped with a microprocessor-based controls package. This allows for accommodation of a wide range of operational scenarios. For example, when rejuvenating a failed septic system, the blower is typically programmed to operate continuously, stopping only to allow a dose of wastewater to flow from the septic tank into the leachfield. As the excess biomat is oxidized, the system back-pressure typically decreases. The microprocessor can sense the change in pressure and reduce the duration and/or frequency of blower operation. The volume of wastewater applied to the leachfield can also be determined via the microprocessor by tracking the number of doses per day. In addition, a water level sensor can be installed in the leachfield to measure actual ponding levels. The controller can automatically adjust system operation accordingly. The SoilAir™ system can be monitored, programmed and operated remotely via a modem. For example, when the system senses uncharacteristically high flows, such as caused by a running toilet, a message can be forwarded to the service provider and the customer.

The SoilAir™ system has been used successfully on leachfields constructed with pipe and stone, plastic chambers, concrete galleries, drip irrigation, dry wells, as well as proprietary systems. The sources of wastewater for these septic systems include family residences, restaurants, municipalities, commercial laundries, hotels, apartment complexes, and various other commercial establishments. Many of these sources had high waste strength and grease accumulations. A number of the rejuvenated leaching systems have been over fifty years old, and some were located under parking lots.

## FIELD OBSERVATIONS

Forced aeration of leachfields with SoilAir™ systems has been an effective method to both rejuvenate hydraulically failed leachfields and improve water quality. When air is introduced into the leachfield and passes through the biomat, ponding is reduced or eliminated. System back-pressure typically diminishes by 25% or more during the first 24 hours of operation as the biomat is oxidized. The system back-pressure is indicative of the ponding level in the leachfield. An example of the effects of aeration on ponding levels in a restaurant leachfield during the first 45 days of operation is shown in Fig. 2.

Prior to starting the aeration system, soil gases in the leachfield are depleted in oxygen and contain high concentrations of carbon dioxide and methane, indicative of anaerobic conditions. Once the system is started, oxygen levels are restored to atmospheric levels, and levels of methane and carbon dioxide are reduced considerably. Fig. 3 shows the concentration of oxygen, methane, and carbon dioxide in soil as a function of time for the same restaurant system as in Fig. 2. When blower operation was interrupted (day 40), oxygen demand exceeded oxygen supply, as indicated by a decreased oxygen level and elevated concentration of carbon dioxide. Our experience indicates that operation of the SoilAir™ system can maintain atmospheric levels of oxygen in soil even in the deepest leaching structures.

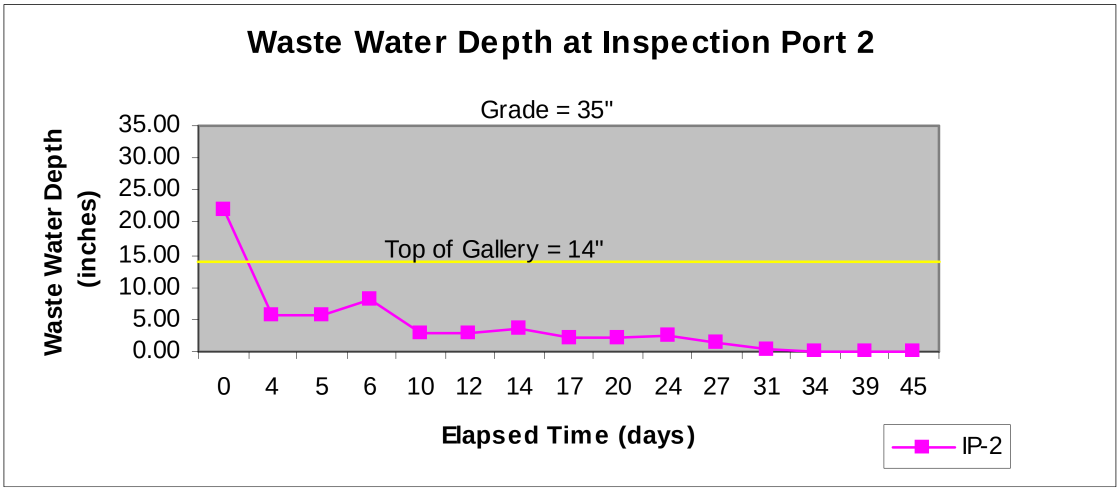


**Fig. 2. Effect of aeration using the SoilAir™ system on wastewater ponding in the leachfield of a restaurant OWTS.**

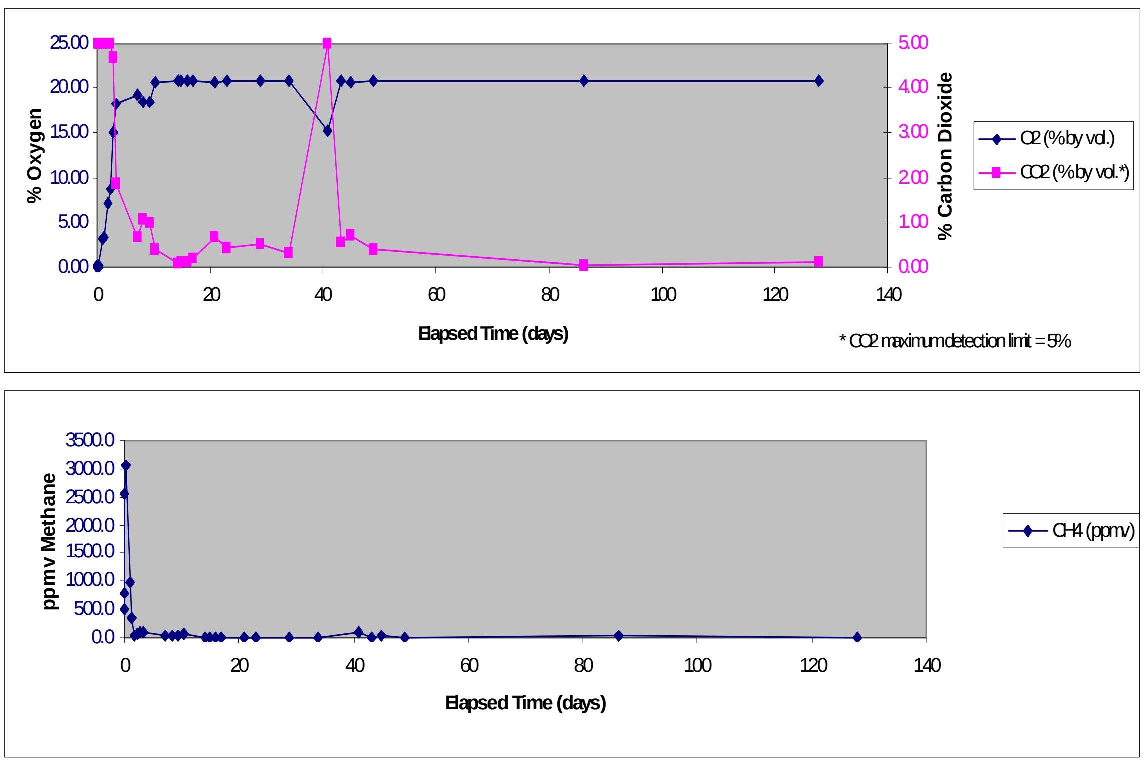


**Fig. 3. Effects of aeration using the SoilAir™ system on the composition of soil gases in the leachfield of a restaurant OWTS. TOP: oxygen and carbon dioxide; BOTTOM: methane.**

Water quality also benefits from leachfield aeration. Preliminary data indicates that enhanced removal of nitrogen, phosphorus BOD and fecal coliform bacteria can be accomplished by operating the blower in conjunction with the dosing of wastewater. A residential septic system leachfield rejuvenated using the SoilAir™ system had removal rates that were > 90% for total N and $BOD_5$ , > 70% for total P, and >99.9% for fecal coliform bacteria 1 ft. below the leachfield trench surface.

## PILOT-SCALE EVALUATION

We conducted a series of pilot-scale experiments to evaluate how aeration of leachfield soil affects the water quality and hydraulic functions of leachfield soil. The experimental setting for these experiments has been described previously (Potts et al., 2004). Briefly, the experiments were conducted using lysimeters dosed with a known volume of septic tank effluent from a two-family household in southeastern Connecticut at regular intervals (Fig. 4). Two main treatments were employed: lysimeters aerated post-dosing to maintain atmospheric levels of oxygen in the headspace (AIR treatment), and lysimeters whose headspace was vented to the gases in an adjacent septic system leachfield (LCH treatment). Each treatment was replicated 3 - 4 times, depending on the experiment.

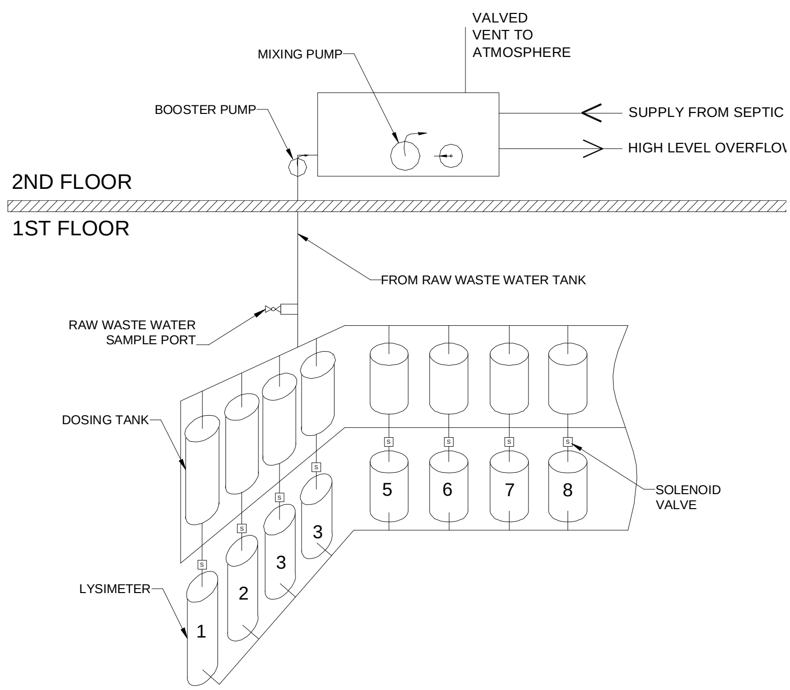


**Fig. 4. Schematic diagram of experimental facility.**

Effects on water quality were assessed by comparing the concentration of total N and P, $BOD_5$, and numbers of fecal coliform bacteria in septic tank effluent and in lysimeter drainage water. Analyses were conducted according to the methods of the American Public Health Association (APHA, 1998).

### Experiment 1

The effects of aeration on water quality were assessed initially using silica sand as an absorption medium. Each treatment was replicated three times. After dosing lysimeters with septic tank effluent at a rate of 4 cm/d (1.6”/d) for 24 months, reduction in total N was negligible in both AIR and LCH treatments and the concentration of total P in drainage water was higher than in inputs in both treatments (Table 1). In contrast, high rates of fecal coliform removal were observed in both treatments. Nearly complete

**Table 1.** Effects of operating conditions on removal of total N, total P, $BOD_5$, and fecal coliform bacteria in aerated (AIR) and unaerated (LEACH) experimental leachfield lysimeters. Data for Experiment 1 are from Potts et al. (2004).

| Exp No. | Media | Depth (cm) | Load (cm/d) | Run time (mo.) | % Removal: Total N AIR | Total N LCH | Total P AIR | Total P LCH | $BOD_5$ AIR | $BOD_5$ LCH | Fecal coliforms AIR | Fecal coliforms LCH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sand | 30 | 4 | 24 | 2.9 | 0.8 | -10.6 | -1.0 | 99.3 | 60.9 | 99.9 | 98.9 |
| | | | 12 | 2 | 23.6 | 1.3 | -13.4 | -8.2 | 99.5 | 29.6 | 99.1 | 98.0 |
| 2 | Sand | 30 | 12 | 11 | 25.1 | NA | 2.9 | NA | 92.1 | NA | 87.2 | NA |
| | | 15 | 12 | 11 | 28.0 | NA | 7.9 | NA | 94.8 | NA | 93.5 | NA |
| | | 7.5 | 12 | 11 | 30.9 | NA | 12.6 | NA | 84.5 | NA | 84.2 | NA |
| 3 | Soil | 30 | 4 | 9 | 21.0 | 20.8 | 75.9 | 69.8 | 99.8 | 87.8 | 100.0 | 100.0 |
| | | | 12 | 7.3 | 41.0 | 15.6 | 66.8 | 79.6 | 99.0 | 82.7 | 99.6 | 97.1 |

removal of $BOD_5$ was observed in the AIR treatment, whereas only 60.9 % of $BOD_5$ was removed in the LCH treatment.

Increasing the hydraulic load from 4 to 12 cm/d (4.7”/day) increased the average removal of total N removal to nearly 24% in AIR, but had no effect in the LCH treatment (Table 1). A small increase in the total P released from both treatments was observed. Removal of $BOD_5$ in the AIR lysimeters was unaffected by the increased hydraulic load, but was nearly half that at the lower load in the LCH treatment. Fecal coliform bacteria were removed less effectively in both treatments at the higher loading rate.

Considerable ponding of wastewater (up to 7”) above the soil surface was observed in LCH lysimeters, whereas infiltration of wastewater into soil was complete in the AIR treatment, regardless of hydraulic loading rate.

**Experiment 2**

The effects of depth of medium on removal of nutrients, $BOD_5$ and fecal coliform bacteria under aerated conditions were determined using silica sand at depths of 30 (12”), 15 (6”), and 7.5 cm (3”). Lysimeters were loaded with septic tank effluent at a rate of 12 cm/d, with each depth replicated three times.

Total N removal increased as medium decreased, with 25.1, 28.0, and 30.9% removal at depths of 30, 15, and 7.5 cm, respectively (Table 1). Total N removal at a depth of 30 cm was comparable to that observed in Experiment 1 at the same loading rate. Unlike the results of Experiment 1, net removal of total P was observed at all depths, with removal increasing as the medium depth decreased. In contrast, removal of $BOD_5$ (84.5%) and fecal coliform bacteria (84.2%) was lowest at a depth of 7.5 cm. Rates of fecal coliform (87.2%) and $BOD_5$ (92.1%) removal at 30 cm were lower than observed in Experiment 1 at the same load.

Complete infiltration of wastewater into soil was observed regardless of depth of medium.

**Experiment 3**

The effects of aeration were also examined using native soil to determine whether the response of water quality parameters to aeration was similar to that for sand lysimeters. Soil (30 cm) from the B and C horizons of soil in the Hinckley series was subjected to AIR or LCH treatments, with four replicate lysimeters employed per treatment. Lysimeters were loaded with wastewater at a rate of 4 cm/d for the first 9 months of the experiment, with the load subsequently increased to 12 cm/d for over 7 months.

The average total N removal at a loading rate of 4 cm/d was roughly 21% in both AIR and LCH treatments (Table 1). Increasing the hydraulic load to 12 cm/d nearly doubled (41%) total N removal in the AIR treatment, but resulted in less effective N removal in LCH lysimeters. Removal of total P ranged from 66 to 80% in soil lysimeters, with higher removal in AIR than LCH treatments at the lower loading rate and higher removal in LCH treatment at the higher loading rate. Nearly complete removal of $BOD_5$ was observed in AIR lysimeters regardless of loading rate, whereas in the LCH treatment removal was 88 and 83% at 4 and 12 cm/d, respectively. Complete removal of fecal coliform bacteria was observed in both treatments at the lower loading rate, with removal decreasing markedly in LCH lysimeters at the higher load.

Under aeration, soil was a more effective medium for total N removal than silica sand, particularly at the higher loading rate (Table 1). Furthermore, soil exhibited considerably higher removal of total P than sand in the AIR treatment at both loading rates. In contrast, removal of $BOD_5$ and fecal coliform bacteria in AIR lysimeters were similar in sand and soil at both loading rates. Removal of total N and P, $BOD_5$, and fecal coliform bacteria was higher in soil than in sand under LCH conditions at both loading rates (Table 1).

LCH lysimeters exhibited extensive ponding of wastewater (up to 7”) above the soil surface, whereas infiltration of wastewater into soil was complete in the AIR treatment, regardless of hydraulic loading rate.

## CONCLUSIONS

Extensive field evaluation of the SoilAir™ system has shown that it can rejuvenate leachfields treating a wide variety of wastewaters in systems for a range of different configurations. The system improves hydraulic function through enhancement of oxygen levels in leachfield soil, which accelerates decomposition of organic materials at the soil/water interface. Pilot-scale studies suggest that aeration enhances water quality from experimental leachfield lysimeters significantly relative to unaerated lysimeters. Notably, it enhances the removal of total N, $BOD_5$, and fecal coliform bacteria. Furthermore, the positive effects of aeration on water quality are generally not sensitive to the depth of medium employed, and are more marked with native soil as the absorption medium than observed for silica sand. Limited field evaluation of effects of aeration on water quality suggest that removal of nutrients and fecal coliform bacteria in rejuvenated leachfield soil may be as good or better than observed in the laboratory. Current research efforts are aimed at establishing whether the water quality benefits of aeration are observed in additional systems.

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