

# US Patent & Trademark Office

## Patent Public Search | Text View

---

United States Patent	12391585
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Sato; Yugo et al.

---

### System and method for performing electrochemically-cycled oxidation on landfill leachate

---

#### Abstract

A system and method for performing electrochemically-cycled oxidation on landfill leachate are provided for the removal of organic materials in landfill leachate which have an ultraviolet absorbance at 254 nm (UVA.sub.254), thus pre-treating the landfill leachate for co-treatment through dilution with municipal sewage. Electrochemical oxidation is performed on the landfill leachate in a first reactor chamber to produce hypochlorite (OCl.sup.-), followed by delayed application of ultraviolet radiation to produce hydroxyl radicals (OH.sup.●) and reactive chlorine species to break bonds in the organic materials. A portion of this partially-treated landfill leachate is then fed to a second reactor chamber for subsequent dichlorination through ultraviolet photolysis. An equivalent volume of fresh landfill leachate is fed into the first reactor chamber to begin the cycle again, allowing for continuous treatment of a source of landfill leachate.

---

**Inventors:** Sato; Yugo (Kowloon, HK), Chen; Guanghao (Kowloon, HK), Liu; Yuewei (Kowloon, HK)

**Applicant:** THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY (Kowloon, HK)

**Family ID:** 1000008767624

**Assignee:** THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY (Hong Kong, CN)

**Appl. No.:** 18/195243

**Filed:** May 09, 2023

#### Prior Publication Data

<b>Document Identifier</b>	<b>Publication Date</b>
US 20230365441 A1	Nov. 16, 2023

## Related U.S. Application Data

us-provisional-application US 63340409 20220510

---

## Publication Classification

**Int. Cl.:** **C02F1/467** (20230101); **C02F1/32** (20230101); **C02F1/461** (20230101); **C02F103/06** (20060101)

**U.S. Cl.:**

**CPC** **C02F1/4674** (20130101); **C02F1/325** (20130101); **C02F1/46109** (20130101); C02F2001/46133 (20130101); C02F2103/06 (20130101); C02F2201/4614 (20130101); C02F2201/4615 (20130101); C02F2201/4617 (20130101); C02F2303/185 (20130101); C02F2305/023 (20130101)

## Field of Classification Search

**CPC:** C02F (1/325); C02F (1/32); C02F (1/4674); C02F (1/4672); C02F (1/46109); C02F (2103/069); C02F (2201/4614); C02F (2201/4615); C02F (2201/4617); C02F (2303/185); C02F (2305/023)

**USPC:** 210/748.13

---

## References Cited

### U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2013/0327353	12/2012	Field	134/1	B08B 7/00

### FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
101734750	12/2009	CN	N/A
102219328	12/2010	CN	N/A
1160203	12/2000	EP	N/A
3400942	12/2002	JP	N/A

### OTHER PUBLICATIONS

Montanaro et al, "UV-assisted electrochemical degradation of coumarin on boron-doped diamond electrodes", Chemical Engineering Journal 323, pp. 512-519 (Year: 2017). cited by examiner  
Xiao, Shuhu, et al. "Degradation of biologically treated landfill leachate by using electrochemical process combined with UV irradiation." Separation and Purification Technology 117 (2013): 24-29. cited by applicant

Ye, Zhihong, et al. "Treatment of landfill leachate using electrochemically assisted UV/chlorine process: effect of operating conditions, molecular weight distribution and fluorescence EEM-PARAFAC analysis." Chemical Engineering Journal 286 (2016): 508-516. cited by applicant

Ren, Xu, et al. "Treatment of membrane concentrated leachate by two-stage electrochemical process enhanced by ultraviolet radiation: performance and mechanism." Separation and Purification Technology 259 (2021): 118032. cited by applicant

*Primary Examiner:* Norris; Claire A

*Attorney, Agent or Firm:* Nath, Goldberg & Meyer

---

## **Background/Summary**

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application claims the benefit of U.S. Provisional Patent Application No. 63/340,409, filed on May 10, 2022.

### **BACKGROUND OF THE INVENTION**

#### **Field of the Invention**

(1) The disclosure of the present patent application relates to the pre-treatment of landfill leachate for co-treatment through dilution with municipal sewage, and particularly to a multi-stage process including electrochemical oxidation and photolysis to remove organic materials in the landfill leachate which have an ultraviolet absorbance at 254 nm (UVA.sub.254).

#### **Description of Related Art**

(2) Leachate from landfills varies widely in composition, depending on both the age of the landfill and the type of waste that it contains. Landfill leachate is primarily created from precipitation percolating through waste deposited in the landfill. Once in contact with decomposing solid waste, the percolating water becomes contaminated, flowing out of the waste material as, primarily, a solution and suspension of various waste products. Additional leachate volume is produced during this decomposition of carbonaceous material, producing a wide range of other materials including methane, carbon dioxide and a complex mixture of organic acids, aldehydes, alcohols and simple sugars.

(3) On-site treatment is commonly applied to landfill leachate prior to its discharge into the environment. Such on-site treatment is typically in the form of a multistage treatment process which is both complex and costly. A common alternative to on-site treatment is co-treatment through dilution of the landfill leachate with municipal sewage. As of 2019, approximately 18 million metric tons of landfill leachate had been co-treated into municipal sewage lines in the United States. In the North East New Territories landfill in Hong Kong, around 1,000 metric tons of landfill leachate is co-treated daily.

(4) Although such co-treatment is far less costly than on-site treatment, co-treatment has been found to be detrimental to the downstream wastewater treatment plant. Landfill leachate contains dissolved organic matter (DOM) at high concentrations. The DOM, when discharged into municipal sewage lines, can absorb ultraviolet (UV) light during the UV disinfection stage at the downstream wastewater treatment plant. Since the DOM absorbs the UV light, the UV power output must be increased to have the same effect it would have on just the wastewater. This increases the overall costs of treatment, along with adding related costs, such as more frequent replacement of UV lamps. The absorption of the UV light by the DOM also increases risks to the general population due to the potential for incomplete or insufficient wastewater disinfection. Thus, in order to mitigate these problems inherent in co-treatment, ultraviolet absorbance at 254 nm must be reduced in the landfill leachate prior to its co-treatment with wastewater.

(5) It has been found that approximately 90% of the materials in the landfill leachate which have an ultraviolet absorbance at 254 nm (UVA.sub.254) derive from small recalcitrant molecules below 1 kDa, thus making conventional treatment methods, such as coagulation-sedimentation and biological treatment, ineffective in reducing the UVA<sub>254</sub>. For this reason, biological treatment has

been found to only reduce between 20-30% of the UVA<sub>254</sub>. Furthermore, advanced filtration processes, such as nanofiltration and reverse osmosis, require high chemical consumption for membrane cleaning and fouling prevention, thus making them costly, both economically and in terms of time. These technologies also generate a secondary waste, referred to as leachate concentrate, which can contain up to 20 times the original leachate concentration with limited options for treatment. Leachate concentrate is also disposed via co-treatment with municipal wastewater, thus, regardless of treatment, the fate of landfill leachate is sewage co-treatment. Therefore, an economic practice to facilitate on-site leachate to sewage co-treatment is necessary.

(6) Advanced oxidation processes (AOPs), such as Fenton oxidation and electrochemical oxidation, have been tested for treating landfill leachate. These processes destroy the organic matter in the leachate to reduce the UVA<sub>254</sub>. However, Fenton oxidation requires expensive hydrogen peroxide dosing to be activated by a non-regenerative catalyst (e.g., iron). Electrochemical oxidation, on the other hand, generates the oxidant in situ through the conversion of chloride in the leachate. The generated product is primarily hypochlorite (OCl<sup>-</sup>), hydroxyl radicals (OH<sup>•</sup>), and reactive chlorine species (RCS), which rapidly attack the organic bonds which bear UVA<sub>254</sub>. Between the three, the order of reactivity is OH<sup>•</sup>>RCS>OCl<sup>-</sup>, although OH<sup>•</sup> and RCS require toxic or fragile electrode coatings for generation.

(7) An alternative to the above electrochemical oxidation technique is to generate OCl<sup>-</sup> with affordable electrodes (e.g., mixed metal oxides) and apply UV radiation to photolyze the OCl<sup>-</sup> into OH<sup>•</sup> and RCS. However, in testing, application of this alternative on landfill leachate required 2-8 hours of treatment, resulting in an energy expenditure of over 260 kWh/m<sup>3</sup>. Electrochemical technologies have strong benefits, such as facile maintenance, no chemical addition, and flexible adjustments to match the desired degradation. Thus, a system and method for performing electrochemically-cycled oxidation on landfill leachate solving the aforementioned problems are desired.

## SUMMARY OF THE INVENTION

(8) The system for performing electrochemically-cycled oxidation on landfill leachate includes a housing divided into first and second reactor chambers. The housing has an inlet adapted for introducing a stream of landfill leachate to be treated into the first reactor chamber, and further has an outlet for releasing a stream of fully treated landfill leachate from the second reactor chamber. An anode and a cathode are received within the first reactor chamber and are connected to an electrical power supply, which may be a direct current (DC) power supply. The anode is made from a metal oxide, such as IrO<sub>2</sub>, RuO<sub>2</sub> or Ta<sub>2</sub>O<sub>5</sub>, and the anode and cathode are used to perform electrochemical oxidation on the landfill leachate in the first reactor chamber to produce hypochlorite (OCl<sup>-</sup>).

(9) At least one first source of ultraviolet radiation is received within the first reactor chamber for applying first ultraviolet radiation to the landfill leachate and the hypochlorite (OCl<sup>-</sup>) following initiation of the electrochemical oxidation of the landfill leachate. The application of the first ultraviolet radiation to the hypochlorite (OCl<sup>-</sup>) produces hydroxyl radicals (OH<sup>•</sup>) and reactive chlorine species (RCS). The hypochlorite (OCl<sup>-</sup>), the hydroxyl radicals (OH<sup>•</sup>) and the reactive chlorine species break bonds in organic materials in the landfill leachate which have an ultraviolet absorbance at 254 nm (UVA<sub>254</sub>), resulting in a partially-treated landfill leachate.

(10) The first ultraviolet radiation is applied to the landfill leachate and the hypochlorite (OCl<sup>-</sup>) beginning at a time between 5 and 20 minutes after the initiation of the electrochemical oxidation of the landfill leachate; i.e., application of the first ultraviolet radiation is delayed by 5 to 20 minutes following initiation of the electrochemical oxidation. The electrochemical oxidation is performed with an electrooxidation current density between 100 A/m<sup>2</sup> and 300 A/m<sup>2</sup>, and the first ultraviolet radiation is applied to the landfill leachate and the hypochlorite (OCl<sup>-</sup>) with an ultraviolet (UV) fluence of between 5 mW/cm<sup>2</sup> and 40 mW/cm<sup>2</sup>.

- (11) At least one second source of ultraviolet radiation is received within the second reactor chamber. A portion of the partially-treated landfill leachate flows into the second reactor chamber such that application of second ultraviolet radiation produced by the at least one second source of ultraviolet radiation thereon removes residual chlorine therefrom by photolysis to produce the fully treated landfill leachate. The at least one second source of ultraviolet radiation applies the second ultraviolet radiation with a UV fluence of between 5 mW/cm<sup>2</sup> and 40 mW/cm<sup>2</sup> for a period of 5 to 10 minutes. A one-way conduit may be provided for one-way transport of the partially-treated landfill leachate from the first reactor chamber to the second reactor chamber. The fully treated landfill leachate is extracted from the second reactor chamber through the outlet.
- (12) After the portion of the partially-treated landfill leachate flows into the second reactor chamber, fresh landfill leachate may be fed into the first reactor chamber. The fresh landfill leachate has a volume equal to the volume of the portion of the partially-treated landfill leachate in the second reactor chamber prior to the extraction thereof. Following the feeding of the fresh landfill leachate into the first reactor chamber, the method for performing electrochemically-cycled oxidation on landfill leachate may be reinitiated, allowing for continuous processing and treatment of a source of landfill leachate.
- (13) These and other features of the present subject matter will become readily apparent upon further review of the following specification.
- 

## Description

### BRIEF DESCRIPTION OF DRAWINGS

- (1) FIG. 1 schematically illustrates a system for performing electrochemically-cycled oxidation on landfill leachate.
- (2) FIG. 2 is a plot showing UV absorbance at 254 nm in landfill leachate as a function of time during both an initial phase and a recycled phase of the method for performing electrochemically-cycled oxidation on landfill leachate using the system of FIG. 1.
- (3) FIG. 3 is a plot showing residual chlorine concentration as a function of time in the initial phase and the recycled phase of FIG. 2.
- (4) FIG. 4 is a graph showing the concentrations of chlorinated by-products released following the method for performing electrochemically-cycled oxidation on landfill leachate.
- (5) Similar reference characters denote corresponding features consistently throughout the attached drawings.

### DETAILED DESCRIPTION

- (6) As shown in FIG. 1, the system for performing electrochemically-cycled oxidation on landfill leachate **10** includes a housing **11** divided into first and second reactor chambers **12**, **14**, respectively. The housing **11** has an inlet **16** adapted for introducing a stream of landfill leachate (LL) to be treated into the first reactor chamber **12**, and further has an outlet **18** for releasing a stream of fully treated landfill leachate (FTLL) from the second reactor chamber **14**. A cathode **20** and an anode **22** are received within the first reactor chamber **12** and are connected to an electrical power supply (V), which may be a direct current (DC) power supply. The anode **22** is made from a metal oxide, such as IrO<sub>2</sub>, RuO<sub>2</sub> or Ta<sub>2</sub>O<sub>5</sub>, and the anode **22** and the cathode **20** are used to perform electrochemical oxidation on the landfill leachate in the first reactor chamber **12** to produce hypochlorite (OCl<sup>-</sup>). The cathode **20** may be formed from any suitable electrode material for electrochemically oxidizing landfill leachate, such as titanium or the like.
- (7) As shown in FIG. 1, one or more magnetic stirrers **30** may be provided in the first reactor chamber **12** for continuously mixing and stirring the landfill leachate during processing thereof. It should, however, be understood that the one or more magnetic stirrers **30** are shown for exemplary purposes only, and that any suitable type of mixers, stirrers, agitators or the like may be used. As a

non-limiting example, the one or more magnetic stirrers **30** may be replaced by, or augmented with, impellers appropriate for continuous mixing of large-scale systems.

(8) Further, it should be understood that the overall configuration of the system for performing electrochemically-cycled oxidation on landfill leachate **10** is shown for exemplary purposes only, and that the positioning, relative dimensions and shape of the first and second reactor chambers **12**, **14**, respectively, may be varied. As a further non-limiting alternative, first and second reactor chambers **12**, **14** may be spatially separated from one another, either within the same overall housing **11** or located within individual separate housings or units. In such an alternative configuration, it should be understood that any suitable type of conduits or other hardware or mechanisms may be provided to transfer the treated leachate in first reactor chamber **12** to the second reactor chamber **14** upon sufficient treatment thereof.

(9) At least one first source of ultraviolet radiation **24** is received within the first reactor chamber **12** for applying first ultraviolet radiation to the landfill leachate and the hypochlorite (OCl.sup.-) following initiation of the electrochemical oxidation of the landfill leachate. In FIG. **1**, eight ultraviolet bulbs **24** are illustrated, however, it should be understood that this is for purposes of illustration only, and that any suitable type and any suitable number of ultraviolet radiation sources may be used.

(10) The application of the first ultraviolet radiation to the hypochlorite (OCl.sup.-) produces hydroxyl radicals (OH.sup.●) and reactive chlorine species (RCS). The hypochlorite (OCl.sup.-), the hydroxyl radicals (OH.sup.●) and the reactive chlorine species break bonds in organic materials in the landfill leachate which have an ultraviolet absorbance at 254 nm (UVA.sub.254), resulting in a partially-treated landfill leachate (PTLL).

(11) The first ultraviolet radiation is applied to the landfill leachate and the hypochlorite (OCl.sup.-) beginning at a time between 5 and 20 minutes after the initiation of the electrochemical oxidation of the landfill leachate; i.e., application of the first ultraviolet radiation is delayed by 5 to 20 minutes following initiation of the electrochemical oxidation. The electrochemical oxidation is performed with an electrooxidation current density between 100 A/m.sup.2 and 300 A/m.sup.2, and the first ultraviolet radiation is applied to the landfill leachate and the hypochlorite (OCl.sup.-) with an ultraviolet (UV) fluence of between 5 mW/cm.sup.2 and 40 mW/cm.sup.2. The combination of electrochemical oxidation and application of the first ultraviolet radiation is performed for approximately 60 minutes, which reduces the UVA.sub.254 content of the landfill leachate by approximately 80%.

(12) At least one second source of ultraviolet radiation **26** is received within the second reactor chamber **14**. In FIG. **1**, six ultraviolet bulbs **26** are illustrated, however, it should be understood that this is for purposes of illustration only, and that any suitable type and any suitable number of ultraviolet radiation sources may be used. A portion of the partially-treated landfill leachate flows into the second reactor chamber **14** such that application of second ultraviolet radiation produced by the at least one second source of ultraviolet radiation **26** thereon removes residual chlorine therefrom by photolysis to produce the fully treated landfill leachate. Between 5% and 50% (by volume) of the partially-treated landfill leachate from the first reactor chamber **12** is transported into the second reactor chamber **14** for subsequent dechlorination. An equivalent volume of fresh landfill leachate is fed into the first reactor chamber **12** through inlet **16**. A one-way conduit **28** may be provided for one-way transport of the partially-treated landfill leachate from the first reactor chamber **12** to the second reactor chamber **14**. As shown in FIG. **1**, one or more magnetic stirrers **31** may be provided in the second reactor chamber **14** for continuously mixing and stirring the landfill leachate during processing thereof. The fully treated landfill leachate is extracted from the second reactor chamber **14** through the outlet **18**. As shown, release of the fully treated landfill leachate may be controlled by a timer valve **32** or the like.

(13) Photolysis within the second reactor chamber further reduces the UVA.sub.254 content of the partially-treated landfill leachate by 15-20%. The at least one second source of ultraviolet radiation

26 applies the second ultraviolet radiation with a UV fluence of between 5 mW/cm<sup>2</sup> and 40 mW/cm<sup>2</sup> for a period of 5 to 10 minutes. Continuous operation of the system for performing electrochemically-cycled oxidation on landfill leachate **10** with the above parameters results in a treatment process with an energy requirement of less than 20 kWh/m<sup>3</sup>.

(14) After the portion of the partially-treated landfill leachate flows into the second reactor chamber **14**, as noted above, fresh landfill leachate may be fed into the first reactor chamber **12**. The fresh landfill leachate has a volume equal to the volume of the portion of the partially-treated landfill leachate in the second reactor chamber prior to the extraction thereof. Thus, following the feeding of the fresh landfill leachate into the first reactor chamber **12**, where it mixes with the partially-treated landfill leachate already contained therein, the method for performing electrochemically-cycled oxidation on landfill leachate may be reinitiated. Whereas the initial phase of treatment in the first reactor chamber **12** is run for approximately 60 minutes, the recycled phase in the first reactor chamber **12** (i.e., where the fresh landfill leachate is mixed with the remaining partially-treated landfill leachate) is only run for 10 to 15 minutes, reducing the chlorine contact time to reduce toxic by-products in the leachate.

(15) FIG. 2 is a plot showing UV absorbance at 254 nm in landfill leachate as a function of time during both the initial phase and the recycled phase. As shown, in the initial phase, the amount of UVA<sub>254</sub> ranges from 9 cm<sup>-1</sup> to 15 cm<sup>-1</sup>, and over the course of 60 minutes of treatment in the initial phase, the amount of UVA<sub>254</sub> is decreased by approximately 80%. Since the recycled phase is performed in the first reactor chamber **12** using a mixture of fresh landfill leachate and the remaining partially-treated landfill leachate, as expected, the amount of UVA<sub>254</sub> is greater at the start than the amount of UVA<sub>254</sub> at the end of the initial phase, but it rapidly decreases in a limited time period of about 15 minutes.

(16) FIG. 3 is a plot showing residual chlorine concentration as a function of time in the initial phase and the recycled phase. Due to the intentional production of hypochlorite (OCl<sup>-</sup>), hydroxyl radicals (OH<sup>•</sup>) and reactive chlorine species, as discussed above, as expected, the residual chlorine concentration in the initial phase (within the first reactor chamber **12**) begins at zero and steadily increases throughout the entire 60 min. cycle. The second reactor chamber **14** relieves the residual chlorine to below 25 mg/L as Cl<sub>2</sub> after each continuous cycle. At 3.5% v/v sewage co-treatment, as practiced in Hong Kong, the residual chlorine which enters the sewage line is below 1 mg/L as Cl<sub>2</sub>.

(17) FIG. 4 is a graph showing the concentrations of chlorinated by-products released following the method for performing electrochemically-cycled oxidation on landfill leachate, particularly showing the concentrations of trichloromethane (TCM), chloral hydrate (CH), dichloropropanone (DCP), trichloropropanone, (TCP), dichloroacetonitrile (DCAN), and trichloronitromethane (TCNM) after treatment and 3.5% v/v dilution into sewage co-treatment. The World Health Organization (WHO) upper limit for TCM is 200 µg/m<sup>3</sup> and the predicted no-effect concentration (PNEC) is 146 µg/m<sup>3</sup>. As shown, the method for performing electrochemically-cycled oxidation on landfill leachate yields a TCM concentration far below either value, clearly indicating that the method for performing electrochemically-cycled oxidation on landfill leachate is safe for use.

(18) It is to be understood that the system and method for performing electrochemically-cycled oxidation on landfill leachate are not limited to the specific embodiments described above, but encompasses any and all embodiments within the scope of the generic language of the following claims enabled by the embodiments described herein, or otherwise shown in the drawings or described above in terms sufficient to enable one of ordinary skill in the art to make and use the claimed subject matter.

## Claims

1. A system for performing electrochemically-cycled oxidation on landfill leachate, comprising: a housing divided into first and second reactor chambers, the housing having an inlet adapted for introducing a stream of landfill leachate to be treated into the first reactor chamber, and the housing further having an outlet for releasing a stream of fully treated landfill leachate from the second reactor chamber; an anode and a cathode received within the first reactor chamber, wherein the anode comprises a metal oxide; an electrical power supply connected to the anode and the cathode, wherein electrochemical oxidation is performed on the landfill leachate in the first reactor chamber to produce hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ); at least one first source of ultraviolet radiation received within the first reactor chamber, wherein the at least one source of ultraviolet radiation applies first ultraviolet radiation to the landfill leachate and the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) following initiation of the electrochemical oxidation of the landfill leachate, wherein the application of the first ultraviolet radiation to the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) produces hydroxyl radicals ( $\text{OH}^{\text{sup.}\bullet}$ ) and reactive chlorine species, the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ), the hydroxyl radicals ( $\text{OH}^{\text{sup.}\bullet}$ ) and the reactive chlorine species breaking bonds in organic materials in the landfill leachate which have an ultraviolet absorbance at 254 nm, resulting in a partially-treated landfill leachate; and at least one second source of ultraviolet radiation received within the second reactor chamber, a portion of the partially-treated landfill leachate flowing into the second reactor chamber such that application of second ultraviolet radiation produced by the at least one second source of ultraviolet radiation thereon removes residual chlorine therefrom by photolysis to produce the fully treated landfill leachate, the fully treated landfill leachate being extracted from the second reactor chamber through the outlet.
2. The system for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 1, wherein the electrical power supply comprises a DC power supply.
3. The system for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 1, wherein the metal oxide of the anode is selected from the group consisting of  $\text{IrO}_2$ ,  $\text{RuO}_2$  and  $\text{Ta}_2\text{O}_5$ .
4. The system for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 1, wherein the first ultraviolet radiation is applied to the landfill leachate and the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) beginning at a time between 5 and 20 minutes after the initiation of the electrochemical oxidation of the landfill leachate.
5. The system and method for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 1, further comprising a one-way conduit for passing the partially-treated landfill leachate from the first reactor chamber to the second reactor chamber.
6. The system for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 1, wherein the electrochemical oxidation is performed with an electrooxidation current density between 100  $\text{A/m}^2$  and 300  $\text{A/m}^2$ .
7. The system for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 6, wherein the first ultraviolet radiation is applied to the landfill leachate and the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) with an ultraviolet fluence of between 5  $\text{mW/cm}^2$  and 40  $\text{mW/cm}^2$ .
8. The system for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 7, wherein the at least one second source of ultraviolet radiation applies the second ultraviolet radiation with an ultraviolet fluence of between 5  $\text{mW/cm}^2$  and 40  $\text{mW/cm}^2$ .
9. A method for performing electrochemically-cycled oxidation on landfill leachate, comprising the steps of: performing electrochemical oxidation on landfill leachate in a first reactor chamber to produce hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ); applying first ultraviolet radiation to the landfill leachate and the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) following initiation of the electrochemical oxidation of the landfill leachate, wherein the application of the first ultraviolet radiation to the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) produces hydroxyl radicals ( $\text{OH}^{\text{sup.}\bullet}$ ) and reactive chlorine species, the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ), the hydroxyl radicals ( $\text{OH}^{\text{sup.}\bullet}$ ) and the reactive chlorine species breaking bonds in organic



materials in the landfill leachate which have an ultraviolet absorbance at 254 nm, resulting in a partially-treated landfill leachate; applying second ultraviolet radiation to a portion of the partially-treated landfill leachate in a second reactor chamber to remove residual chlorine therefrom by photolysis to produce a fully treated landfill leachate; and extracting fully treated landfill leachate from the second reactor chamber.

10. The method for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 9, further comprising the step of feeding fresh landfill leachate into the first reactor chamber, the fresh landfill leachate having a volume equal to a volume of the portion of the partially-treated landfill leachate in the second reactor chamber prior to the extraction thereof from the second reactor chamber.

11. The method for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 10, wherein, following the step of feeding the fresh landfill leachate into the first reactor chamber, the method for performing electrochemically-cycled oxidation on landfill leachate is reinitiated.

12. The method for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 9, wherein the step of applying the first ultraviolet radiation to the landfill leachate and the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) begins at a time between 5 and 20 minutes after initiation of the electrochemical oxidation of the landfill leachate.

13. The method for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 9, wherein the step of performing the electrochemical oxidation is performed with an electrooxidation current density between 100 A/m<sup>2</sup> and 300 A/m<sup>2</sup>.

14. The method for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 13, wherein the first ultraviolet radiation is applied to the landfill leachate and the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) with an ultraviolet fluence of between 5 mW/cm<sup>2</sup> and 40 mW/cm<sup>2</sup>.

15. The method for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 14, wherein the second ultraviolet radiation is applied to the partially-treated landfill leachate with an ultraviolet fluence of between 5 mW/cm<sup>2</sup> and 40 mW/cm<sup>2</sup>.

16. A system for performing electrochemically-cycled oxidation on landfill leachate, comprising: a housing divided into first and second reactor chambers, the housing having an inlet adapted for introducing a stream of landfill leachate to be treated into the first reactor chamber, and the housing further having an outlet for releasing a stream of fully treated landfill leachate from the second reactor chamber; an anode and a cathode received within the first reactor chamber, wherein the anode comprises a metal oxide; an electrical power supply connected to the anode and the cathode, wherein electrochemical oxidation is performed on the landfill leachate in the first reactor chamber to produce hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ); at least one first source of ultraviolet radiation received within the first reactor chamber, wherein the at least one source of ultraviolet radiation applies first ultraviolet radiation to the landfill leachate and the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) following initiation of the electrochemical oxidation of the landfill leachate, wherein the application of the first ultraviolet radiation to the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ) produces hydroxyl radicals ( $\text{OH}^{\text{sup.}\bullet}$ ) and reactive chlorine species, the hypochlorite ( $\text{OCl}^{\text{sup.}-}$ ), the hydroxyl radicals ( $\text{OH}^{\text{sup.}\bullet}$ ) and the reactive chlorine species breaking bonds in organic materials in the landfill leachate which have an ultraviolet absorbance at 254 nm, resulting in a partially-treated landfill leachate; a one-way conduit for passing a portion of the partially-treated landfill leachate from the first reactor chamber to the second reactor chamber; and at least one second source of ultraviolet radiation received within the second reactor chamber, such that application of second ultraviolet radiation produced by the at least one second source of ultraviolet radiation on the portion of the partially-treated landfill leachate in the second reactor chamber removes residual chlorine therefrom by photolysis to produce the fully treated landfill leachate, the fully treated landfill leachate being extracted from the second reactor chamber through the outlet.

17. The system for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 16, wherein the metal oxide of the anode is selected from the group consisting of  $\text{IrO}_2$ ,  $\text{RuO}_2$  and  $\text{Ta}_2\text{O}_5$ .

18. The system for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 16, wherein the first ultraviolet radiation is applied to the landfill leachate and the hypochlorite ( $\text{OCl}^-$ ) beginning at a time between 5 and 20 minutes after the initiation of the electrochemical oxidation of the landfill leachate.

19. The system and method for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 16, wherein the electrochemical oxidation is performed with an electrooxidation current density between  $100 \text{ A/m}^2$  and  $300 \text{ A/m}^2$ .

20. The system for performing electrochemically-cycled oxidation on landfill leachate as recited in claim 19, wherein the first ultraviolet radiation is applied to the landfill leachate and the hypochlorite ( $\text{OCl}^-$ ) with an ultraviolet fluence of between  $5 \text{ mW/cm}^2$  and  $40 \text{ mW/cm}^2$ , and wherein the at least one second source of ultraviolet radiation applies the second ultraviolet radiation with an ultraviolet fluence of between  $5 \text{ mW/cm}^2$  and  $40 \text{ mW/cm}^2$ .

---