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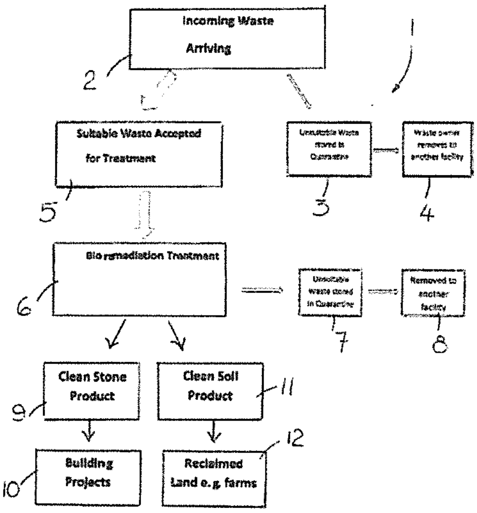
(71) Applicant(s):
GERARD PATRICK MCDONNELL
Co. Louth
Ireland

(72) Inventor(s):
GERARD PATRICK MCDONNELL

(74) Agent and/or Address for Service:
NAOISE GORDON
NP Gordon & Associates
Annyalla, Castleblaney
Co. Monaghan
Ireland

(54) **A remediation process**

(57) A process and bioremediation facility for the bioremediation of soil contaminated with a hydrocarbon such as oil in which the process comprises removing the contaminated soil from the contaminated site, placing the contaminated soil in a bioremediation facility having a series of heated bays for receiving the removed contaminated soil and treating the contaminated soil with a microbial cleaner in the heated bays to digest the hydrocarbon and decontaminate the soil in the bays.
<Figure 1>



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A Remediation Process

Introduction

This invention relates to a remediation process and more particularly to a process for the bioremediation of soils, stone, sands and similar natural materials polluted with hydrocarbons.

Background of the Invention

Hydrocarbon soil contamination frequently occurs as a result of accidental spillages. Such spillages can occur on a domestic or industrial scale while examples of hydrocarbon pollutants include kerosene, diesel, petrol, industrial oils and the like.

Hydrocarbon contamination on soil, stone, sand and the like (generally described as products having European Waste Code 17 05 04 and hereinafter referred to collectively as soil) can be difficult to treat and known methods suffer from a number of disadvantages. For example, large volumes of hydrocarbon contaminated soil mixed with stone and concrete are sometimes deposited in landfill sites with obvious negative environmental consequences. More particularly, the failure to recycle and re-use contaminated soils in favour of disposal by landfilling gives rise to maximal carbon emissions so that an extremely negative carbon footprint results.

Similarly, negative environmental impacts result from the use of harsh chemicals to treat contaminated soil. In some instances, it is known to remove contaminated soils and treat the removed soils at treatment sites which are long distances from the spillage site resulting in excessive transportation costs with high carbon emissions. In general, such treatment sites are also energy intensive further increasing energy costs whilst impacting negatively on the carbon footprint of the treatment process. In comparison, recycling on average saves on average 743.2 kg carbon emissions per tonne.

It is also known to use microbe-based bioremediation in the treatment of contaminated soils. For example, US Patent Specification No. 5,364,789 describes the use of a two-part microbial cleaner made up of a biocatalyst solution and a microbe blend activated by the biocatalyst to digest contaminating hydrocarbons in soils. However, in the method of US Patent Specification No. 5,364,789, the microbial cleaner is used in-situ at the site of the contamination which is frequently undesirable or indeed not possible where immediate removal of the contamination is required while use of the microbial cleaner in such an uncontrolled environment results in an unsatisfactorily long treatment time.

Summary of the Invention

According to the invention there is provided a process for the bioremediation of soil contaminated with a hydrocarbon comprising:

removing the contaminated soil from the contaminated site;

placing the contaminated soil in a bioremediation facility, and

treating the contaminated soil with a microbial cleaner to digest the hydrocarbon and decontaminate the soil.

Suitably, the contaminated soil is heated prior to treatment with the microbial cleaner to remove moisture from the contaminated soil.

Advantageously, stone is removed from the dried contaminated soil. Suitably, the stone is removed by screening.

Preferably, the contaminated soil is heated during digestion. More preferably, the contaminated soil is heated to a temperature of from about 18°C to about 50°C. Most preferably, the contaminated soil is heated to a temperature of from about 18°C to about 25°C.

Optimally, the digestion step is performed for a period up to about 30 days. Suitably, the digestion step is performed for a period of from 20 days to 30 days.

Preferably, unsuitable waste (e.g. non European Waste Code 17 05 04 material) is removed from the contaminated soil before digestion.

In a preferred embodiment of the invention, the bioremediation facility comprises a series of bays for receiving the removed contaminated soil. Preferably, the series of bays comprises three bays. More preferably, the bays comprise a heating system. Most preferably, the walls and floors of the bays comprise a heating system.

Suitably, the heating system comprises an underfloor heating system.

Preferably, each bay is separately heatable.

The invention also extends to the use of a microbial cleaner for the bioremediation of soil contaminated with a hydrocarbon wherein the contaminated soil is removed to a bioremediation facility prior to treatment with the microbial cleaner to digest the hydrocarbon.

Preferably, the microbial cleaner comprises a two-part microbial cleaner made up of a biocatalyst solution and a microbe blend activated by the biocatalyst. More preferably, the microbe blend comprises naturally occurring hydrocarbon digesting microbes. Most preferably, the naturally occurring hydrocarbon ingesting microbes comprise *Pseudomonas* and *Bacillus*.

Preferably, the biocatalyst solution comprises nutrients to activate and nourish the microbes. More preferably, the nutrients comprise urea and sodium hexamethaphosphate.

Advantageously, the biocatalyst further comprises a non-ionic surfactant, a chlorine absorbing salt and water. Preferably, the non-ionic surfactant comprises nonylphenol polyethylene glycol. More preferably, the chlorine-absorbing salt comprises sodium thiosulfate.

Preferably, the contaminated soil is heated during digestion. More preferably, the contaminated soil is heated to a temperature from about 18°C to about 25°C and up to 50°C if required.

Optimally, the digestion step is performed for a period up to about 30 days. Suitably, the digestion step is performed for a period of from 20 days to 30 days.

The invention also extends to a bioremediation facility for the bioremediation of soil contaminated with a hydrocarbon comprising a series of bays for receiving the removed contaminated soil and treating the contaminated soil with a microbial cleaner to digest the hydrocarbon and decontaminate the soil in the bays.

Preferably, the series of bays comprises three bays. More preferably, the bays comprise a heating system for heating the contaminated soil.

Suitably, the walls and floors of the bays comprise a heating system.

Optimally, the heating system comprises an underfloor heating system.

Preferably, each bay is separately heatable.

The advantages of the invention are many. The bioremediation process of the invention is a fast, cost efficient, environmentally friendly, natural and sustainable way of treating hydrocarbon contaminated soil using a highly efficient bioremediation facility. More particularly, in contradistinction with the landfilling methods of the prior art, contaminated soil can be treated in the bioremediation facility of the invention and then re-used with minimal carbon emissions resulting in a treatment method for contaminated soil having a desirable carbon footprint saving about 743.2 kg per tonne in carbon emissions.

Removal of contaminated soil from the site of a spillage to the bioremediation facility allows for the immediate availability of the site while treatment of the contaminated soil at a bioremediation facility where the contaminated soil can be heated speeds up the digestion and decontamination process whilst eliminating waste streams. In particular, no waste streams or waste by-products are generated by the process and bioremediation facility while the end products include clean, reusable soil and stone which can be used in building and land reclamation or farming projects.

The necessary inputs are minimal as the bioprocess is designed to be self-sustaining (microbes regenerate themselves and are recirculated within the process) and energy efficient.

The process of the invention is cost efficient, both in the short-term and long-term life cycle assessment. The process of the invention also enjoys minimal environmental emissions.

Additional savings are achieved when environmental externalities such as carbon footprint, greenhouse gas emissions and climate change mitigation costs from other processes are considered.

Due to its environmentally friendly profile, the bioremediation facility employed in the process of the invention can be easily established on a local or regional basis providing an easily accessible bioremediation service and reducing the need for long distance transport of material.

The process of the invention safeguards the environment – humans, animals, plants, aquifers etc. in a highly cost-effective and economical manner. Waste is managed without endangering human health or a nuisance through noise or odours

In summary, the bioremediation process and facility of the invention facilitate reduced landfilling, reduced energy use, reduced transport costs, reduced carbon footprint and the elimination of environmental emissions and waste streams.

Brief Description of the Drawings

The invention will now be described, by way of example only, with reference to the accompanying drawings and Example in which:

Figure 1 is a schematic representation of the bioremediation process of the invention;

Figure 2 is a perspective view from above and front side of the three heated treatment bays adapted for use in the bioremediation process of Figure 1;

Figure 3 is a photograph of contaminated soil subjected to heating in the bays of Figure 2 in the absence of the microbial cleaner and sowed with grass seed to indicate the poor degree to which the soil has been bioremediated for re-use;

Figure 4 is a photograph of contaminated soil subjected to heating in the bioremediation process of the invention in the presence of the microbial cleaner in the bays of Figure 2 in which the bioremediated soil has been successfully sowed with grass to show the effectiveness of the bioremediation process in producing re-useable soil, and

Figure 5 is a graph of the total carbon footprint in Kg of CO_{2e} for different methods of treating one tonne of hydrocarbon contaminated soil including transport compared with the process of the invention.

Detailed Description of the Invention

As shown in the drawings, in the bioremediation process 1 of the invention, contaminated soil first arrives 2 at a bioremediation facility in accordance with the invention. Typically, contaminated soil is removed from a spill site and loaded into skips for transportation to the bioremediation facility. On arrival at the facility, the waste is deposited in an inspection area, where all contents are carefully inspected for any materials not suitable for the facility. If any alien material is found, it is stockpiled in an allocated quarantine area 3 and the owner of that waste is notified to collect same for removal to another facility 4.

The remaining suitable waste is accepted for treatment 5.

The accepted waste material is stockpiled in a series of treatment bays 13. The series of treatment bays 13 is made up of a first treatment bay 14 for heavily contaminated waste, a second treatment bay 15 for mildly contaminated waste and a third treatment bay 16 for lightly contaminated waste.

The bays 14,15,16 are allocated the waste in accordance with the contamination level of the waste. The series of bays 13 is generally formed from concrete and each bay 14,15,16 is made up of a floor 17 having a rear wall 18, a first sidewall 19 and a second sidewall 20 upstanding therefrom. The floor 17 and first and second sidewalls 19,20 of each bay are provided with underfloor heating 21 so that each bay 14,15,16 can be heated. The underfloor heating 21 is contained within insulated profile panels 22 in the floor 17 and sidewalls 19,20. The underfloor heating 21 can be made up of heating pipes having a diameter of about 16mm with a wall thickness of 2mm to give a 14mm bore.

The underfloor heating within each bay 14,15,16 is individually controllable as required to allow for independent heating of each bay 14,15,16 for targeted and effective bioremediation within the bays 14,15,16 and to conserve energy as required. Temperature sensors (not shown) are also provided in the bays 14,15,16 to monitor the bay temperatures and to control activation of the heat source/boiler as necessary.

In the present embodiment, the first bay 14 has a width of about 6.7M, the second bay 15 a width of about 6.3M and the third bay 16 a width of about 6.45M. Each bay 14,15,16 has a depth of about 3.2M while the rear wall 18 has a height of about 2M.

Following acceptance of the waste for treatment 5 and allocation of the waste material to the appropriate bays 14,15,16, bioremediation treatment 6 is commenced.

The waste is first heated and dried in the appropriate bays 14,15,16 to remove any moisture. Following drying, the waste is then screened to remove stone from the waste before returning the soil from the waste to the bays 14,15,16 for subjection to digestion.

The removed stone is then washed for re-use. In general, it is not necessary to subject stone to digestion as, not being permeable, the stone does not absorb hydrocarbon contaminants. However, where the stone is permeable, the stone could be subjected to digestion if desired.

More particularly, the waste material within the bays 14,15,16 is sprayed with microbial cleaner in accordance with the invention.

Microbial Cleaner

A suitable microbial cleaner is a two-part microbial cleaner made up of a biocatalyst solution and a microbe blend activated by the biocatalyst to ingest contaminating hydrocarbons in soils. As indicated above, a suitable microbial cleaner is described in US Patent Specification No. 5,364,789 and is available under the brand name Oil Away (Trade Mark).

The microbe blend is typically made up of naturally occurring hydrocarbon ingesting microbes such as *Pseudomonas* and *Bacillus*. The biocatalyst contains nutrients essential to activate and nourish the microbes. A suitable biocatalyst as described in US Patent Specification No. 5,364,789 is made up of a non-ionic surfactant, a chlorine absorbing salt, nutrients and water. A preferred non-ionic surfactant is nonylphenol polyethylene glycol while a preferred chlorine-absorbing salt is sodium thiosulfate. The preferred nutrients are urea and sodium hexamethaphosphate.

The microbial cleaner is generally mixed by pouring and mixing (by shaking) the biocatalyst and the microbe blend. The microbial blend should be mixed 30 days prior to use for optimal microbial activity.

Weekly additions of microbial cleaner may be made to the bays 14,15,16 as required to control culture levels and microbial activity in the bioremediation process.

During the bioremediation digestion process, the waste within the bays 14,15,16 is generally heated to a temperature from about 18°C to about 25°C via the underfloor heating 21 for optimal microbial activity and digestion of the hydrocarbons. However, the temperature can be raised to about 50°C when required for more heavily contaminated materials. At these heating levels, digestion and bioremediation of the soil can be completed in under about 30 days i.e. in contradistinction with the processes of the prior art a maximum digestion time of about 30 days is required regardless of the level of soil contamination.

If desired, the temperature and digestion time can be varied as required e.g. a higher digestion temperature may be desirable for petrol contaminants. Similarly, water can be applied intermittently as required during the digestion process.

Following digestion to remove the hydrocarbons from the soil, unsuitable waste (e.g. plastics materials) is removed and quarantined 7 and then removed to another facility 8 for disposal.

The remaining cleaned soil 11 can be re-used as required e.g. in reclaimed land applications such as farms and the like 12.

The process as described above recreates prime conditions for exponential microbial growth and optimal digestion of hydrocarbons.

The bioremediation process of the invention was performed as outlined in the following Examples.

<u>Example 1</u>

A laboratory scaled down version of a bay was employed namely a wooden box measuring 1 metre square by ½ metre deep. The box was filled with a typical mixture of soil and stone (approx 1 tonne) which was badly contaminated with kerosene caused by an escape of oil from a domestic heating system.

The contaminated soil and stone was heated to 25°C on a timer set to two hourly intervals for a period of 28 days.

After the heating process, the weight of soil and stone was reduced to approximately 16 cwt. Following stone removal, the weight was further reduced to approximately 13 cwt. Grass seed was sown in the remaining soil. As shown in Figure 3, germination was poor demonstrating failed bioremediation.

The process was then repeated for a period of approximately 2.5 weeks but this time the soil was treated with the microbial cleaner. Grass was sown as before. As shown in Figure 4, germination was highly successful thus demonstrating effective bioremediation of the soil.

Example 2

197.04 tonnes of hydrocarbon contaminated soil was subjected to the bioremediation process 1 in the treatment facility described above.

More particularly, the contaminated soil was placed in the treatment bays 14,15,16 as appropriate and subjected to treatment with appropriate quantities of microbial cleaner. The contaminated soil with microbial cleaner was then heated to a temperature from about 18°C to about 25°C via the underfloor heating for less than thirty days. All hydrocarbon contaminant was removed and it was calculated that the total CO_{2e} saved was 146.44 tonnes when compared with the equivalent landfill method.

Example 3

The total carbon footprint in Kg of CO_{2e} for different methods of treating one tonne of hydrocarbon contaminated soil including transport was compared with carbon footprint of the process 1 of the invention described above.

As shown in Figure 5, the process of the invention resulted in a significantly reduced carbon footprint when compared with equivalent landfill transport and treatment methods employed in the United Kingdom and Germany. More particularly, the process of the invention resulted in a total carbon footprint of only 39 Kg CO_{2e} when compared with a carbon footprint of 795 Kg CO_{2e} for landfill in the United Kingdom, 828 Kg CO_{2e} for landfill in Germany and 292 Kg CO_{2e} for thermal treatment in the United Kingdom and 325 Kg CO_{2e} for thermal treatment in Germany.

The invention is not limited to the embodiments herein described which may be varied in construction and detail without departing from the scope of the invention.

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Claims

1. A process for the bioremediation of soil contaminated with a hydrocarbon comprising:

removing the contaminated soil;

placing the contaminated soil in a bioremediation facility, and

treating the contaminated soil with a microbial cleaner to digest the hydrocarbon and decontaminate the soil.

2. A process as claimed in Claim 1 wherein the contaminated soil is heated prior to treatment with the microbial cleaner to remove moisture from the contaminated soil.

3. A process as claimed in Claim 1 or Claim 2 wherein stone is removed from the dried contaminated soil before treating the contaminated soil with the microbial cleaner.

4. A process as claimed in Claim 3 wherein the stone is removed by screening.

5. A process as claimed in any of Claims 1 to 4 wherein the contaminated soil is heated during digestion of the hydrocarbon.

6. A process as claimed in Claim 5 wherein the contaminated soil is heated to a temperature from about 18°C to about 50°C.

7. A process as claimed in Claim 6 wherein the contaminated soil is heated to a temperature from about 18°C to about 25°C.

8. A process as claimed in any of Claims 1 to 7 wherein the digestion step is performed for a period up to about 30 days.

9. A process as claimed in Claim 8 wherein the digestion step is performed for a period of from 20 days to 30 days.

10. A process as claimed in any of Claims 1 to 9 wherein unsuitable waste is removed from the contaminated soil before digestion.

11. A process as claimed in any of Claims 1 to 10 wherein the bioremediation facility comprises a series of bays for receiving the removed contaminated soil.

12. A process as claimed in Claim 11 wherein the series of bays comprises three bays.

13. A process as claimed in Claim 11 or Claim 12 wherein the bays comprise a heating system.

14. A process as claimed in Claim 13 wherein the walls and floors of the bays comprise a heating system.

15. A process as claimed in Claim 14 wherein the heating system comprises an underfloor heating system.

16. A process as claimed in any of Claims 13 to 15 wherein each bay is separately heatable.

17. Use of a microbial cleaner for the bioremediation of soil contaminated with a hydrocarbon wherein the contaminated soil is removed to a bioremediation facility prior to treatment with the microbial cleaner to digest the hydrocarbon.

18. Use as claimed in Claim 17 wherein the microbial cleaner comprises a two-part microbial cleaner made up of a biocatalyst solution and a microbe blend activated by the biocatalyst.

19. Use as claimed in Claim 18 wherein the microbe blend comprises naturally occurring hydrocarbon digesting microbes.

20. Use as claimed in Claim 19 wherein the naturally occurring hydrocarbon ingesting microbes comprise Pseudomonas and Bacillus.

21. Use as claimed in any of Claims 18 to 20 wherein the biocatalyst solution comprises nutrients to activate and nourish the microbes.

22. Use as claimed in Claim 21 wherein the nutrients comprise urea and sodium hexamethaphosphate.

23. Use as claimed in any of Claims 18 to 22 wherein the biocatalyst further comprises a non-ionic surfactant, a chlorine absorbing salt and water.

24. Use as claimed in Claim 23 wherein the non-ionic surfactant comprises nonylphenol polyethylene glycol.

25. Use as claimed in Claim 23 or Claim 24 wherein the chlorine-absorbing salt comprises sodium thiosulfate.

26. A bioremediation facility for the bioremediation of soil contaminated with a hydrocarbon comprising a series of bays for receiving the removed contaminated soil and treating the contaminated soil with a microbial cleaner to digest the hydrocarbon and decontaminate the soil in the bays.

27. A bioremediation facility as claimed in Claim 26 wherein the series of bays comprises three bays.

28. A bioremediation facility as claimed in Claim 26 or Claim 27 wherein the bays comprise a heating system for heating the contaminated soil.

29. A bioremediation facility as claimed in Claim 28 wherein the walls and floors of the bays comprise a heating system.

30. A bioremediation facility as claimed in Claim 29 wherein the heating system comprises an underfloor heating system.

31. A bioremediation facility as claimed in any of Claims 28 to 30 wherein each bay is separately heatable.

32. A process for the bioremediation of soil contaminated with a hydrocarbon substantially as hereinbefore described with reference to the Examples and/or the accompanying drawings.

33. Use of a microbial cleaner for the bioremediation of soil contaminated with a hydrocarbon substantially as hereinbefore described with reference to the Examples and/or the accompanying drawings.

34. A bioremediation facility for the bioremediation of soil contaminated with a hydrocarbon substantially as hereinbefore described with reference to the Examples and/or the accompanying drawings.

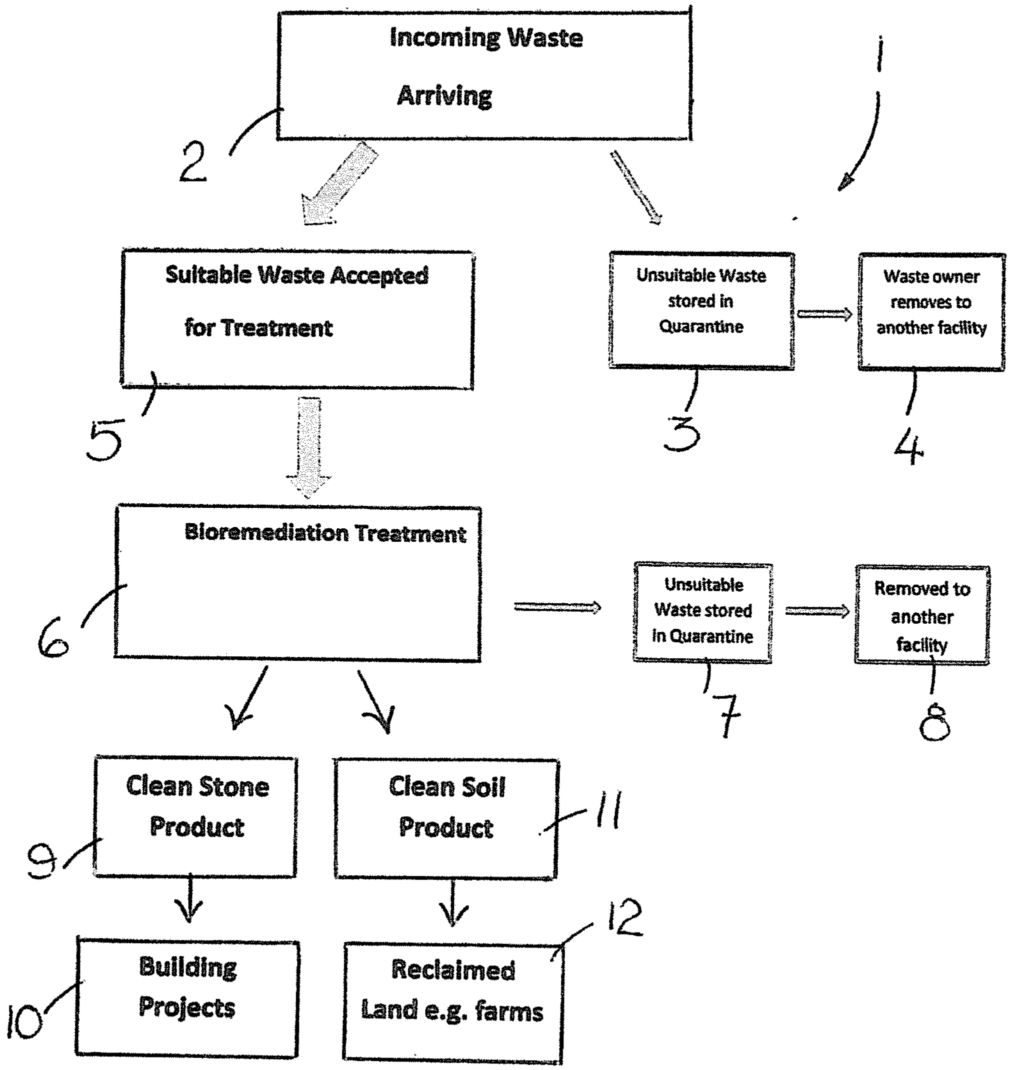

Incoming Waste Arriving
Suitable Waste Accepted for Treatment
Unsuitable Waste stored in Quarantine
Waste owner removes to another facility
Bioremediation Treatment
Unsuitable Waste stored in Quarantine
Removed to another facility
Clean Stone Product
Clean Soil Product
Building Projects
Reclaimed Land e.g. farms
1
2
3
4
5
6
7
8
9
10
11
12

Fig. 1

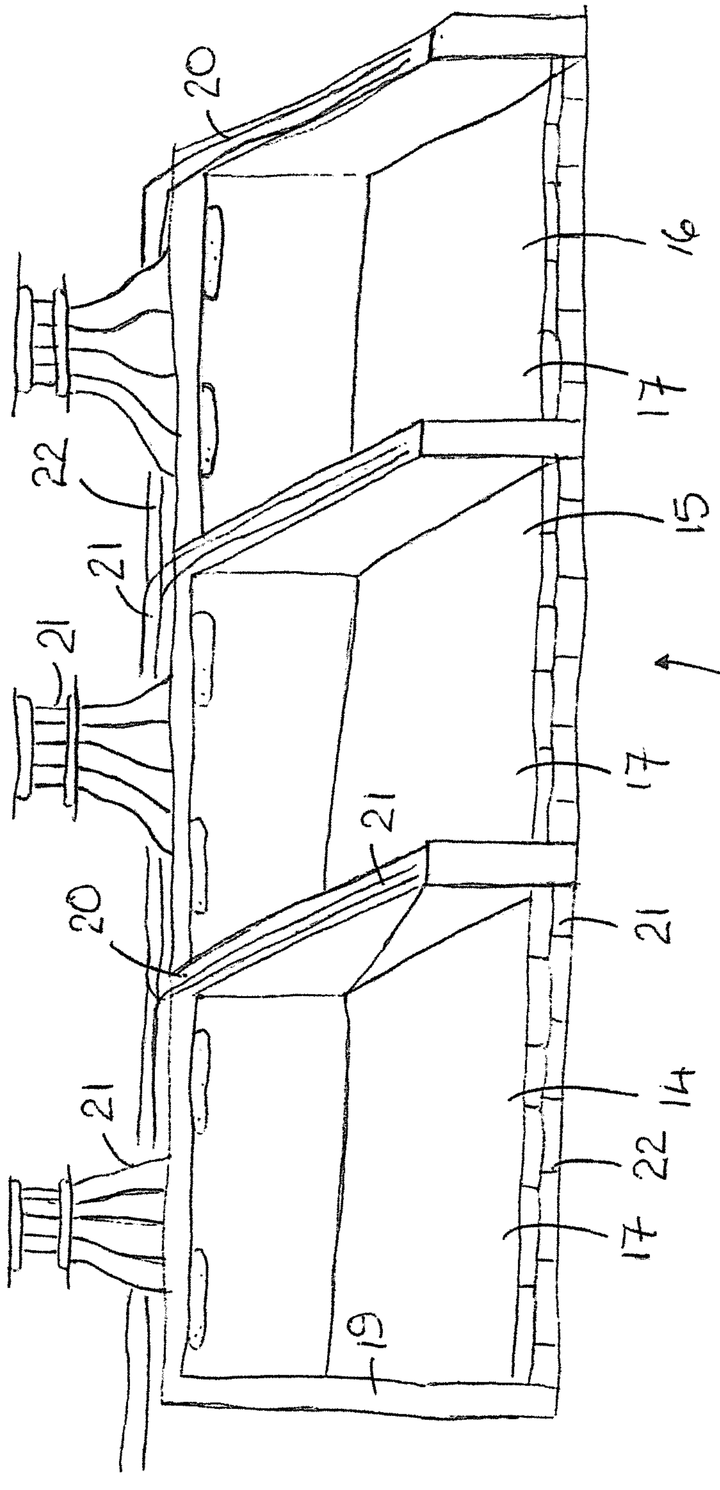


Fig 2

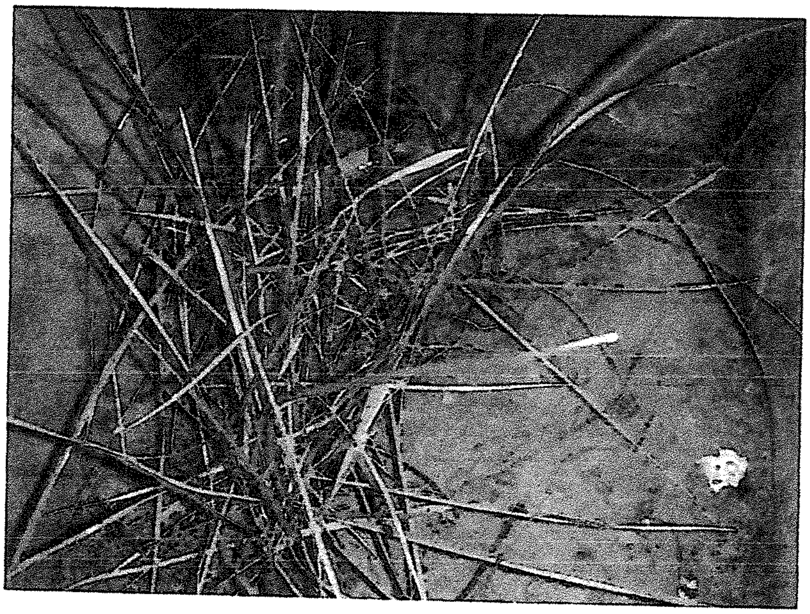


Fig. 3

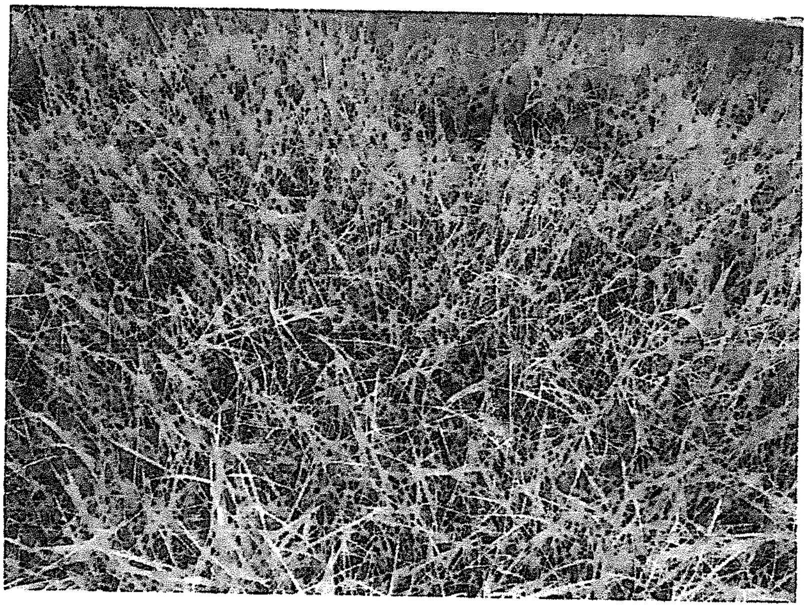
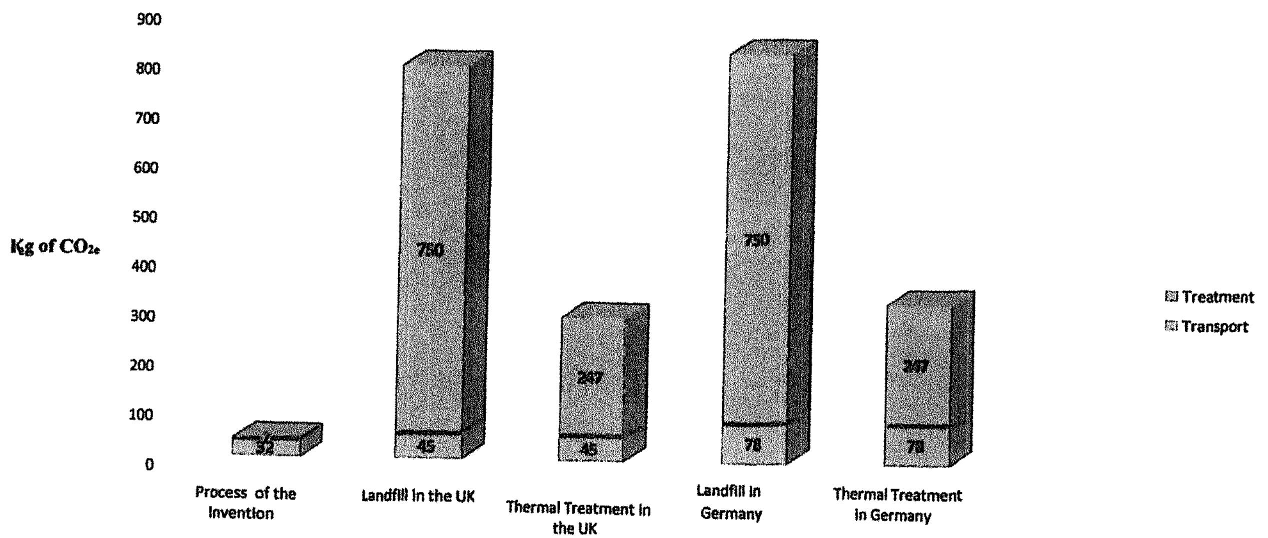


Fig. 4

Total Carbon Footprint in Kg of CO_{2e} for different methods of treating one tonne of Hydrocarbon contaminated soil including transport



	Process of the Invention	Landfill in the UK	Thermal Treatment in the UK	Landfill in Germany	Thermal Treatment in Germany
Treatment	7	750	247	750	247
Transport	32	45	45	78	78

Fig. 5