



(51) **International Patent Classification:**
C02F 1/44 (2006.01) **B01D 63/00** (2006.01)
B01D 61/00 (2006.01)

(21) **International Application Number:**
PCT/AU2010/001617

(22) **International Filing Date:**
1 December 2010 (01.12.2010)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
2009905857 1 December 2009 (01.12.2009) AU

(71) **Applicant (for all designated States except US):** **UNIVERSITY OF QUEENSLAND** [AU/AU]; St. Lucia, Queensland 4072 (AU).

(72) **Inventor; and**

(75) **Inventor/Applicant (for US only):** **TRAU, Mathias** [AU/AU]; 59 Bunowang Street, Balmoral, Queensland 4171 (AU).

(74) **Agents:** **CURWEN, Julian Charles Barton** et al.; Davies Collison Cave, 1 Nicholson Street, Melbourne, Victoria 3000 (AU).

(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) **Title:** WATER TREATMENT

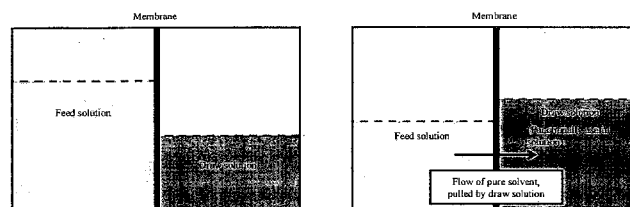


FIGURE 1

(57) **Abstract:** A method of producing a non-potable, functionally useful solution, which method comprises: providing on respective sides of a semi-permeable membrane a feed solution and a draw solution, wherein the draw solution comprises an osmotic agent that is functionally useful and that creates an osmotic pressure difference between the feed solution and the draw solution; and allowing solvent to diffuse through the semi-permeable membrane from the feed solution to the draw solution in order to produce the functionally useful solution. The invention also provides a method of producing a potable solution, which method comprises: providing on respective sides of a semi-permeable membrane an aqueous feed solution and a draw solution, wherein the draw solution comprises an osmotic agent that creates an osmotic pressure difference between the feed solution and the draw solution and an additional agent that serves to maintain or prolong the osmotic pressure difference as the draw solution is diluted and/or increase the rate of flux of solvent molecules moving from the feed solution to the draw solution when compared with an equivalent draw solution absent the additional agent; and allowing water to diffuse through the semi-permeable membrane from the feed solution to the draw solution to produce a potable solution.



- 1 -

Water treatment

Technical field of the invention

5 The present invention relates to the processing/treatment of a solvent-containing solution, such as water, in order to render it useful. More specifically, the present invention involves forward osmosis to generate non-potable, functionally useful solutions. The present invention also relates to non-potable, functionally useful solutions produced in accordance with the present invention, and to components and devices in which such
10 aqueous solutions may be generated.

Aspects of the invention also relate to the application of forward osmosis to generate potable water-containing solutions, and to solutions produced in accordance with these aspects.

15

Background of the invention

Concerns over dwindling water reserves have seen much emphasis on the recycling of water, particularly grey water, highly saline and/or polluted water. Thus, it is now
20 commonplace for grey water to be used domestically for irrigation, and the like. The quality of grey water does mean however that it is not suitable for certain applications. For example, grey water that has been produced as output from a washing machine is not generally fit to be reused for that purpose.

25 Similarly, the quality of other sources of water may render it unsuitable for certain applications without prior treatment or conditioning. For example, water that has relatively high mineral content (mainly as calcium and magnesium ions) is typically unsuitable for washing purposes since it does not readily form a lather with detergent and because deposits can form due to calcification.

30

- 2 -

The present invention seeks to enable a greater range of water sources to be rendered practically useful.

The same issues also arise in connection with certain non-aqueous solutions.

5

In relation to potable solutions, there is an on-going need to provide technology which allows consumable water to be produced from water that is otherwise unsuitable.

Summary of the invention

10

In one embodiment the present invention provides a method of producing a non-potable, functionally useful solution, which method comprises:

15

providing on respective sides of a semi-permeable membrane a feed solution and a draw solution, wherein the draw solution comprises an osmotic agent that is functionally useful and that creates an osmotic pressure difference between the feed solution and the draw solution; and

20

allowing solvent to diffuse through the semi-permeable membrane from the feed solution to the draw solution in order to produce the functionally useful solution.

25

The present invention may be applied to the production of water-based functionally useful solutions. The present invention may also be applied to the production of non-aqueous functionally useful solutions. Irrespective of the proposed use, in this aspect of the invention the solutions are non-potable and the general principles underlying this aspect of the invention are not intended to generate potable solutions. Practical applications of the present invention are discussed below.

30

In an embodiment, the invention does relate to the production of a potable solution from an otherwise non-potable source solution. In this embodiment there is provided a method of producing a potable solution, which method comprises:

- 3 -

- providing on respective sides of a semi-permeable membrane an aqueous feed solution and a draw solution, wherein the draw solution comprises an osmotic agent that creates an osmotic pressure difference between the feed solution and the draw solution and an
5 additional agent that serves to maintain or prolong the osmotic pressure difference as the draw solution is diluted and/or increase the rate of flux of solvent molecules moving from the feed solution to the draw solution when compared with an equivalent draw solution absent the additional agent; and
- 10 allowing water to diffuse through the semi-permeable membrane from the feed solution to the draw solution to produce a potable solution.

Details of each of these embodiments are discussed in more detail below.

15 Brief discussion of the drawings

Embodiments of the present invention are illustrated with reference to the accompanying non-limiting drawings in which:

- 20 Figure 1 is a schematic illustrating an embodiment of the present invention;

Figure 2 is a schematic illustrating an embodiment of the present invention;

Figure 3 is a schematic illustrating an embodiment of the present invention;

25

Figure 3A is a schematic illustrating an embodiment of the present invention;

Figure 4 is a plot illustrating experimental results obtained in the example;

- 30 Figure 5 is a plot illustrating experimental results obtained in the example; and

- 4 -

Figure 6 is a plot illustrating experimental results obtained in the example.

Detailed discussion of the invention

5 The present invention relies on an osmotic process, that is the transport (flux) of solvent molecules across a selectively permeable membrane. This transport is driven by a difference in solute concentration across the membrane that allows movement of solvent molecules but impedes the movement of other molecules, such as ions, salts, starches, sugars, proteins, viruses and bacteria. In accordance with the present invention the
10 concentration difference (osmotic pressure) is due to the presence of a specifically selected osmotic agent in a draw solution.

Herein the expression "draw solution" is used to refer to the solution containing the osmotic agent. In the present invention the draw solution is specifically formulated so that
15 solvent molecules will be transported into the draw solution across a semi-permeable membrane from a source of solvent that is relatively more dilute with respect to the solvent than the draw solution. Herein that source of solvent is referred to as a "feed solution". The feed solution is a source of solvent from which it is desired to recycle or recover solvent molecules so that the draw solution may be diluted thus forming a functionally
20 useful aqueous solution.

Figure 1 is a schematic illustrating in general terms the process underlying forward osmosis. Potential feed solutions include such things as hard water, salt water, contaminated (e.g. by metals) water, and the like. Bearing in mind intended functionality,
25 potential draw solutions may include detergent, fertilizer, mine tailings, etc.

An important aspect of the present invention is the nature of the osmotic agent that is used. Specifically, the osmotic agent is responsible for the functionality of the (aqueous or non-aqueous) solution that is formed when the draw solution receives solvent from the feed
30 solution across the semi-permeable membrane. The invention is believed to have particular applicability to the production of a non-potable, functionally useful aqueous

- 5 -

solution. In such embodiments the solvent is water. Thus, the invention provides a method of producing a non-potable, functionally useful aqueous solution, which method comprises:

- 5 providing on respective sides of a semi-permeable membrane a feed solution and a draw solution, wherein the draw solution comprises an osmotic agent that is functionally useful and that creates an osmotic pressure difference between the feed solution and the draw solution; and
- 10 allowing water to diffuse through the semi-permeable membrane from the feed solution to the draw solution in order to produce the functionally useful aqueous solution.

In one such embodiment the osmotic agent is a detergent and the functionally useful aqueous solution is intended to be used for washing purposes, for example of clothes or
15 crockery etc. The aqueous solution could be produced for hand-washing of clothes or crockery etc but more likely the aqueous solution will be produced for use in a washing machine or dishwasher. Aqueous solutions containing a suitable detergent may have numerous other possible applications, such as in washing of vehicles. However, it is envisaged that the present invention may have particular utility in producing a detergent-
20 containing solution for use in clothes washing.

In another embodiment the functionally useful aqueous solution produced in accordance with the invention is specifically adapted for use in horticulture or agriculture. In this case the osmotic agent may be a suitably active horticultural or agricultural agent, such as a
25 fertilizer, herbicide or pesticide.

The feed solution may be any suitable source of water from which water (molecules) may be recovered in accordance with the present invention taking into account of course the characteristics of the semi-permeable membrane and draw solution used, and the
30 characteristics of the functionally useful aqueous solution to be produced. Thus, the feed solution must be capable of giving up water to the draw solution across the semi-

- 6 -

permeable membrane so that a suitable dilution of the draw solution takes place in order to produce the functionally useful aqueous solution. Taking into account the transport characteristics of the semi-permeable membrane that is used, the feed solution should not contain any species that will find their way into the draw solution and that will cause problems with respect to the intended practical application for the aqueous solution to be produced.

The feed solution may be grey water, i.e. waste water generated from activities such as laundry, dish washing and bathing. The use of water from sanitation equipment will not be used if the end-use of the aqueous solution is for washing purposes. It may be acceptable in certain applications to use sewage as the feed solution but this would need to be assessed carefully. Some processing of the sewage may also be required prior to use as feed solution, for example filtration.

In another embodiment the feed solution may be water that is otherwise unsuitable for the intended end use. For example, hard water, brackish water and seawater are generally unsuitable for washing purposes due to the presence of dissolved ions. In this case the present invention may be applied to prevent the transmission of such undesirable species from the feed solution to the draw solution. Here the characteristics of the semi-permeable membrane will influence the molecular species that are able to migrate from the feed solution to the draw solution.

The feed solution may also include toxic or noxious species which make the feed solution unsuitable for use in a given application. For example, mine site waste water might be a source of feed solution, depending upon the intended end use. In this case the invention may be applied to effectively filter out undesirable species such as heavy metals, and the like. In this example, soluble fertiliser can be used as the draw solution in order to produce functionally useful water (e.g., water for agricultural purposes) from toxic mine-site water such as waste water from coal-seam gas production plants.

- 7 -

Desirably, the functionally useful aqueous solution that is produced in accordance with the present invention may be used as is. However, it is possible that, depending upon the dilution of osmotic agent that may be achieved, some further dilution may be required to achieve a desired concentration of osmotic agent. Similarly, one or more other active ingredients may be added to the functionally useful aqueous solution in order to tailor its properties. It may not be appropriate to include such actives in the draw solution initially.

The osmotic agent must be solubilised or dispersed in (the solution phase of) the draw solution under the intended conditions at which the invention is to be implemented. The concentration of osmotic agent in the draw solution is typically pre-selected based on the nature of the feed solution, the characteristics of the semi-permeable membrane and the intended concentration of osmotic agent in the aqueous solution to be produced. Generally, the osmotic agent provides an osmotic concentration of from 1 bar to 200 bar.

The semi-permeable membrane used in the present invention is of conventional type and numerous types of useful membranes are commercially available. Examples of useful membrane materials include hydrophilic and cellulose ester-based membranes.

In other embodiments the solvent may be non-aqueous in character. Thus, according to a further embodiment the invention may be applied to clean and recycle cleaning fluids, such as dry cleaning fluid. In this case, solvent is extracted from a used fluid (feed solution) and transferred to a concentrated draw solution containing relevant cleaning fluid components. One skilled in the art would be familiar with suitable semi-permeable membranes that may be used in such embodiments.

25

Typically, the feed solution and draw solution are provided in respective compartments (or chambers) with a window or wall-member of semi-permeable membrane separating the two solutions. In an embodiment one of the draw solution and feed solution may be provided in a bag formed from or including a wall portion formed of the semi-permeable membrane. In use the bag will be immersed in the complementary solution and withdrawn when the osmotic process has taken place. In another embodiment the respective solutions

30

- 8 -

are provided in compartments that have a mutual window or wall-portion of semi-permeable membrane. The compartments may be adapted to allow re-stocking of draw and feed solutions as necessary. This arrangement may be automated as the characteristics of respective solutions change with the osmotic process. In another embodiment, the feed
5 solution may be pumped through cylindrical tubes formed by the membrane in order to maximise the surface area of contact with the membrane, and also to maximise flux through the membrane.

In an embodiment of the invention the activity of the draw solution with respect to osmotic
10 uptake from a feed solution may be potentiated, maintained or prolonged by including suitable particulate matter in the draw solution. By way of example, the draw solution may be a super-saturated solution of osmotic agent and the particulate matter may be the same or different osmotic agent that is insoluble in the draw solution at the prevailing concentration but that will be soluble on dilution of the draw solution. Thus, as dilution of
15 the draw solution proceeds, the particles (begin to) dissolve thereby increasing the concentration of the draw solution and its capacity to extract water from an associated feed solution. The same effect may be achieved using certain types of particulate matter that is inherently insoluble in the draw solution. In either case the particle size of such matter is likely to be relevant to its activity, and the particle size may be optimised to enhance the
20 results obtained. It is envisaged that fine particle dispersions, such as mine site tailings or similar slurries, could be used as a draw solution. The suspended particles in such situations would typically be sized from approximately 1 nanometer in diameter to greater than 1 micron.

25 In this embodiment the draw solution may be regarded as being "active" or "passive" depending upon the characteristics of the particulate matter. In the context of the present invention an "active" draw solution is a dispersion/suspension in which (colloidal) particles dissolve as the draw solution is diluted by an influx of pure solvent. The process of dissolution maintains the solute concentration in the draw solution at a saturation level
30 (hence minimising the reduction in osmotic pressure) during an influx of pure solvent into the draw solution. This maintains or prolongs the efficacy of the draw solution. The

- 9 -

particles may also increase the rate of flux of solvent molecules across the membrane. In the context of the present invention a “passive” draw solution is a dispersion/suspension in which the particles are inherently insoluble in the draw solution. Their presence however creates an osmotic pressure gradient across the membrane that causes fluid to flow.

5

The nature and composition of the particles to be used in the active and passive approaches will be driven by the proposed end use of the functionally useful fluid to be produced. For a laundry or washing-type application, the draw solution may be a colloidal suspension of a washing detergent in liquid form, or the draw solution prepared from such liquid
10 detergent.

15

The use of the “active” and “passive” approaches referred to above is illustrated with the aid of Figures 2 and 3. Figure 2 shows the use of a specially formulated draw solution containing particles (e.g. crystals) dispersed in a saturated solution. The particles are
15 soluble in the draw solution but not under the prevailing concentration conditions of the draw solution. However, as the draw solution is diluted with solvent from the feed solution, the particles can dissolve to at least some extent thereby boosting the concentration of the draw solution. In turn this helps to maintain or prolong the efficacy of the draw solution, and possibly hasten the flux of solvent across the membrane. Note that
20 in the right hand diagram in Figure 2, there are fewer particles as a result of particle dissolution.

25

Figure 3 illustrates the “passive” approach in which the particles are inherently insoluble in the draw solution. The particles serve to increase the osmotic pressure as compared to an
25 equivalent draw solution absent the particles. However, as solvent fluxes from the feed solution to the draw solution no dissolution of particles takes place. In the “passive” approach the process pulling the solvent across the membrane is likely to be relatively slower than with the “active” approach. The draw solution may be mine site tailings and in this case the invention may be implemented in large ponds at the mine sites where
30 contaminated mine water can be cleaned slowly over several days/weeks.

- 10 -

More than one of the approaches described may be employed in combination to enhance, potentiate or prolong the efficacy of the draw solution and/or increase the rate of flux of solvent molecules across a semi-permeable membrane. Thus, in an embodiment of the invention, the draw solution further comprises particulate matter that serves to increase the rate of flux of solvent molecules moving from the feed solution to the draw solution when compared with an equivalent draw solution absent the particulate matter

The functionally useful (aqueous or non-aqueous) solution produced in accordance with the present invention may be used immediately or it may be stored in a suitable reservoir (storage stability being considered) for subsequent use. The osmotic process is not rapid and production of a practically useful volume of the aqueous solution may take some time so that continuous production and storage of the solution may be preferred.

The present invention also provides a functionally useful (aqueous or non-aqueous) solution when produced in accordance with the methodology described.

The present invention also provides device incorporating componentry to enable implementation of the present invention. The device may be a stand-alone system that includes respective compartments for the draw solution and feed solution and a suitably positioned semi-permeable membrane. The system may feed directly into related devices such as a washing machine or dishwasher, and here a reservoir of functionally useful solution may be required.

In another embodiment, componentry necessary to implement the invention may be integrated as part of a larger device that requires the solution for operation, such as a washing machine or dishwasher. Desirably, componentry enabling implementation of the invention is compact and thus can be fitted into an existing washing machine, or the like.

The semi-permeable membrane may require cleaning from time to time and preferably this may be undertaken automatically by spray washing, scraping or the like.

- 11 -

In another embodiment the present invention relates to the production of a potable solution from an otherwise non-potable feed solution. Accordingly, in this embodiment there is provided a method of producing a potable solution, which method comprises:

- 5 providing on respective sides of a semi-permeable membrane an aqueous feed solution and a draw solution, wherein the draw solution comprises an osmotic agent that creates an osmotic pressure difference between the feed solution and the draw solution and an additional agent that serves to maintain or prolong the osmotic pressure difference as the draw solution is diluted and/or increase the rate of flux of solvent molecules moving from
10 the feed solution to the draw solution when compared with an equivalent draw solution absent the additional agent; and

allowing water to diffuse through the semi-permeable membrane from the feed solution to the draw solution to produce a potable solution.

15

- Central to this embodiment is the use in the draw solution of an additional agent that serves to maintain or prolong the osmotic pressure difference between the draw and feed solutions as the draw solution is diluted with solvent from the feed solution. The agent in question is typically particulate in nature. The agent may be soluble or insoluble in the draw solution
20 as dilution of the draw solution progresses. This aspect is also discussed above where it is referred to as "active" and "passive" in relation to the production of non-potable functional solutions.

- In this embodiment the solvent is water and the feed solution may be seawater, brackish
25 water, or the like. The draw solution may be sugar-containing. The additional agent may be a sugar or salt or the like. Typically, the draw solution will be a super-saturated sugar solution containing undissolved sugars or salts that serve to potentiate or prolong the efficacy of the draw solution.

- 12 -

It is envisaged that in the field this embodiment will be implemented using a specially designed pack that has respective chambers for feed and draw solutions divided by a semi-permeable membrane. Such packs are known in the art and a typical arrangement is shown in Figure 3A which may be understood with reference to the following key:

5

SPM Semi-permeable membrane

- 1 Red bag = Dirty 'hard' water sample
- 2 Green bag = Draw solution (e.g, sugar)
- 3 'Clean' water
- 10 4 Left over impurities
- 5 Flux of solvent molecules

15 In use one chamber (2) is loaded with draw solution (including the additional agent) and the other chamber with feed solution (1). Over time water migrates (5) across the membrane (SPM) from the feed solution (1) into the draw solution (2) to produce a potable solution (3) from the draw solution. Impurities (4) are left in the chamber originally housing the feed solution (1). The same basic arrangement may be used to produce a non-potable, functionally useful solution in accordance with the invention as described herein.

20 The use of an agent in the draw solution to maintain or prolong the uptake potential of the draw solution with respect to the feed solution and/or increase the rate of flux of solvent molecules into the draw solution means that the efficacy of the draw solution can be improved. In turn, for a given volume of water to be transferred from the feed solution, this may allow weight reduction in the draw solution as compared with a draw solution
25 absent the additional agent. As the draw solution is something that may need to be carried in the field, any weight reduction that can be achieved will be advantageous. In this embodiment the agent should preferably be one that can be consumed in the dilute draw solution that is produced. Otherwise, in the case of an insoluble agent, the draw solution will need to be filtered or flocculated prior to consumption.

30

- 13 -

This particular embodiment may have particular use in military applications where the weight of equipment carried can be critical, and in non-military outdoor application, such as camping and the like.

- 5 Many modifications will be apparent to those skilled in the art without departing from the scope of the present invention.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will
10 be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or
15 admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

The following non-limiting examples illustrate embodiments of the present invention.
20

Example

It is known that continuous laundering in hard water can reduce the life of clothes by up to 40% and contribute to the inefficient operation and failure of water-using appliances.

25

This example aims to show that commercially available osmotic membranes (Hydration Technology Innovations [HTI] SeaPack & XPack) can be used with commercial laundry detergents to reduce water hardness, calcium carbonate concentration.

- 14 -

The osmotic flow rates for the following solutions were examined;

1. Water (negative control)
- 5 2. Sugar solution (positive control)
3. SDS (model detergent)
4. Commercially available laundry detergent powder
- 10 5. Commercially available laundry detergent liquid

Success was determined by the commercial laundry detergents inducing osmotic flow rates similar to the model sugar solution whilst reducing the calcium carbonate concentration of the osmotically transferred water.

Desalination SeaPacks with an inner 1800 mL capacity 'sample' bag and external 2000 mL capacity water bag, referred to as the "Green" and "Red" bags were filled with 200mL of sample or 1600mL of tap water, respectively. Osmotic flow rates were measured using 200 mL of the following sample solutions 5 or 50% w/v of sugar, SDS, detergent powder, or liquid detergent, plus a pure water solution (negative control). The changes in the Green and Red bag volumes were measured every 30 minutes for 6 hours, with a final reading taken after 24 hours.

The increase in green bag volume with time for all the samples tested are shown in Figure 4. As expected, the 50% solutions gave rise to larger osmotic pressures than the 5% solutions and therefore greater changes in the green bag volume. The sugar solution and powder detergent solutions gave rise to similar high osmotic flow rates, followed by the liquid detergent solutions. All three (sugar, powder and liquid detergent) of the 50% solutions gave rise to a final (24 hr) green bag volume of 1500 mL, a 7.5 fold increase. As expected the control water solution gave rise to no increase in green bag volume as no

- 15 -

osmotic pressure was expected. Interestingly the model SDS detergent solution also did not give rise to a change in green bag volume. Furthermore, upon further investigation SDS was also found in the red bag, indicating that the SDS permeated through the membrane and thus was not suitable for further use.

5

From the measured osmotic flow data, it was also possible to determine the required membrane area to treat 1L of water in an hour, as given in Table 1.

The minimum surface area required was 3,630 and 4,767 cm² for the HTI sugar solution and detergent powder solution, respectively. As seen with the flow rate data reducing the solution concentration from 50 to 5% reduced the osmotic flow rate and therefore required approximately 4 times the membrane surface area to clean 1L of water.

Table 1: Calculated Osmotic Flow Rates and Required Membrane Area

15

	Flow Rate (mL/hr)	Flow Rate per ml cm ² hour ⁻¹	Required membrane area (cm ²) for 1L/hr
Sugar Solution 5%	84	0.087	11,440
Sugar Solution 50%	264	0.275	3,630
Liquid detergent 5%	30	0.031	32,390
Liquid detergent 50%	128	0.133	7,508
Powder detergent 5%	67	0.070	14,298
Powder detergent 50%	201	0.210	4,767

Use of Membranes for reduction of Calcium Carbonate Water Hardness.

- 20 Calcium carbonate (CaCO₃) solution, in parts per million (ppm), was used as a model system to represent water hardness(KH). Calcium carbonate concentrations were measured using a commercially available test for water hardness (KH Carbonate Hardness Test Kit – Aquarium Pharmaceuticals). The commercial test was independently calibrated (Figure 5) against a series of CaCO₃ solutions being, 10, 20, 50, 100, 200 and 500ppm.
- 25 The test was found to be sensitive enough to measure ~10ppm changes in CaCO₃ concentration, down to 4.5ppm.

- 16 -

The effectiveness of the osmotic membrane to prevent the transfer of CaCO_3 and thereby reduce the hardness of the transferred water in the green bag, was tested by replacing the 1600 mL of tap water in the red bag with 1600 mL of a 50, 100 or 200ppm CaCO_3 solution. 200mL of a 50 % sugar solution was placed in three green bags, 200mL of a 50g detergent powder slurry in a fourth. The change in green and red bag volumes and CaCO_3 concentrations were measured after 4 hours.

After 4 hours for all three CaCO_3 concentrations studied (50, 100 and 200ppm) approximately $925 \pm 25\text{mL}$ (sugar solution) and $675 \pm 75\text{mL}$ (detergent) was transferred from the red to the green bag. The green bag CaCO_3 concentrations after osmosis were all below the CaCO_3 test sensitivity for the sugar solution, (4.5ppm), FIG 6. This was significantly lower than the initial red bag original concentrations (50, 100, or 200ppm) it was in contact with indicating that the membrane was able to reduce the water hardness in the transferred water to the green bag, as desired. It was not possible to gather a reading for the green bag of the detergent solution, as the powder interfered with the KH test solution.

The red bag CaCO_3 concentrations were found to increase to 72, 180 or 375ppm for the sugar solution and 90, 180 and 287ppm for the detergent powder from their initial concentrations of 50, 100 or 200 ppm, respectively. These concentrations were less than expected (120, 240 and 475ppm sugar and 94, 188 and 320ppm for the detergent), as calculated from the measured volume decrease in the red bags and if no CaCO_3 permeated through the membrane. Unfortunately, the accuracy of these measurements was impaired, especially at the higher concentrations (>200 ppm) due to the insolubility of CaCO_3 . Therefore, red bag measurements may be less than theoretical values. Future tests should use naturally occurring hard water, as it more accurately represents environmental conditions and higher concentrations of CaCO_3 are possible due to the presence of other salts.

Major findings and Conclusions

The HTI packs functioned well outside of their intended use when used in conjunction with the detergent products. The powder detergent solution in particular gave comparable
5 flow rates to the HTI sugar solution provided, and outperformed the model sugar system at lower concentrations.

These results successfully indicate that osmotic membranes could have potentially positive implications with regards to future commercial laundry applications.

10

From the experiments it was also shown that the membranes were capable of preventing the transfer of the model water hardness system - calcium carbonate across from the 'dirty' red bag to the useable green bag. There is a potential limitation in using this system however, in the insolubility of CaCO_3 in water when not in the presence of other salts.
15 Aggregation of CaCO_3 could possibly be occurring inside the red membrane bag (due to it being static for the majority of the experiments), which would lead to inaccuracy in the final measurements of that bag.

20

Also, the size of the particles when partially in suspension could prohibit them passing though the membrane which could falsely indicate that the membranes were effective in reducing water hardness. It is difficult to accurately recreate 'hard' water without the addition of other chemicals, which would be tested in future work. However, it is believed that the membranes used are capable of removing biological pathogens from water passed through them which would suggest they are capable of the removal of larger species.

- 18 -

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of producing a non-potable, functionally useful solution, which method comprises:
 - 5 providing on respective sides of a semi-permeable membrane a feed solution and a draw solution, wherein the draw solution comprises an osmotic agent that is functionally useful and that creates an osmotic pressure difference between the feed solution and the draw solution; and
 - allowing solvent to diffuse through the semi-permeable membrane from the feed solution
 - 10 to the draw solution in order to produce the functionally useful solution.
2. A method according to claim 1, wherein the feed solution contains water and the non-potable, functionally useful solution is an aqueous solution.
- 15 3. A method according to claim 1, wherein the osmotic agent is a detergent and the functionally useful solution is intended to be used for washing purposes.
4. A method according to claim 1, wherein the osmotic agent is a horticulturally or agriculturally active ingredient and the functionally active solution is intended to be used
- 20 in horticulture or agriculture.
5. A method according to claim 4, wherein the osmotic agent is a fertiliser, herbicide or pesticide.
- 25 6. A method according to claim 2, wherein the feed solution is grey water, hard water, brackish water or seawater.
7. A method according to claim 1, wherein the functionally useful solution is intended to be used as a dry cleaning fluid and the osmotic agent is a cleaning fluid
- 30 component.

- 19 -

8. A method according to claim 1 or 2, wherein the draw solution further comprises particulate matter that serves to maintain or prolong osmotic uptake of the draw solution from the feed solution as the draw solution is diluted with solvent from the feed solution.
- 5 9. A method according to claim 1, wherein the draw solution further comprises particulate matter that serves to increase the rate of flux of solvent molecules moving from the feed solution to the draw solution when compared with an equivalent draw solution absent the particulate matter.
- 10 10. A method according to claim 7, wherein the draw solution takes the form of a colloidal suspension in which the particulate matter is dispersed in a solution.
11. A method according to claim 9, wherein the draw solution comprises a liquid detergent.
- 15 12. A method of producing a potable solution, which method comprises:
providing on respective sides of a semi-permeable membrane an aqueous feed solution and a draw solution, wherein the draw solution comprises an osmotic agent that creates an osmotic pressure difference between the feed solution and the draw solution and
20 an additional agent that serves to maintain or prolong the osmotic pressure difference as the draw solution is diluted and/or increase the rate of flux of solvent molecules moving from the feed solution to the draw solution when compared with an equivalent draw solution absent the additional agent; and
allowing water to diffuse through the semi-permeable membrane from the feed
25 solution to the draw solution to produce a potable solution.
- 13 A method according to claim 12, wherein the draw solution is a sugar-containing solution.

- 20 -

14. A non-potable functionally useful solution when produced by the method of claim 1.
- 5 15. A potable solution when produced by the method of claim 12.

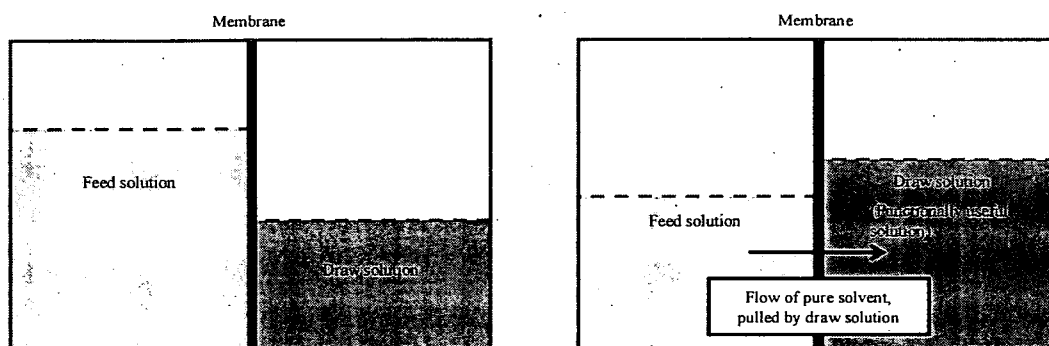


FIGURE 1

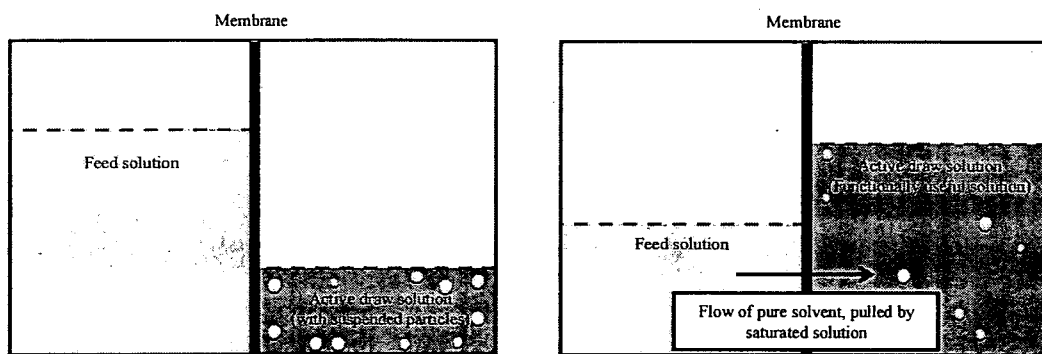


FIGURE 2

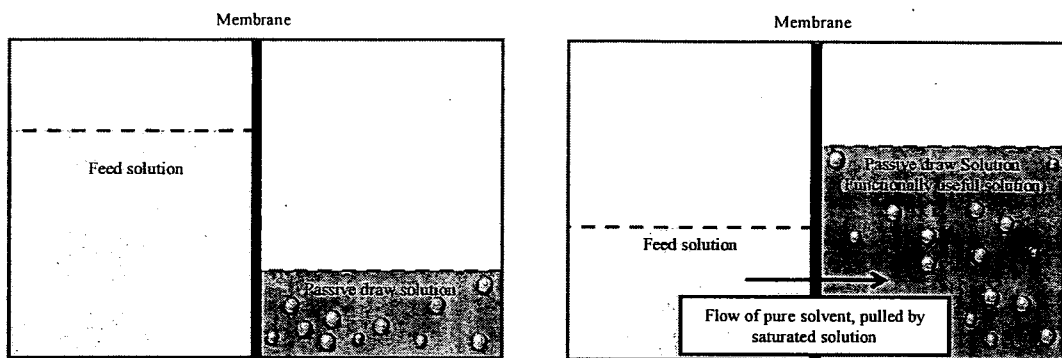


FIGURE 3

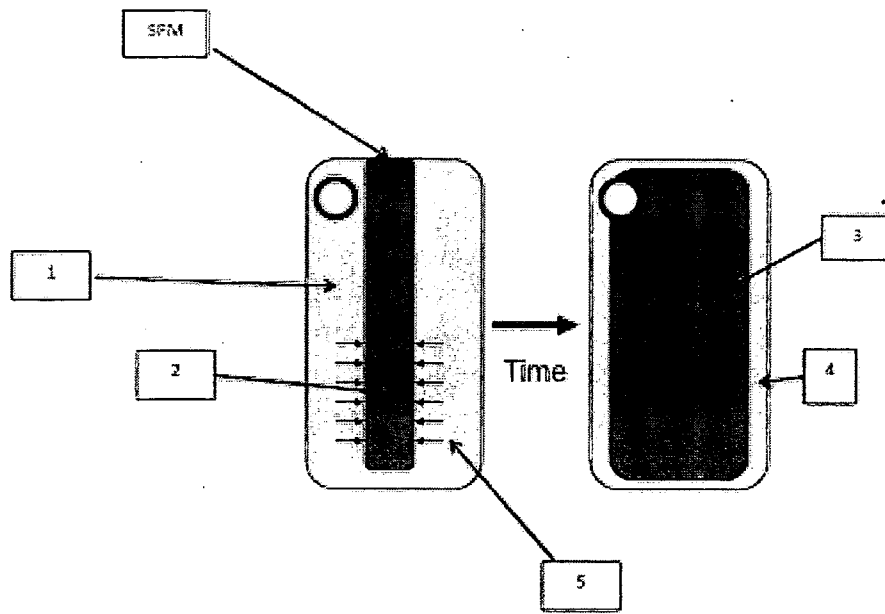


FIGURE 3A

5/7

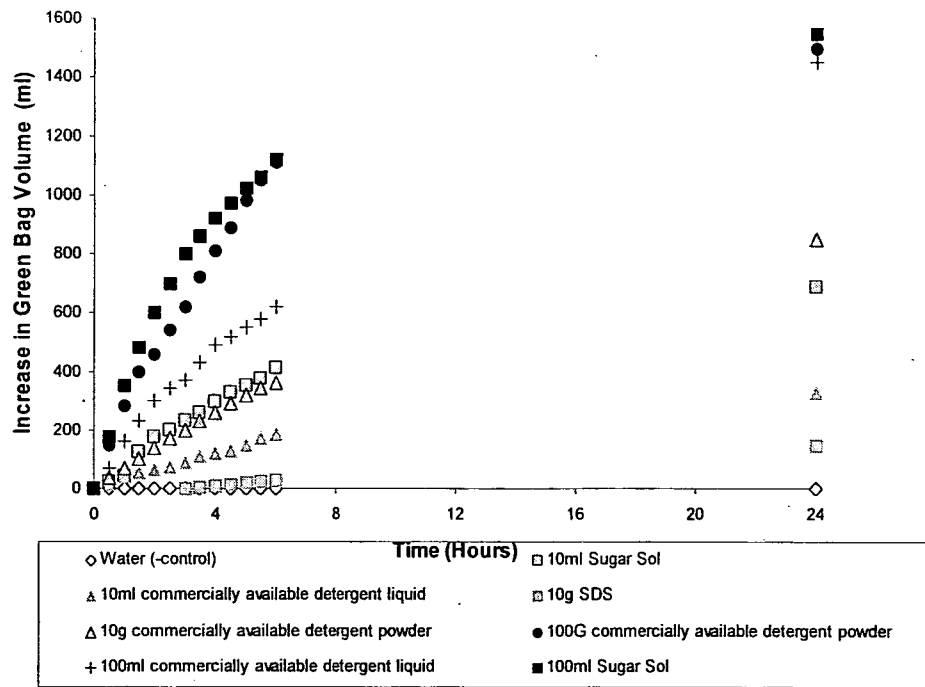


FIGURE 4

6/7

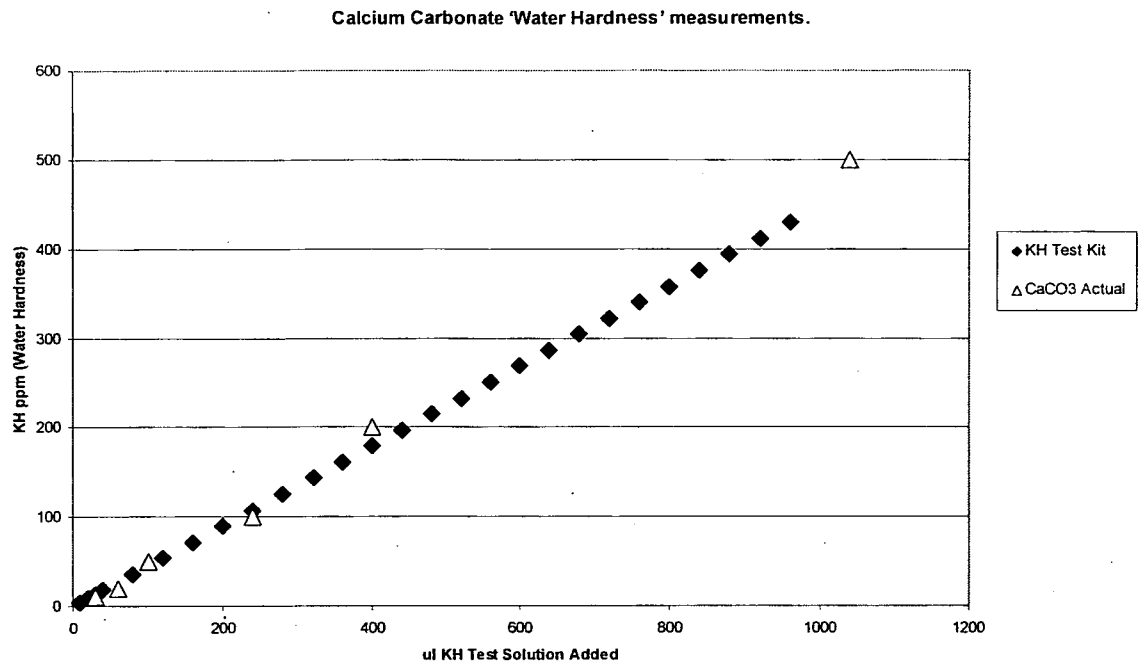


FIGURE 5

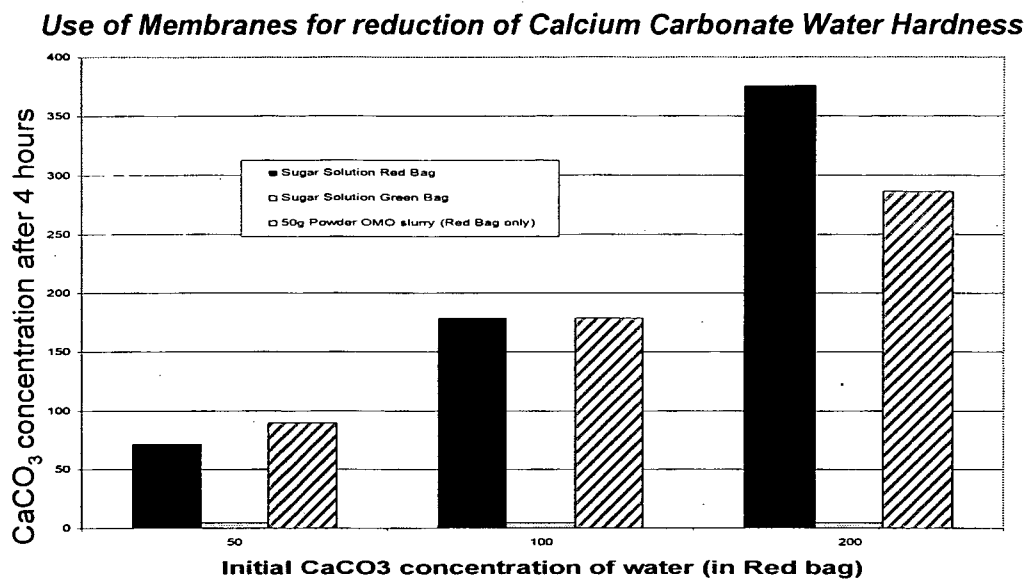


FIGURE 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2010/001617

A. CLASSIFICATION OF SUBJECT MATTER		
Int. Cl.		
C02F 1/44 (2006.01) B01D 61/00 (2006.01) B01D 63/00 (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used): EPODOC/WPI: (IC/EC Marks and Keywords):- C02F1/44, B01D61/00, B01D61/36, B01D61/58, B01D63/00 and Forward_Osmosis/Direct_Osmosis/, +OSMOSIS/OSMOTIC/ FLUX/GRADIENT/DIFFUSION/CONCENTRATION, FEED/WATER/SOLVENT/SOLUTION/AQUEOUS Google patents/SPACE: prolong, extend, enhance, maintain along with similar keywords		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006/047577 A1 (CASCADE DESIGNS INC) 4 May 2006 abstract, page 4: lines 8-22 and page 6-7	1-15
P, X	GB 2464956 A (CASCADE DESIGNS INC et al.) 05 May 2010 abstract, page 10: paragraph (0052), page 15: paragraph (0081)	1, 2, 6, 8-9, 12, 14-15
A	US 3721621 A (William T Hough) 20 March 1973 Whole document	
☐ Further documents are listed in the continuation of Box C ☒ See patent family annex		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "I" 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 "E" earlier application or patent but published on or after the international filing date "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "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) "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 "O" document referring to an oral disclosure, use, exhibition or other means "&" document member of the same patent family "P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 20 January 2011		Date of mailing of the international search report 21 JAN 2011
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustalia.gov.au Facsimile No. +61 2 6283 7999		Authorized officer VEENA BHAT AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 7963

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2010/001617

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 Member	
WO	2006047577	AU	2005299387
		EP	1833595
		CA	2585407
		US	2007278153
		CN	101287537
GB	2464956	WO	2010043914
US	3721621	NONE	
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			
END OF ANNEX			