APPARATUS FOR IN-SITU REMEDIATION USING ACLOSED DELIVERY SYSTEM

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ABSTRACT: In the ever-emerging field of in-situ remediation many strides are being taken to improve the efficacy of degradation. Countless hours and unparalleled research is constantly being performed in order to improve or replace current technologies. These technologies include in-situ chemical oxidation, anaerobic processes, bioaugmentation, zero valent iron, stimulation, etc. Due to the advancements in modern chemistry, modeling, and general understanding of the industry as a whole, there are innumerable options for low cost remediation of contaminated soil and groundwater. In the past, most technical developments concentrated on the actual chemicals of concern or the processes needed for successful degradation, thus arising the need for successful delivery of the remedial compounds into the subsurface. Many technologies fall short of their potential due to an inability to distribute the remedial compounds successfully. A closed, pressurized delivery system has been developed which utilizes a combination of gas and liquid delivery systems in which all delivery vessels are interconnected and valved, allowing for mixings, washings, filling, and discharge of materials via pressurized delivery vessels and mechanical pumping systems. The system utilized allows for a variety of dissimilar compounds to be delivered via a single injection line. Further, the switching between feed systems is accomplished without any loss of pressure to the delivery line eliminating the common problems experienced from the vacuum developed down-hole as pressure is released and reapplied. The flexibility, and thus the field success of the system, is due to the unique configuration of gas and liquid feed systems allowing for greater horizontal infiltration below grade and delivery to low permeability soils such as compacted clays, which is readily accomplished. Lastly, the current system may be mounted in a mobile trailer, being fully self-contained and requiring no electrical external supply. The only site utility requirement is an available water source for slurry preparation.

INTRODUCTION

There are many methods and apparatus purposed for the treatment of contaminated matter. Excavation, incineration, disposal, pump and treat, vacuum extraction, and microbial purification are just a few available options. Excavation requires the removal and transportation of contaminated materials from the subject site in order to be disposed of at an accepted facility. This can be costly due to transportation, backfilling and classification costs, in addition to the fact that buildings may have to be demolished in order to access the contaminated soils. Incineration is another available option. The purpose of incineration is to burn off the contaminants and leave only the clean soil. However, this may be a very expensive process and not very feasible if large volumes of soil need to be treated. Also, it may have pollution side effects of vapor and air pollution while the soil is being removed and moved to the incineration site. Vacuum extraction is a simple and economical purification method, however organochloric compounds in a concentration of several ppm or lower cannot be efficiently removed. Pump and treat systems also tend to fail to meet required cleanup criteria.

In order to solve the problems with the above-described methods many professionals are utilizing a direct push injection technology. This method does not require any digging of the soil, so it can be performed in-situ. In order to perform this in-situ treatment, an apparatus of delivery is needed. The most common and practical practice utilizes a steel injection rod, with an expendable point, forced into the soil, which causes preferential pathways when materials are forced from its terminus, often along the interface between the rod and the soil. The injection rod is a hollow pipe with a discharge hole so that it allows for the injectant to be injected into the contaminated material. This process is not only practical, but also very economical. However, problems still exist. For example, many times the material being injected will follow the path of least resistance, which tends to be the annular space between the injection rod and the soils. These pathways prevent efficient application of remedial materials to the target zone. Switching between feed systems also creates a problem that cannot be accomplished without loss of pressure to the delivery line because of problems experienced from the vacuum developed downhole as pressure is released and reapplied. This is a problem when it is desired, for efficiency, to use a single injection line for the delivery of dissimilar compounds. It is because of these problems experienced from the vacuum developed downhole as pressure is released and reapplied that many remedial technologies fail when transitioned from laboratory to field application. This is a problem that is further exacerbated when it is desired to deliver dissimilar compounds sequentially for appropriate remediation to occur.

DISCUSSION

To alleviate this problem, a hollow injection rod with lateral discharge holes allows for liquids to be injected into the contaminated material and, when performed well, in-situ injections are not only practical but also very economical. The configuration and design of these injection points vary depending on injection sequence and lithology. This is combined with a closed, pressurized delivery system (Figure 1). This system has been devised for in-situ delivery for sub-soil remediation compounds to underground contaminated matter which includes first a liquid diaphragm pump connected to an inflow source of water, the liquid diaphragm pump being also in fluid communication with a plurality of bioslurry tanks connected in parallel, the bioslurry tanks each having a drain. A second liquid diaphragm pump having an inlet port for receiving the combined flow of the bioslurry tanks has an outlet in fluid communication with a system discharge port. The system further includes a source of compressed gas in fluid communication with the discharge port. A discharge rod is connected to the discharge port for delivery of remedial fluids to

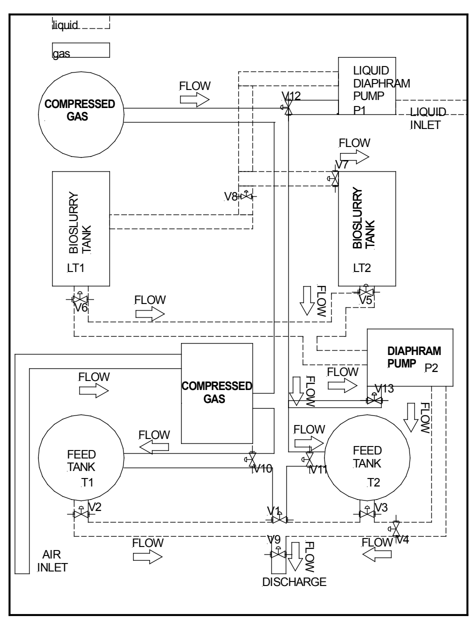

FIGURE 1 Flow Diagram.

underground soils. A gas pressure line leads from a source of compressed gas to the discharge port and is also in fluid communication with a plurality of feed tanks for storage of injectants under pressure, the feed tanks being individually pressurized by the selective fluid communication with the pressure line. Each feed tank includes a separately valved exhaust port connected to the system discharge port such that the source of the injectant may be switched from the bulk feed tanks to any of the feed tanks without loss of delivery pressure.

The above-described closed delivery system utilizes a combination of gas and liquid delivery systems in which all delivery vessels are interconnected and valved, allowing for mixings, washings, filling, and discharge of materials via pressurized delivery vessels and mechanical pumping systems. The system utilized allows for a variety of dissimilar compounds to be delivered via a single injection line. Further, the switching between feed systems is accomplished without any loss of pressure to the delivery line eliminating the common problems experienced from the vacuum developed down-hole as pressure is released and reapplied. The flexibility, and thus the field success of the system, is due to the unique configuration of gas and liquid feed systems allowing for greater horizontal infiltration below grade and delivery to low permeability soils such as compacted clays, which is readily accomplished. Lastly, the current system may be mounted in a mobile trailer, being fully self-contained and requiring no electrical external supply. The only site utility requirement is an available water source for slurry preparation. A schematic of this type of system is shown below (Figure 2).

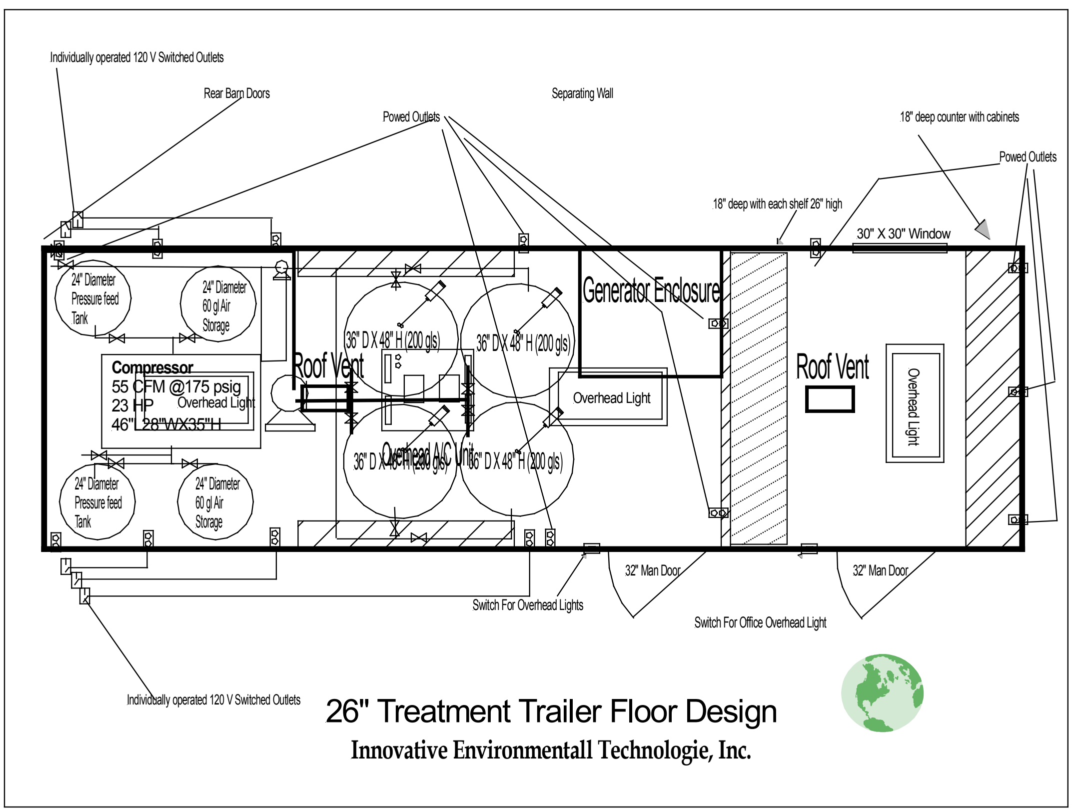

FIGURE 2. Treatment Trailer Floorplan

The typical injection process is as follows:

- *Subsurface Pathway Development*

Initially, compressed gasses such as compressed air, nitrogen or carbon dioxide shall be delivered to the subsurface via the injection trailer system. Nitrogen or CO_2 gas is used so as not to introduce oxygen into an environment targeted for anaerobic processes. The gas is introduced at approximately 175 psi, such that delivery pathways and voids are established. Pathway development shall be verified by observing a substantial pressure drop.

- *Sequenced Remedial Compound Injections*

A solution that prepares the subsurface for remedial processes is immediately injected into the subsurface fractures and voids that were developed during the gas injection step. This may include but is not limited to Oxygen scavengers for anaerobic processes, dilute H2O2 for aerobic processes, pH adjusts or colloidal zero valent iron using a Fenton's reagent

- *Remedial Compound Injections*

This step introduces the main components of the remedial process such as viscous liquids (lactates, butyrate,) peroxides, permanganates, colloidal suspensions, etc.

- *Liquid Rinse*

This injection is conducted to clear the injection lines and to provide for in-situ mixing and penetration of the main remedial products. This step will usually contain much of the same preparatory liquids used in the second step.

- *Post Liquid Injection - Gas Injection*

Lastly, the injection lines are cleared of liquids and all injectants are forced into the created formation and upward into the vadose zone.

Once the injection cycle is complete, the injection point is temporarily capped to allow for the pressurized subsurface to accept the injectants. Once backpressure diminishes, the injection rods are extracted. Injection boring locations are then sealed with bentonite to prevent short-circuiting from adjacent injection locations.

CONCLUSIONS

The science of delivering, monitoring and verifying in-situ biological mineralization via augmentation with, or without stimulation, at any depth, is often poorly or incompletely accomplished. In part, this is due to partitioning of responsibility in the field. Delivery is frequently assigned to a drilling subcontractor who has little experience with the complex chemistry and physics associated with multi-component remedial programs. The development of an effective closed delivery system capable of introducing a variety of remedial compounds has been a genesis. The first systems utilized off-the-shelf pumping systems, however there were several issues encounter with the systems' application in the field. Most of the pumping systems utilized developed only minimal lateral infiltration and frequently produced vertical pathways for the introduced liquids.

Based on the field experiences of the early systems, the most current delivery system utilizes a combination of gas and liquid delivery systems. All of the vessels are interconnected and valved, allowing for mixings, washing, filling and discharge of materials via pressure vessels or mechanical pumping systems. The field pilot system to be utilized in the demonstration of biological stimulation products allows for a variety of dissimilar compounds to be delivered via a single injection line. Further, switching between feed systems is accomplished without any loss of pressure to the delivery line eliminating the common problems experienced from the vacuum developed down-hole as pressure is released and reapplied. Lastly, the current system is fully self-contained requiring no electrical supply. The only site utility requirement is an available water source for slurry preparation.

The value of the interconnection of the liquid and gas systems has been demonstrated at a variety of sites where effective delivery of remedial agents necessitated alternating pulsing between the liquid and gas phases. In many of the applications, where heating of the delivered compound(s) to temperatures in excess of 180^{o} Fahrenheit was necessary to accomplish optimal lateral delivery the system has performed flawlessly.

By utilizing the closed delivery system a variety of liquids, gases and colloidal suspensions may be effectively delivered to targeted hydro geological zones at pressures, which allow for maximum lateral penetration without the creation of new subsurface fractures. To date Innovative Environmental Technologies has injected via the system lactates, nutrient augmentation packages, liquid heterotrophs, colloidal iron suspensions, sodium and potassium permanganates and mixtures thereof, oxygen scavenger compounds, HRC, ORC, calcium peroxide, hydrogen peroxide and viscous liquids. These materials were delivered via the on-board compressor, nitrogen or CO_2 tube trailers based on site-specific needs.