

### Composition and Method for Remediation of PFAS Contaminants.

5        [0001] The present application claims the benefit of U.S. Provisional Application No. 63/534,880, filed August 28, 2023.

### TECHNICAL FIELD

10       [0002] This invention pertains to a composition for remediation of PFOS, PFAS and AFFF contaminants. More particularly, the invention pertains to a composition for remediating soil, bedrock, groundwater, and impermeable surfaces of PFAS contaminants.

### 15       BACKGROUND ART

      [0003] Perfluorooctanoic acid (PFOA) is an anthropogenic perfluorinated carboxylic acid produced and used worldwide as an industrial surfactant. This product is known as an emerging health concern and subject of regulatory action and  
20       voluntary industrial phase-outs.

      [0004] Perfluorooctanesulfonic acid (PFOS) is anthropogenic fluorosurfactant and a global pollutant. PFOS was the key ingredient in numerous stain repellants. PFOS is a toxic anthropogenic chemical that has been produced and gradually  
25       released into the environment for the past seven decades. Trace levels concentrations of PFOS in aquatic media can pose significant risks to living organisms, such as immunotoxicity, hepatotoxicity, renal toxicity, and carcinogenicity, as well as development and reproductive effects, according to a report published by Lau et al in 2007. (Lau, C. Anitole, K. Hodes, C., Lai, D.,  
30       Pfahles-Hutchens, A., Seed, J., 2007. Perfluoroalkyl acids: A review of monitoring and toxicological findings. Toxicol, Sci., 99, 366-394).

[0005] Aqueous Film Forming Foam (AFFF) is a fire suppressant used to extinguish flammable liquid fires such as fuel fires. AFFF is often used in shipboard and shore facility fire suppression systems, fire vehicles, and at firefighting training facilities. Many AFFF formulations contain PFAS and larger and smaller C<sub>8</sub> carbon-chain derivatives, and therefore AFFF is also treated as a serious contaminant in a same way as PFAS and PFOS.

[0006] Due to the extreme stability of the PFAS compounds, they are referred to as “forever chemicals”. Given the toxicity and longevity of these compounds, there is an urgent need for the development of methods and products to remove PFAS from contaminated soils, bedrock, groundwater, and impermeable surfaces in the vicinity of human habitat, food sources and livelihood spaces.

[0007] In a self-proclaimed “first study” made to assess the capacity of in situ flushing technology to remediate PFOS contaminated soil and ground water, the authors demonstrated a 98% PFOS removal by flushing soil beds with five bed volumes of 50% ethanol solution. This report is entitled: (In situ soil flushing to remediate confined soil contaminated with PFOS - an innovative solution for emerging environmental issue, by S.T.M.L.D. Senevirathna, Reza Mahinroosta, Miao Li, and Karthika Krishna Pillai, from Charles Sturt University, Bathurst, Australia. This report was published in Chemosphere, Volume 262, January 2021, Ref 127606). This document is also referred to herein as the Australia report.

[0008] The remediation efficiency of ethanol as described in the above-mentioned report is exceptional. However, the use of a 50% ethanol solution to remediate larger sites approaching one acre or more in situ, for example, would be financially unfeasible, and presents fire hazards and occupational health concerns, and requires transportation as a dangerous good.

[0009] In another perspective, of which the relevance will be understood in the following pages, Ivey International, Inc. (# 7, 19122-27 Avenue, Surrey, British Columbia, V3Z 5T1, Canada) manufactures surfactants for in situ decontamination of soils, bedrock, and groundwater contaminated with a wide range of Non-Aqueous Phase Liquids (NAPL), globules, and sorbed phase paint thinner, gasoline, diesel fuel, kerosene, lubricants, Bunker C oil and chlorinated dry cleaning-type chemicals. The company's products are known under the trademarks Ivey-sol™ 103, Ivey-sol™ 106, Ivey-sol™ 106CI, and Ivey-sol™ 108.

[00010] Ivey-sol™ is a registered trademark. The “trademark symbol ™ is omitted hereinafter, and the registered attribute is acknowledged by using a bold font, for convenience.

[00011] The precursors of **Ivey-sol 103**, **Ivey-sol 106**, **Ivey-sol 106CI**, and **Ivey-sol 108** are described in US Patent **6,319,882**, issued on November 20, 2001, to George A. Ivey. These surfactants have been used successfully around the world for the last twenty-plus years. The four surfactants mentioned above are part of a family of **IVEY** surfactants that can be tailored to suit different contaminants, situations, and hydrogeological conditions. This family of **IVEY** surfactants are referred to herein as the **IVEY** surfactants.

[00012] Because of a civic duty, by curiosity, or by business interest, Ivey International, Inc. has dedicated some research time and resources for studying and experimenting on the possibility of developing a method or a compound suitable for in situ decontamination of soil, bedrock, and groundwater, and impermeable surfaces of PFAS.

## DISCLOSURE OF INVENTION

5           [00013] In the present invention, there is provided a remediation surfactant formulation capable of decontaminating soil, bedrock, groundwater, and impermeable surfaces of PFAS. The new remediation surfactant contains a variant formulation of an **IVEY** surfactant. This variant formulation of an **IVEY** surfactant is referred to herein as the new **Ivey blend**. The new PFAS remediation surfactant  
10 comprises a minuscule amount ethanol mixed with the **Ivey-blend** in a water solution. In use, the **Ivey-blend** is diluted to 4% in a remediation solution, wherein the ethanol content is 0.20% by volume. The designation for the new PFAS remediation solution has been registered under the trademark of PFAS-SOL™.

15           [00014] PFAS-SOL™ is also a registered trademark. The “trademark symbol™” is also omitted hereinafter and the registered attribute is acknowledged by using a bold font, for convenience.

          [00015] The **Ivey-blend** formulation is made of a blend of molecules  
20 having affinity with water and with PFAS contaminant. Each molecule is expressed as follows:  $2C+5CH_3+CH_2+O[2CH_2+O]_n + H$ , wherein  $[2CH_2+O]$  is a hydrophilic head end of the molecule and  $2C+5CH_3+CH_2+O$  is a hydrophobic tail end of the molecule. The hydrophilic head end is repeatable “n” times, by polymeric reaction. The repeat has two forms:  $[2CH_2+ O]$  and  $[CH_2+O]$ . The  
25 presence of one form or another is a random occurrence. The molecules in **Ivey-blend** are characterized by their solubility with water and their selective interaction between water and PFAS molecules.

          [00016] When the hydrophilic head end of an **Ivey-blend** molecule is  
30 repeated one to four times, the molecule is insoluble in water and has a capacity to bring water into PFAS contaminants. When the hydrophilic head end is

repeated more than four times, the molecule is soluble in water and has a capacity to bring PFAS contaminants into water. When preparing the **Ivey-blend**, the water-soluble molecules are mixed into water solution first, which then permits the addition of the otherwise insoluble molecules to make the final composition blend.

[00017] The **Ivey-blend** contains molecules of different lengths to provide a dual effect on PFAS contaminants. The **Ivey-blend** formulation may also contain other surfactants.

[00018] **PFAS-SOL** formulation is non-toxic, non-corrosive, non-caustic, biodegradable, and pH neutral. It is based on non-ionic formulations, with a novel additive, that can selectively desorb contaminants and render sorbed, globular and non-aqueous phase liquids (NAPL) soluble in the aqueous phase. This means it forms a non-emulsified mixture with water and can thus be more easily controlled and removed from impacted soil, bedrock, groundwater, and surface water while maintaining plume control.

[00019] Based on this modulated structure, these surfactants offer multiple properties that improve effectiveness of most remediation strategies, predominantly by overcoming the limitations associated with contaminant sorption and low solubility. In addition, they lower the relative surface tension of water and overcome interfacial tension, thereby improving its wetting and associated hydraulic property across broader soil textures.

[00020] **PFAS-SOL** can selectively remove PFAS from sorbed soil and bedrock surfaces, from globule and/or NAPL phase-partitioned layers, to make them more available for enhance physical, biological, and/or chemical remediation.

[00021] PFAS-SOL makes PFAS contaminants more miscible in water and improves combination reactions, decomposition reactions, single replacement reactions, double replacement reactions, relating to various treatments of PFAS.

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[00022] The PFAS-SOL has been used in a four flushes process in columns of contaminated building soil containing 10% by mass of activated carbon. The new PFAS-SOL surfactant increased PFAS concentrations in drained water by up to 622%, removing 99.979% of the PFAS present in the soil of the columns. This column test is described in more detail hereinafter on page 8.

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[00023] This result compares advantageously with the experiments disclosed in the Australia report, where a five flushes process using 50% ethanol solution gave a 98% removal of PFAS.

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[00024] In another property of the present invention, the PFAS-SOL surfactant, has improved soil drainage. This new surfactant has reduced interfacial surface tension of water from 73 dynes to less than 30 dynes. The new PFAS-SOL surfactant also reduces the interfacial surface tension of PFAS to values in the vicinity of 30 dynes or less.

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[00025] Such reduction in interfacial surface tension reduces capillary forces, increases air and liquid permeability of soils, bedrock and increases soil drainage. When water and contaminant move “hand-in-hand” through tight soil matrix passages in a remediation process, the same interfacial surface tension of the two elements lowers the risk of one or the other losing this intimate grip to other attractive surfaces along the way.

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[00026] Furthermore, during experiments using the PFAS-SOL surfactant, water molecule clustering has been reduced significantly. The PFAS-SOL surfactant

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causes larger (normal) water clusters to break up into smaller size clusters of fewer molecules. Small water clusters with smaller interfacial surface tension, and less physical retardation, allows a remediation solution to enter and move easily through finer grain soil. The remediation solution can easily flow in and out of small pores, cracks, crevices, and voids in a soil structure, to accomplish a more complete remediation of that soil, bedrock, groundwater, and impermeable surfaces.

[00027] In further aspects of the invention, ethanol is economically produced and environmentally safe. The new **Ivey-blend** is also made of biodegradable elements and is also environmentally safe. When used in a **PFAS-SOL** solution, organic hydrocarbon contaminants present in the PFAS contaminated soils are also removed, due to the **Ivey-blend** components of the solution. It will also be appreciated that the ethanol-new **Ivey-blend** combination has more PFAS remediation capacity than each component individually.

## BRIEF DESCRIPTION OF DRAWINGS

[00028] The accompanying drawings are incorporated herewith to explain the structure of the **PFAS-SOL** surfactant and some of its properties.

[00029] **FIG. 1** is an approximate representation of a PFAS molecule, showing its polarity;

[00030] **FIG. 2** is an approximate representation of a molecule of the new **Ivey-blend**, and its polarity;

[00031] **FIG. 3** is a representation of an ethanol molecule and its polarity;

[00032] **FIG. 4** is a representation of a water molecule and its polarity;

[00033] FIG. 5 is a representation of a possible tandem coordinated positioning of the new **Ivey-blend** and ethanol molecules in an uplifting and integrated rafting arrangement enclosing a PFAS molecule with water molecules, in a remediation solution.

## BEST MODE FOR CARRYING OUT THE INVENTION

[00034] The composition of the **PFAS-SOL** surfactant is best explained as follows: **PFAS-SOL** surfactant is made from new **Ivey-blend**, water, and ethanol in the following proportions:

[00035] A batch of new **Ivey-blend** is sold in a 10% aqueous solution. A typical batch of new **Ivey-blend** contains 1000 liters; that is for example, 95 liters of a new **Ivey-blend** in 855 liters of water. A volume of 50 liters of ethanol is added to the batch of new **Ivey-blend** to transform that batch into **PFAS-SOL** concentrate. The ethanol content in the **PFAS-SOL** concentrate is therefore 50 liters /1000 liters, or 5.00% by volume.

[00036] In decontamination use, **PFAS-SOL** concentrate is diluted to 4% in an aqueous remediation solution. Therefore, the ethanol content in a remediation solution is  $4\% \text{ of } 5.00\% = 0.20\%$  by volume.

### Column Test

[00037] This diluted **PFAS-SOL** solution was tested in column tests in a laboratory at the University of Greenwich, England, by Dr. Cecilia MacLeod, in collaboration with Dr. David Holmes, and George Ivey of Ivey International, Inc. The results of these tests are referred to as the Greenwich tests.

[00038] The tests were done in columns of soil made of building soil and 10% by mass of powdered activated carbon providing absorptive organic content. The

columns were slowly saturated with water from the base and drained to a set volume. The columns were each spiked with 250 mg of PFOA and 250 mg of PFOS to mimic a PFAS source zone and then drained and filled with the effluent sampled to show  
5 contaminant recovery in water. For comparison, tests were made with a 50% methanol-water solution, and with the **PFAS-SOL** solution at a 4% concentration. The columns were then drained, with the increased concentration in the effluent in the **PFAS-SOL** column showing a large increase in PFAS concentration. The columns were then slowly taken apart to deliver a moisture profile and obtain soil  
10 samples to measure retained PFAS.

[00039] The results showed significant mass PFAS removal from the **PFAS-SOL** flushes. Flushes with water alone yielded PFAS recovery of approximately 5 micrograms per liter, whereas **PFAS-SOL** surfactant flushes exhibited improved  
15 recovery of up to 30.45 micrograms per liter. This means an average improvement in PFAS removal of 240%, with concentration spikes of up to 622%. PFOA recovery averaged 160%, with best results of 185%. PFOS recovery averaged 297%, with best results of 732%. Total PFAS recovery averaged 242%, with best results of 622%.

20 [00040] It was also found that the **PFAS-SOL** solution increased drainage (less soil retention) by 15% as compared to the methanol solution. The **PFAS-SOL** solution improves column drainage time (lowering capillary effect) by more than 200% as compared to water alone. It took 5 minutes of drainage for the **PFAS-SOL**  
25 solution alone versus 20 minutes for the same volume of methanol or for the same volume of water. Similarly, the time for the soil to reach saturation was significantly decreased with the **PFAS-SOL** solution; that is from 20 minutes to 5 minutes.

[00041] Data available from the Greenwich tests and from the Australia report  
30 are summarized herein in the **Table 1** below.

[00042] Referring to the drawings, **FIGS. 1, 3 and 4** represent, as best understood, molecules of PFAS, ethanol, and water respectively.

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[00043] **FIG. 2** is a representation of a new **Ivey-blend** molecule as best understood. The right-hand end (head) of the molecule is extendable “n” times for tailoring the molecule to work conditions such as a specific contaminant to be removed, soil type, temperature, humidity level, solubility thereof, solubility of the contaminant or the depth of the contamination, etc. In a preferred analogy, the left-hand portion (tail end) of the molecule is a horse sled, and the right-hand portion (head end) is an extendible draw bar of that sled to which can be harnessed as many horses as needed. **Ivey-blend** can modulate the number (n) of horses to the sled to enhance solubility (modulate the hydrophilic capacity) across small to medium to large molecule sizes and masses.

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[00044] The hydrophilic head in the **Ivey-blend** molecule is extendable from 1 to 30+. When (n) equals 1 to 4, the molecule is insoluble in water and has the capacity to bring water into contaminants. When (n) is 5 to 30 or larger, the molecule is soluble and has the capacity to bring contaminants into water. When both forms are present in **PFAS-SOL**, a unique dual capacity is obtained. **PFAS-SOL** so modified can undertake the cleaning of contaminants which phases separate as floating or sinking layers, to globules, or to absorbed or adsorbed phases of contamination, by simultaneously pulling water into the contaminant PFAS phase and contaminant PFAS phase into water.

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[00045] When treating small contaminant molecules, with lower sorption and agglomeration capacities, (n) is preferably between 1 and approximately 10 or larger. When treating medium size molecules with moderate sorption and agglomeration capacities, (n) is preferably between about 10 or smaller and about 20 or larger. Similarly, when treating large contaminant molecules with relatively large sorption

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and agglomeration capacities, (n) is preferably between about 20 or smaller and about 30 or larger.

5        [00046] As mentioned before, the extendible head portion of the **Ivey-blend** molecule has alternate random forms that do not affect the performance of the solution.

10        [00047] Referring to **FIG. 5**, the diagram illustrated therein is an attempt to describe the mechanistic attachment of the **PFAS-SOL** surfactant to a molecule of PFAS. The exact remediation process is not known, notwithstanding what has been said herein above, and the connections shown in this illustration do not explain the extraordinary result obtained from a small addition of ethanol to the new **Ivey-blend**. The drawing is a candid attempt to explain the affinity of each molecule to each other  
15        to make connections.

20        [00048] It will be appreciated that the illustration in **FIG. 5** is a two-dimension illustration. The actual physical arrangement is a three-dimension cylindrical, and/or spherical array, where several new **Ivey-blend** - ethanol molecules connect to several parts of, along and around, the PFAS molecule, while numerous water molecules integrate varying cluster sizes with the new **Ivey-blend** - ethanol molecules to supply intramolecular tractive force to uplift, raft and transport the PFAS molecules.

25        [00049] As a summary, **PFAS-SOL** used in a 4% aqueous solution, containing as little as 0.20% by volume of ethanol has achieved significant improvement in drainage rate and increased PFAS desorption of up to 622%, as compared to water flushes alone.

30        [00050] A comparison of the ethanol contents in the remediation solutions described in the Australia report and the Greenwich tests is a ratio of 250:1. In view of such difference, it become apparent that the remediation performance of **PFAS-**

SOL is not attributable only to the ethanol element of the solution, but to a synergy of the three components together.

5     **AFFF decontamination**

[00051] The PFAS-SOL has also shown outstanding performance in the remediation of AFFF from pump, piping, valves, gauges, probes and storage tank at an AFFF storage installation in an oil and gas facility. The decontamination process was carried out in 5 cycles, described as follows:

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[00052] In a first cycle, an aqueous surfactant solution of 5% (by volume) of PFAS-SOL and 95% filtered potable water was prepared and heated to 40<sup>0</sup> C. This solution was recirculated within the piping system for approximately 1.5 hours. The spent solution was discharged to the emptied storage tank after recirculation. The piping system was subsequently purged with filtered potable water heated to 40<sup>0</sup> C to remove any remnant of the aqueous surfactant solution. The purging product was also discharged to the storage tank.

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[00053] The second cycle was a repeat of the first one but using an aqueous solution of 4% (by volume) of PFAS-SOL and 96% filtered potable water. The third, fourth and fifth cycles were also repeats of the first one, but using 3%, 2% and 1% (by volume) respectively of PFAS-SOL.

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[00054] A total of twelve PFAS analytes larger and smaller than C<sub>8</sub> were detected on the piping interior surface following AFFF purge and potable water wash. These are shown in **Table 2** herein-below.

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[00055] Heated purified water high velocity triple flush reduced the surface concentration of each detected analyte. The sum of twelve PFAS analyte concentrations were reduced to 94.56976%. Subsequent decontamination with heated PFAS-SOL reduced ten of the twelve PFAS analytes to non-detectable levels.

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The PFAS-SOL decontamination process further reduced the sum of detected PFAS analytes by 99.99998%.

5           [00056]   The decontamination process employed have been highly successful in reducing detected PFAS analytes from piping interior surface seven orders of magnitude lower than AFFF purging followed by potable water wash alone.

10           [00057]   In a subsequent ex-situ soil wash of PFAS-impacted soil, using 200 grams of soil with 200 ml of **PFAS-SOL** solution for 1 minute showed a potentially near total PFAS recovery.

15           [00058]   It will be appreciated that although a minuscule volume of ethanol has shown outstanding result in a PFAS remediation solution, it is believed that other volumes of ethanol, other formulas of the new **Ivey-blend** and other straight linear alcohol, or branched, or cyclic alcohol content as a substitute for ethanol may also work.

20           [00059]   Referring to the **Table 2**, it will be appreciated that the **PFAS-SOL** has some merit in remediating environments from PFAS contaminants, its precursors, derivatives and remnants from C<sub>4</sub> to C<sub>12</sub> variants. (larger and smaller than C<sub>8</sub>).

25           [00060]   It will also be appreciated that the volume of ethanol used is too small to constitute a serious component in the remediation solution. It is believed that the presence of ethanol in the **Ivey-blend** constitutes a reagent, stimulating or motivating the **Ivey-blend** to outperform its expected remediation capacity.

30           [00061]   The synergy of the three components of the **PFAS-SOL** may partly be explained by a specific characteristic of the **Ivey-blend**. As explained, the collective presence of soluble and insoluble molecules in the **Ivey-blend** cooperates with other

surfactants in the **Ivey-blend** to obtain surprising innovative effects to make insoluble contaminants soluble. These two classes of amendments to the **Ivey-blend** create new mechanistic ways in which one can interact with sorbed, globular, numerous non-aqueous phase liquids (free phase), and vapors to remediate soil, bedrock, groundwater, and impermeable surfaces of these contaminants.

[00062] It is believed this capacity of the **Ivey-blend** surfactants to selectively dissolve or not, is working/cooperating well with ethanol to obtain a unique ability to uplift and transport PFAS contaminants into a remediation solution.

[00063] Referring to **FIG. 5**, the **Ivey-blend** molecule has a double-end affinity with the PFOS molecule and water molecules. The ethanol molecule has an affinity to the PFOS and water molecules to assist in the lifting of the PFOS molecule from its environment, regardless of potential affinity with the **Ivey-blend** molecule.

[00064] Table 1

|                                        |                |         |
|----------------------------------------|----------------|---------|
| 50%Methanol solution, 5 flushes        | PFAS reduction | 99.965% |
| 50% Ethanol solution, 5 flushes        | PFAS reduction | 98%     |
| <b>PFAS-SOL</b> 4% solution, 5 flushes | PFAS reduction | 99.979% |

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[00065] Table 2

| <b>Detected PFAS Analytes</b>             | <b>Chemical formula</b>                                         | <b>Reduction</b> |
|-------------------------------------------|-----------------------------------------------------------------|------------------|
| Perfluorobutanoic acid (PFBA)             | C <sub>4</sub> F <sub>7</sub> CO <sub>2</sub> H                 | 99.96055%        |
| Perfluoropentanoic acid (PFPeA),          | C <sub>5</sub> HF <sub>9</sub> O <sub>2</sub>                   | 99.99369%        |
| Perfluorohexanoic acid (PFHxA),           | C <sub>6</sub> HF <sub>11</sub> O <sub>2</sub>                  | 99.99956%        |
| Perfluoroheptanoic acid (PFHpA),          | C <sub>7</sub> HF <sub>13</sub> O <sub>2</sub>                  | 99.99201%        |
| Perfluorooctanoic acid (PFOA),            | C <sub>8</sub> HF <sub>15</sub> O <sub>2</sub>                  | 99.99876%        |
| Perfluorononanoic acid (PFNA),            | C <sub>9</sub> HF <sub>17</sub> O <sub>2</sub>                  | 99.99278%        |
| Perfluorodecanoic acid (PFDA),            | C <sub>10</sub> HF <sub>19</sub> O <sub>2</sub>                 | 99.99650%        |
| Perfluoroundecanoic acid (PFUnDA),        | C <sub>11</sub> HF <sub>21</sub> O <sub>2</sub>                 | 99.96291%        |
| Perfluorododecanoic acid (PFDoA),         | C <sub>12</sub> HF <sub>23</sub> O <sub>2</sub>                 | 99.98844%        |
| Perfluorooctanesulfonic acid (PFOS),      | C <sub>8</sub> HF <sub>17</sub> O <sub>3</sub> S                | N/C              |
| 6:2 Fluorotelomer sulfonic acid (6.2 FTS) | C <sub>8</sub> H <sub>5</sub> F <sub>13</sub> O <sub>3</sub> S  | 99.99998%        |
| 8:2 Fluorotelomer sulfonic acid (8.2 FTS) | C <sub>10</sub> H <sub>5</sub> F <sub>17</sub> O <sub>3</sub> S | 99.99999%        |

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## INDUSTRIAL APPLICABILITY

5           [00066] In view of the findings described herein, and the experimentations done so far, it is believed that the new **PFAS-SOL** product can be used to decontaminate soil, bedrock, groundwater and impermeable surfaces of PFAS and PFOS and their derivatives in the form of carbon content less than C<sub>4</sub> and larger than C<sub>12</sub>. It is also believed that the new **PFAS-SOL** surfactant can be used to  
10 decontaminate hard and soft surfaces of environmental field monitoring equipment, pumping installations, tanks, pumps, valves, and piping, clothing, Gore-Tex™, upholstery, carpets, electronic instruments as well as medical equipment and associated anthropogenic environments. Furthermore, it is believed that the new **PFAS-SOL** product is well suited for use in vertical well push-pull, sweep, deep well  
15 arrays, and/or horizontal well in-situ decontamination processes. The new **PFAS-SOL** is also suitable for batch-type or continuous ex-situ soil washing decontamination processes. Because the **PFAS-SOL** is environmentally safe it can also be used in in-situ or ex-situ aerobic or anaerobic bioremediation of PFAS, in-situ or ex-situ chemical oxidation or chemical reduction processes, or to clean up  
20 PFAS spills along a shoreline or a forest floor for example. Furthermore, as demonstrated herein, **PFAS-SOL** is a good alternative to incineration to treat spent used granular activated carbon or granular absorptive substrates of PFAS, in all areas of industry.

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## CLAIMS

5           What is claimed is:

1.   A molecule having affinity with water and with PFAS contaminant, for remediation of soil, bedrock, groundwater, and impermeable surface of PFAS contaminants, characterized in that said molecule has the form of  
10        $2C+5CH_3+CH_2+O[2CH_2+O]_n + H$ , wherein  $[2CH_2+O]$  is a hydrophilic head end of said molecule and  $2C+5CH_3+CH_2+O$  is a hydrophobic tail end of said molecule and said hydrophilic head end is repeatable  $n$  times.
2.   The molecule as claimed in **claim 1** wherein a repeat of said hydrophilic head  
15       end has an alternate random form of  $[CH_2+O]$ .
3.   The molecule as claimed in **claim 2**, wherein said molecule has selective solubility with water according to a length of said hydrophilic head end.
- 20    4.   The molecule as claimed in **claim 3**, wherein said hydrophilic head end is repeated one to four times, and said molecule is insoluble in water and has a capacity to bring water into PFAS contaminants.
- 25    5.   The molecule as claimed in **claim 2**, wherein said hydrophilic head end is repeated more than four times, and said molecule is soluble in water and has a capacity to bring PFAS contaminants into water.
- 30    6.   The molecule as claimed in **claim 5**, wherein said head end is repeatable more than 30 times for correspondingly increasing said capacity to bring PFAS contaminants into water.

7. A remediation solution for soil, bedrock, groundwater, and impermeable surface remediation of PFAS contaminants, characterized in that said solution contains a blend of molecules each having the form of
- 5  $2C+5CH_3+CH_2+O[2CH_2+O]_n + H$ , in an aqueous solution and a reagent.
8. The remediation solution as claimed in **claim 7**, wherein  $[2CH_2+O]$  is a head end of each of said molecules and  $2C+5CH_3+CH_2+O$  is a tail end of each of said molecules and said head end is repeatable  $n$  times.
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9. The remediation solution as claimed in **claim 8** wherein a repeat of said head end has an alternate random form of  $[CH_2+O]$ .
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10. The remediation solution as claimed in **claim 7**, wherein said reagent is an alcohol.
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11. The remediation solution as claimed in **claim 7**, wherein said reagent is ethanol.
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12. The remediation solution as claimed in **claim 8**, wherein said blend of molecules has molecules with different head end lengths.
13. The remediation solution as claimed in **claim 11**, having affinity with PFAS contaminants and with  $C_4$ - $C_{12}$  variants of said PFAS contaminants.
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14. The remediation solution as claimed in **claim 7**, wherein each of said molecule has selective solubility with water according to a respective length of said head end thereof.
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15. The remediation solution as claimed in **claim 13**, wherein when said head end of one of said molecule is repeated less than five times, said molecule is insoluble in water and has a capacity to bring water into PFAS contaminants.

16. The remediation solution as claimed in **claim 13**, wherein when said head end of one of said molecule is repeated more than five times, said molecule is soluble in water and has a capacity to bring PFAS contaminants into water.

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17. The remediation solution as claimed in **claim 15**, wherein said head end of each of said molecule is repeatable more than 30 times for increasing said capacity of said molecule to bring PFAS contaminants into water.

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18. The remediation solution as claimed in **claim 7**, being non-toxic, non-corrosive, non-caustic, biodegradable, and pH neutral.

19. The remediation solution as claimed in **claim 10**, comprising 10% of said blend of molecules in said aqueous solution.

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20. The remediation solution as claimed in **claim 18**, wherein a content of said ethanol therein is 0.20% by volume.

21. A method for remediating a contaminated environment of PFAS contaminants, wherein said contaminated environment is an element from a soil, a bedrock, a groundwater and an impermeable surface, and said PFAS contaminants comprises at least one contaminant selected from a group of contaminants including PFAS contaminants, precursors, derivatives, and remnants of said PFAS contaminants from C<sub>4</sub> to C<sub>12</sub> variants of said PFAS contaminants, characterized in that said method comprises the steps of: flushing said contaminated environment with a remediation solution made of an aqueous solution comprising 4% of a blend of molecules of different lengths each having the form of  $2C+5CH_3+CH_2+O[2CH_2+O]_n + H$ , in an aqueous solution and 0.20% by volume of ethanol as a reagent.

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22. The method as claimed in **claim 21**, wherein said step in flushing said contaminated environment is done in-situ in a process belonging to remediation processes comprising vertical well-push-pull, sweep, deep well multilevel arrays and horizontal well decontamination.

23. The method as claimed in **claim 21**, wherein said step of flushing said contaminated environment is done ex-situ in a process belonging to remediation processes comprising batch-type, continuous soil washing process, aerobic, anaerobic bioremediation, chemical oxidation and chemical reduction processes.

24. The method as claimed in **claim 21**, wherein said step of flushing said contaminated environment is done in any of remediation processes known as aerobic, anaerobic, bioremediation, chemical oxidation, chemical reduction, and electrokinetics.

25. The method as claimed in **claim 21**, wherein said contaminated environment is a fabric product in a group of fabric products including clothing, Gore-Tex™, upholstery, and carpet.

26. The method as claimed in **claim 21**, wherein said contaminated environment is a hard surface product in a group of hard surface products including, pumps, valves, tanks, piping and probes.

27. The method as claimed in **claim 21**, wherein said contaminated environment is an intricate hard surface product in a group of intricate hard surface products including electronic equipment and medical instruments.