PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 :		(11) International Publication Number:
C02F 3/32	A1	WO 90/02710
		(43) International Publication Date: 22 March 1990 (22.03.90)

(21) International Application Number: PCT/AU89/00372

(22) International Filing Date: 5 September 1989 (05.09.89)

(30) Priority data:
PJ 0245 5 September 1988 (05.09.88) AU

(71) Applicant *(for all designated States except US)*: COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION [AU/AU]; Limestone Avenue, Campbell, ACT 2601 (AU).

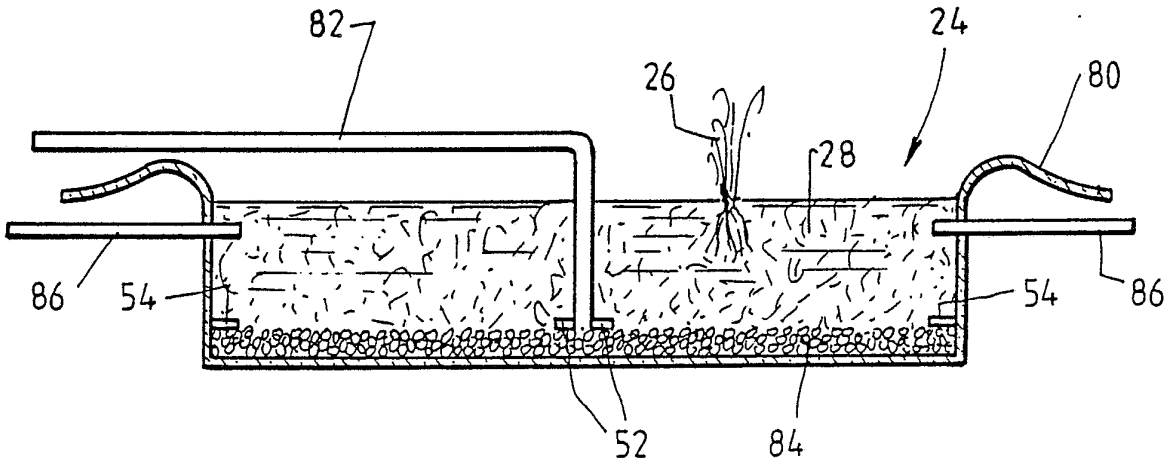
(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : BREEN, Peter, Francis [AU/AU]; 4 Montrose Court, Murrumbeena, VIC 3163 (AU). CHICK, Alan, John [AU/AU]; Flat 2, 73 Hood Street, Coffs Harbour, NSW 2450 (AU). MITCHELL, David, Searle [AU/AU]; 69 Buller Crescent, Albury, NSW 2640 (AU).

(74) Agents: KILBORN, Paul, Anthony et al.; Sirotech Limited, 580 Church Street, Richmond, VIC 3121 (AU).

(81) Designated States: AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CF (OAPI patent), CG (OAPI patent), CH (European patent), CM (OAPI patent), DE (European patent), DK, FI, FR (European patent), GA (OAPI patent), GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL (European patent), NO, RO, SD, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.

(54) Title: WASTEWATER TREATMENT SYSTEM



(57) Abstract

A wastewater treatment system and method utilising emergent aquatic plants wherein the plants (48, 68, 26) are planted in a porous substrate (41, 72, 28) enclosed by a water impervious boundary (44, 74, 80). The roots of the plants extend into the substratum to form a root zone. An inlet means (50, 76, 82) is arranged such that wastewater enters the system below the rootzone and flows upwardly through the substratum. The wastewater is removed by outlet means (60, 86) located adjacent the rootzone.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MR	Mauritania
BE	Belgium	GA	Gabon	MW	Malawi
BF	Burkina Fasso	GB	United Kingdom	NL	Netherlands
BG	Bulgaria	HU	Hungary	NO	Norway
BJ	Benin	IT	Italy	RO	Romania
BR	Brazil	JP	Japan	SD	Sudan
CA	Canada	KP	Democratic People's Republic of Korea	SE	Sweden
CF	Central African Republic			SN	Senegal
CG	Congo	KR	Republic of Korea	SU	Soviet Union
CH	Switzerland	LI	Liechtenstein	TD	Chad
CM	Cameroon	LK	Sri Lanka	TG	Togo
DE	Germany, Federal Republic of	LU	Luxembourg	US	United States of America
DK	Denmark	MC	Monaco		

WASTEWATER TREATMENT SYSTEM

This invention relates to a water treatment system and method and is particularly concerned with a system and method for wastewater treatment using aquatic plants.

Artificial wetlands have a potential for low maintenance, low-cost treatment of rural, urban and industrial wastewaters for removal of nutrients and heavy metals and particulate material.

A combination of physiological, microbiological and physico-chemical processes, which are most active in the rootzone, are important in the treatment of wastewater. These are:

- absorption of nutrients by the plants;

- the conversion of the organic forms of nitrogen and ammonia to nitrate at aerobic microsites where small amounts of oxygen leak from the plant roots into the otherwise anaerobic system;

- adsorption of waste substances onto the inorganic and organic particles in the substratum;

- sedimentation of particles so the the water becomes clear.

Most artificial wetland systems have been based on horizontal flow formats, either the longitudinal flow trench style design (Seidel, 1976; Pope 1981), or the transverse flow rootzone method design (Kickuth, 1977; Brix 1987).

Artificial wetlands have typically been simple earth structures (usually trench shaped) filled with a porous

substratum such as gravel and planted with emergent aquatic macrophytes. In this conventional system, wastewater is introduced into the system and allowed to percolate down through and out of the system under gravity. The performance of these common trench-style systems is variable. The main problem with the conventional system is considered to be the non-ideal hydrology resulting in poor wastewater-root zone contact.

Tracer experiments carried out by us on flow patterns in trench style systems have shown divergence from the ideal plug flow condition for that system. The results indicate short circuiting of between half to three quarters of the upper strata of the trench profile. These hydraulic results are considered to be a direct function of the system design and to have a major influence on the system treatment process. Plant root densities usually decrease with the depth down the profile. As a result, the growth of aquatic plants in trench systems results in a profile with increasing hydraulic conductivity with depth, as roots progressively occupy the interstitial spaces in the upper strata. Consequently the wastewater short circuits the rootzone.

It is an object of the present invention to overcome or at least mitigate the abovementioned problem attending conventional systems. In particular it is an object to provide a system and method which improve wastewater-root zone contact.

The term "wastewater" as used herein is to be construed in its widest sense and includes domestic, agricultural and industrial effluent for example primary settled sewage, effluent from abattoirs and feedlots, seepage from mine tailings and water impoundments at mine sites.

In one aspect the present invention provides a method of treating wastewater, said method comprising the steps of:

providing a porous substratum planted with a plurality of emergent aquatic plants wherein the roots thereof extend at least partially into said porous substratum to provide a rootzone therein;

supplying said wastewater to said substratum at a location below said rootzone so as to cause vertical upflow of said wastewater; and

removing treated wastewater from one or more locations adjacent said rootzone

In a further aspect the invention provides a wastewater treatment system comprising:

a porous substratum contained within a substantially water impervious boundary;

a plurality of emergent aquatic plants planted in said substratum such that the roots thereof extend at least partially into said substratum to form a rootzone therein;

means for supplying wastewater to said substratum at a position below said rootzone; and

one or more system effluent outlets located adjacent the plant root zone.

The plants utilised may be any suitable aquatic plant and may be, for example, *Typha domingensis*, *Phragmites*

australis, *Schoenoplectus lacustris* or *Schoenoplectus validus*.

Preferably the system is conditioned before use by controlling the amount of nutrient entering the system so as to ensure sufficient root mass. If high nutrient material such as primary settled sewage is provided too early, insufficient root mass may develop.

The system may be above-ground or in-ground. In the case of the former, the substantially impervious boundary may be a plastic, cement, metal or like containment material. In the case of an in-ground system the boundary may be consolidated earth, such as that used in an earth dam, clay or plastic lining. By "substantially water impervious" we mean that the boundary is sufficiently impervious to prevent significant seepage from the system.

The porous substratum may be formed from gravel and the like or any other suitable particulate water insoluble material. Preferable the porous substratum is formed from gravel having a diameter of approximately 3 to 10 mm, preferably 5 to 10 mm.

The means for supplying wastewater may be a pipe or conduit extending downwardly into the body of the porous substratum. There may be a network of pipes into the system. Alternatively, the means may be external to the system and have an outlet communicating with the substratum. The system outside walls may, together with one or more substantially water impervious partitions, form the sides of the means for supplying wastewater. For example, a partition may be located vertically within the system boundary so that it extends between opposite walls of the boundary to form a trench-like structure adjacent the substratum. The bottom of the partition may be spaced from

the system base so as allow influent to pass to the substratum.

The means for supplying wastewater may be filled with relatively large particulate material to augment the treatment of the influent wastewater. The diameter of the relatively large particulate material may be larger than that of the substratum material. Preferably the diameter of this particulate material is in the range of about 40 to 50 mm. This relatively large particulate material may extend horizontally in the body of the system and so support the relatively fine particulate material of the substratum and allow a relatively even supply of influent across the horizontal profile of the substratum. Further the relatively large particulate material is less prone to blocking by solid material in influent such as primary settled sewage.

The one or more system outlets are located adjacent the rootzone. It is particularly advantageous to locate the system outlet(s) at least 5 cm below the substratum surface as this prevents both obnoxious odours being produced and insect (eg mosquitoes) breeding in the system. The system outlet(s) may be a pipe or other conduit. The diameter of the pipe may be 100 mm and conventional agricultural PVC pipe may be used. The capacity of the system outlet(s) may be chosen to equalise flow paths between the system inlet(s) and outlet(s).

In a further embodiment the system of the invention may also include means to avoid short circuiting of influent up any level surfaces of the structure. These means may be one or more flanges extending from the system outside wall(s) and/or from around the outlet of the means for supplying wastewater. These flanges may be made from any suitable

material such as plastic film, marine board, compacted clay the like.

The performance of experimental systems using the vertical upflow regime of the present invention with respect to concentration and reduction of impurities in primary settled sewage using a 5 day retention time is given in Table 1.

TABLE 1

Typical System Performance - Daily summary

Variable	Summer		Winter	
Concentration ($mg\ l^{-1}$)	In	Out	In	Out
TN	20.5	1.0	36.0	2.1
TP	4.6	0.2	6.8	0.4
TCOD	122.1	59.1	208.1	52.3

Load ($mg\ m^{-2}d^{-1}$)	In	Out	% removal	In	Out	% removal
TN	310.6	7.2	97.7	545.2	23.6	95.7
TP	69.0	1.8	97.3	102.9	4.0	96.1
TCOD	1849.0	449.0	75.7	3159.5	602.4	80.9

Temperature conditions (^{o}C):

Mean max.	32.7	21.2
" min.	17.2	3.1
" daily	24.9	12.2
Median	25.0	12.3
Range	12-40	1-27

Abbreviation:

TN - Total Nitrogen
TP - Total Phosphorus
TCOD - Total Chemical Oxygen Demand

It will be clear from these results that the present invention provides essentially a single unit alternative to a conventional secondary-tertiary system combination. The invention provides high treatment performance particularly for removal of problem elements such as phosphorous.

The system of the invention is a particularly attractive alternative when the cost advantage is considered. We have found that loads can be increased, and retention times decreased several-fold with no drop-off in performance. Thus the system of the present invention is particularly flexible and easily managed under a range of operating conditions. A particular advantage of the system of the present invention is that the influent can be primary settled sewage thus reducing the need for extra plant.

The system is a particularly suitable for small community sewage requirements. For example, for a 1,000 person equivalent system, where the population will be becoming on-line over a period of time, four 250 person equivalent units may be used. The depth of each unit may be about 1 metre, have a Pore Volume factor of about 3 and a retention time in the order of 5 days. For the following person equivalent discharge rates, the 250 person equivalent sizes are:-

200 L person $^{-1}$ d^{-1} system area 450 m^{2} (27 x 27m)

300 L person $^{-1}$ d^{-1} system area 675 m^2 (33 x 33m)

Retention times may be as low as 1.25 days. The upper limit on size of the system of the invention is set by the ability to provide the plants with sufficient water.

The invention will now be described more particularly, by way of example only, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is top plan view of one embodiment of the invention;

Figure 2 is a sectional view taken generally along A-A of Figure 1;

Figure 3 shows a top plan view of a further embodiment of wastewater treatment system in accordance with the invention;

Figure 4 a sectional view taken along B-B of Figure 3;

Figure 5 illustrates a domestic system in accordance with the invention.

BEST MODES FOR CARRYING OUT THE INVENTION

It is to be understood that invention is not limited to the following described embodiments.

Referring first to Figures 1 and 2 there is shown a wastewater treatment system 30 which comprises an approximately 700 mm deep substantially porous substratum 41 comprising 5 to 10 mm washed gravel contained within a retaining wall 44 formed from consolidated earth. If the

earth is not sufficiently water impervious a clay lining may be provided.

The substratum 41 is planted with plants 48 such that their roots extend therein. The planted surface of the system may have an area ranging from 11x11 m to 35x35 m, although it will be clear that the size of the planted area may be selected to suit the load to be placed on the system.

Wastewater for treatment is supplied through pipe 50 which may be 1.2 -1.8 m standard culvert pipe. This pipe is filled with 40 to 50 mm cobbles and communicates with the substratum via a layer of cobbles of 40 to 50 mm diameter on the floor of the system. Preferably the cobbles in the pipe extend above the level of the substratum surface so that the influent wastewater passes over dry cobbles to assist in the treatment of carbon. This layer may have a depth of 200 to 300 mm.

Flange 52 is located around the outlet of the pipe 50 so as to prevent short circuiting of the wastewater up the level exterior surface of the pipe. The flange may be formed from plastic film. A flange 54 is also provided at the inside wall of the structure so as to prevent short circuiting up the level surfaces of the containing wall(s).

One or more system outlets 60 are provided at least 5 cm below the substratum surface. These outlet may be conventional 100 mm PVC agricultural pipe.

In operation wastewater 10 is introduced into the system through pipe 50 setting up vertical upflow of wastewater so that the wastewater is forced upwards against gravity towards the rootzone of plants 48. The purified

wastewater then exits from the system through the one or more outlets 60.

We have found that the above system maximises waste water-root zone contact and reduces short circuiting. The upflow movement of wastewater also results in the system being virtually flood proof. The system can be operated so that there is no freestanding surface water for pests, for example mosquitoes, and odour is minimised.

Figures 3 and 4 illustrate alternative arrangement of the system of the invention in which the wastewater is introduced to the system via a trench like structure. Here substratum 72 of washed 5 to 10 mm gravel, planted with plants 68 is contained within retaining walls 74. In this case the planted surface area is 15x5 m. A 15 m water impervious partition 78 extends between opposite walls 74 and is located approximately 1 metre from the parallel retaining wall 74a to form a trench inlet 76. Inlet 76 is filled with 40 to 50 mm cobbles and communicates with the substratum 72 via a layer of cobbles 70, the combined depth of the substratum and cobbles being approximately 1 m. A flange 80 is located perpendicularly to the base of the partition 78 to prevent short circuiting up the partition. Flange 82 extends from the wall(s) 74 to prevent short circuiting up the retaining walls. One or more system outlets 86 are located adjacent the rootzone at least 5 cm under the substratum surface. This structure may have a substratum bed area of 6m by 15m.

Wastewater such as primary settled sewage is introduced into the system through inlet 76 and enters the substratum 72 via cobbles 70 and then vertically upwards towards the rootzone.

Figure 5 illustrates a single house domestic treatment unit **24** in accordance with the invention. The system comprises a 5 m diameter containment wall **80** fabricated from fibreglass, concrete or other suitable material. Plants **26** are planted in a 5 mm gravel layer **28**. Influent from a septic tank is introduced into the system through pipe **82**. The wastewater passes from the pipe **82** upwardly towards the rootzone via cobble layer (40 mm) **84**. Purified effluent is removed at points **86**. The capacity of the unit can be set by the cubic metres of gravel used in the system.

Finally, it is to be understood that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts previously described without departing from the spirit or ambit of the invention.

REFERENCES

SEIDEL, K. (1976). Macrophytes and water purification. In Biological control of water pollution (eds. Tourbier, J. & Pierson, R.W.). University of Pennsylvania Press, Philadelphia, pp. 109-121

POPE, P.R. (1981). Wastewater treatment by rooted aquatic plants in sand and gravel trenches. (EPA-600/2/81-091), US Environmental Protection Agency, Cincinnatti, Ohio.

KICKUTH, R. (1977) Degradation and incorporation of nutrients from rural wastewaters by plant rhizosphere under Limnic conditions. In Utilization of manure by land spreading. (Ed Voorburg, J.H.) Commission of European Communities EUR 567Ze, London, pp 335-343.

BRIX H. (1987) Treatment of wastewater in the rhizosphere of wetland plants - the rootzone method. Water Science Technology. 19: 107-118

CLAIMS

1. A wastewater treatment system comprising:

a porous substratum contained within a substantially water impervious boundary;

a plurality of emergent aquatic plants planted in said substratum such that the roots thereof extend at least partially into said substratum to form a rootzone therein;

means for supplying wastewater to said substratum at a position below said rootzone; and

one or more system effluent outlets located adjacent the plant root zone.

2. The system defined in claim 1 wherein the porous substratum comprises particulate material of a diameter in the range of about 3 to 10 mm, preferably 5 to 10 mm.

3. The system defined in claims 1 or 2 wherein the means for supplying wastewater is/are one or more pipe(s) or like conduits.

4. The system of claim 1 or 2 wherein the means for supplying wastewater is formed by the association between one or more partitions with one or more walls of the system boundary.

5. The system of claim 4 wherein the means for supplying wastewater comprises a vertical partition extending between opposite sides of the system boundary to form a trench-like

structure, said structure having an outlet communicating with said substratum.

6. The system defined in claim 5 wherein said partition is spaced from the floor of the system boundary so as to allow wastewater to pass to the said substratum.

7. The system defined in any one of claims 2 to 6 wherein the means for supplying wastewater contains particulate material of larger diameter than that of said substratum.

8. The system defined in claim 7 wherein the particulate material in the wastewater supply means is cobbles of diameter ranging from approximately 40 to 50 mm.

9. The system defined in any one of claims 1 to 8 including a layer of relatively large diameter particulate material below said substratum, said means for supplying wastewater communicating with said layer.

10. The system defined in claim 9 wherein said layer comprises cobbles of a diameter ranging from 40 to 50 mm.

11. The system defined in claims 1 to 10 wherein the system outlet is located at least 5 cm below the substratum surface.

12. The system defined in any one of claims 1 to 11 further including means to avoid short circuiting of wastewater up any level surface in the system.

13. The system defined in claim 12 wherein the means to avoid short circuiting is one or more flanges extending from the walls of the boundary.

14. The system defined in claim 12 or 13 wherein the means to avoid short circuiting is a flange extending from the outlet of the wastewater supply means.

15. A method for treating wastewater, said method comprising the steps of:

providing a porous substratum planted with a plurality of emergent aquatic plants wherein the roots thereof extend at least partially into said porous substratum to provide a rootzone therein;

supplying said wastewater to said substratum at a location below said rootzone so as to cause upflow of said wastewater; and

removing treated wastewater from one or more locations adjacent said rootzone.

16. The method defined in claim 15 wherein the porous substratum comprises particulate material of a diameter in the range of about 3 to 10 mm, preferably 5 to 10 mm.

17. The method defined in claims 15 or 16 wherein the said wastewater is supplied to said substratum by means comprising one or more pipes or conduits.

18. The method defined in claim 15 or 16 wherein wastewater is supplied to said substratum by supply means formed by the association between one or more partitions with one or more walls of the system boundary.

19. The method defined in claim 18 wherein the means for supplying wastewater comprises a vertical partition extending between opposite sides of the system boundary to

form a trench-like structure, said structure having an outlet communicating with said substratum.

20. The method defined in claim 19 wherein said partition is spaced from the floor of the system boundary so as to allow wastewater to pass to the said substratum.

21. The method defined in any one of claims 17 to 20 wherein the means for supplying wastewater contains particulate material of larger diameter than that of said substratum.

22. The method defined in claim 21 wherein the particulate material in the wastewater supply means is cobbles of diameter ranging from approximately 40 to 50 mm.

23. The method defined in any one of claims 15 to 22 wherein said wastewater is supplied to said porous substratum via a layer of relatively large diameter particulate material below said substratum.

24. The method defined in claim 23 wherein said layer comprises cobbles of a diameter ranging from approximately 40 to 50 mm.

25. The method defined in claims 15 to 24 wherein said wastewater is removed from said system from a location at least 5 cm below said substratum surface.

26. The method defined in any one of claims 15 to 25 with means are provided to avoid short circuiting of said wastewater away from the rootzone.

27. The method defined in claim 26 wherein the means to avoid short circuiting is one or more flanges extending from the walls of the boundary.

28. The method defined in claim 26 or 27 wherein the means to avoid short circuiting is a flange extending from the outlet of the wastewater supply means.

29. The method defined in any one of claims 15 to 28 wherein the wastewater is sewage.

30. The method defined in claim 29 wherein the wastewater is primary settled sewage.

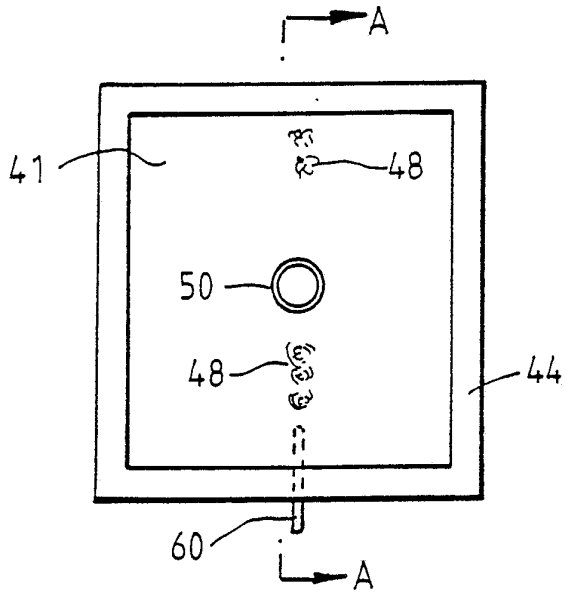


FIG. 1.

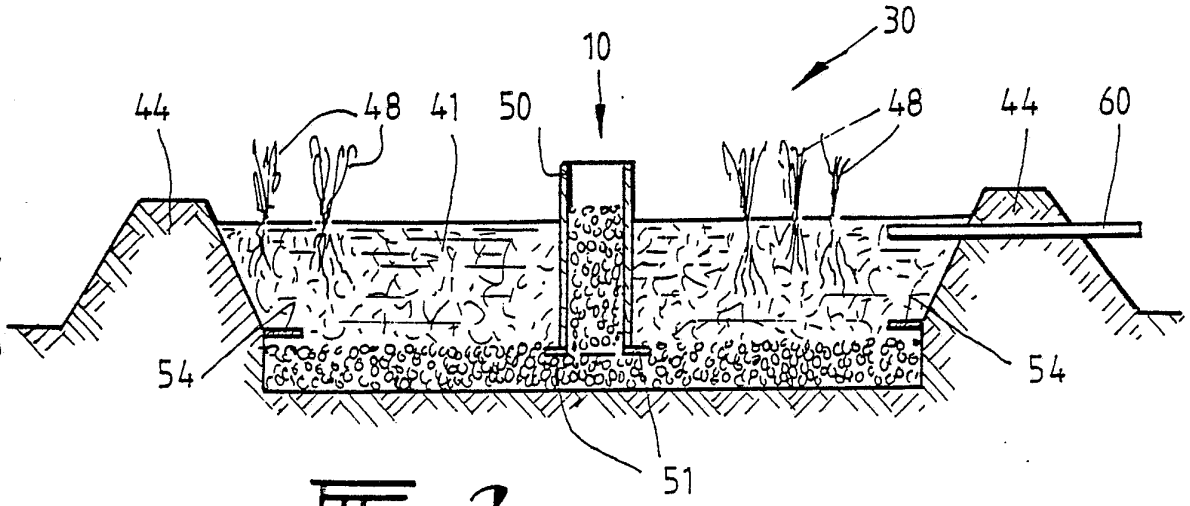


FIG. 2.

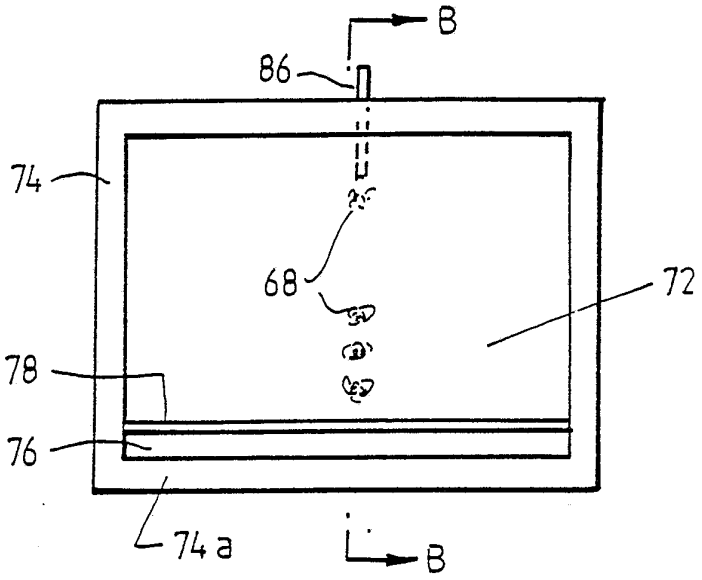


FIG. 3.

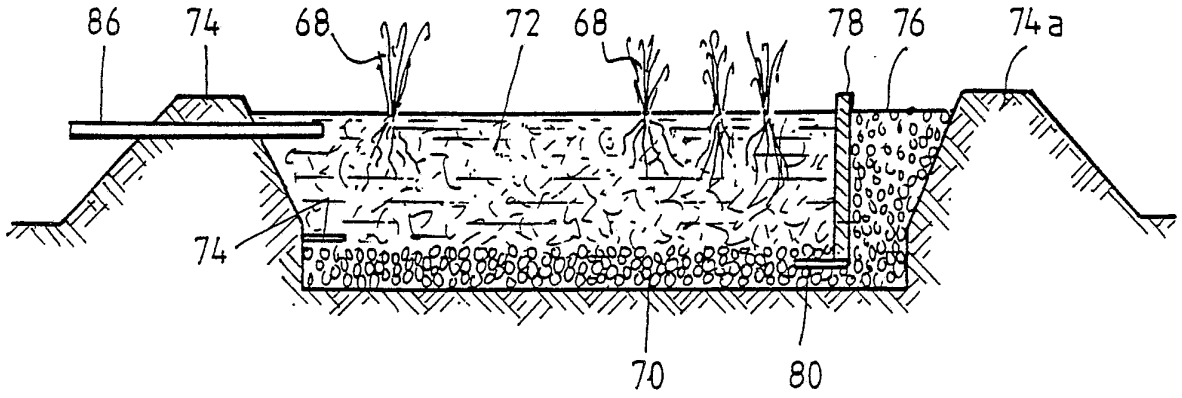


FIG. 4.

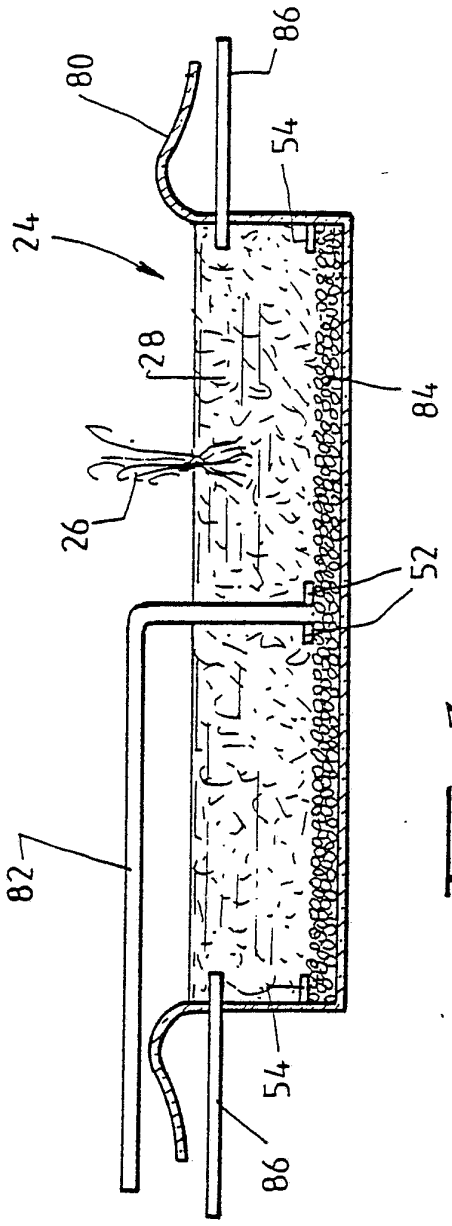


Fig. 5.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 89/00372

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[4] C02F 3/32

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	C02F 3/32, 1/02
US Cl	210/602, 405/128

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X	US,A, 4415450 (WOLVERTON) 15 November 1983 (15.11.83)	1-3, 7-11
A	US,A, 4678582 (LAVIGNE) 7 July 1987 (07.07.87)	15-17, 21-25
A	US,A, 4169050 (SERFLING et al) 25 September 1979 (25.09.79)	1-30

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
5 December 1989 (05.12.89)	11/12/89
International Searching Authority	Signature of Authorized Officer
Australian Patent Office	G. CARTER

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 89/00372

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
US 4678582	AU 69000/87	DK 4954/87	EP 290463
	NO 873989	WO 8704424	

END OF ANNEX