



(51) International Patent Classification:

C02F 1/44 (2006.01) *B01D 71/64* (2006.01)
B01D 71/56 (2006.01) *B01D 71/28* (2006.01)
C02F 101/20 (2006.01) *C02F 1/62* (2006.01)
B01D 61/02 (2006.01)

(21) International Application Number:

PCT/MY2010/000085

(22) International Filing Date:

25 May 2010 (25.05.2010)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

PI 20092161 27 May 2009 (27.05.2009) MY

(71) Applicant (for all designated States except US):

UNIVERSITI TEKNOLOGI MALAYSIA [MY/MY];
81310 UTM Skudai, Johor (MY).

(72) Inventors; and

(75) Inventors/Applicants (for US only):

UJANG, Zaini [MY/MY]; Institute of Environmental and Water Resource, Management, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor (MY). **HAMDZAH, Myzairah** [MY/MY]; Institute of Environmental and Water Resource, Management, Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor (MY). **OZAKI, Hiroaki** [JP/MY]; Department of Civil Engineering, Osaka Sangyo University, Osaka 574-8530 (JP).

(74) Agent: **LOK CHOON HONG**; Suite 6.03, 6th Floor, Wisma Mirama, Jalan Wisma Putra, 50460 Kuala Lumpur (MY).

(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.

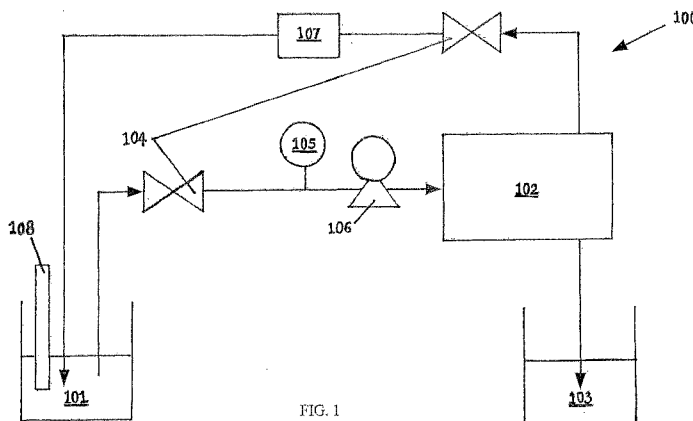
(84) Designated States (unless otherwise indicated, for every kind of regional protection available):

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, 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: A METHOD FOR TREATING WASTEWATER CONTAINING HEAVY METALS



(57) Abstract: A method for treating wastewater containing heavy metals comprising directing the wastewater across a reverse osmosis aromatic polyamide membrane at low pressure ranging from 40-120psi, the membrane being capable of removing at least 90% of the target heavy metals from the wastewater.

WO 2010/137941 A1

A METHOD FOR TREATING WASTEWATER CONTAINING HEAVY METALS

Field of Invention

5

This present invention relates to a method for treating wastewater containing heavy metals. In more particular, the present invention relates to a method for treating wastewater containing heavy metals by a reverse osmosis membrane at low pressure to remove high amount of heavy metals.

10

Background of The Invention

Utilization of low energy membranes operating at low pressure for treating wastewater is developed to reduce operational and maintenance costs of a water treatment system. Depending on the operating conditions of the water treatment system, the low energy membranes can remove contaminants including micro-pollutants, nano-sized anionic substances and metals.

As compared to a conventional cellulose acetate membrane, an aromatic polyamide membrane improves membrane technology by offering better rejection towards salts and water soluble organics, providing a better resistance against hydrolysis and biological attack, withstanding higher temperatures and operating over a wide pH range of 2-10.

The aromatic polyamide membrane has better salt rejection than cellulose acetate membrane due to lower diffusivity of NaCl but higher permeability, solubility and diffusivity of water across the aromatic polyamide membrane.

There are some prior arts relating to several membrane systems or methods for treating wastewater or saline water by reverse osmosis.

30

Japanese Patent No. 2007105572 claims a water purification system where raw water is filtered by a reverse osmotic membrane type filter means separating into permeate or purified water and retentate of non-transparent water. A water purification circulating route branches from an injector-pipe way pours the permeate into a reservoir and supplies water to the reverse osmotic membrane type filter means according to irrigation operation by a control means.

Another Japanese Patent No. 2001113136 discloses a reverse osmosis treatment device comprising a pump which raises raw water to a predetermined pressure for supplying to a reverse osmosis membrane module, a bypass passage which bypasses raw water provided in a discharge side of the pump and breathed out from the pump to the reverse osmosis membrane module, a flow control valve provided in the bypass passage to adjust a bypass rate of the raw water.

United States Patent No. 2007289904 describes a reverse osmosis system including a membrane chamber having a feed line to generate into a permeate stream and a brine stream, a booster device having a turbine portion in fluid communication with the brine stream and a pump portion in fluid communication with the feed line.

In the prior art, a method of operating the reverse osmosis system comprising pressurizing the feed line, generating a first flow signal corresponding to a flow of fluid in the permeate stream, operating a variable frequency drive in response to the first flow signal, controlling the motor in response to the variable frequency drive, generating a second flow signal corresponding to a flow of fluid in the brine system and controlling opening of a variable size nozzle coupled to the turbine portion in response to the second flow signal.

United States Patent No. 6162361 claims a method for separating and recovering heavy metals from a wastewater stream comprising passing the wastewater stream through a plurality of nano-filtration membranes being arranged in a series or parallel

arrangement providing a permeate and a concentrate output stream and passing the concentrate output stream through an electro dialysis device for additional concentration of heavy metal ions. The claimed method shall further comprising a step of passing the permeate output stream through a plurality of nano-filtration membranes arranged in a series or parallel arrangement.

Typical reverse osmosis membrane requires high operating pressure in water treatment systems. However, it is important to reduce the operational and maintenance costs of the system by utilizing a low energy membrane which can operate at low pressure but at the same time provide satisfactory performance for treating wastewater by removal of various pollutants in high amount.

Summary of The Invention

The primary object of the present invention is to invent a method for treating wastewater containing heavy metals by utilizing a reverse osmosis membrane operating at a low pressure range to save operational and maintenance costs and to increase the lifespan of the membrane.

Another object of the present invention is to invent a method for treating wastewater containing heavy metals by passing the wastewater across a low energy reverse osmosis membrane which has high salt rejection and high water flux for removing various pollutants including high amount of heavy metals.

At least one of the preceding objects is met, in whole or in part, by the present invention, in which the embodiment of the present invention describes a method for treating wastewater containing heavy metals comprising directing the wastewater across a reverse osmosis aromatic polyamide membrane at low pressure ranging from 40-120psi, the membrane being capable of removing at least 90% of the target heavy metals from the wastewater.

In the present invention, a reverse osmosis aromatic polyamide membrane has high salt rejection on pollutants having molecular weights greater than 100 and existing in nanometer sizes such as anionic substances. The membrane operates at a low pressure range for treating wastewater containing heavy metals of removal to at least 90% target heavy metals. At the optimum operating conditions of a wastewater treatment system, the low energy reverse osmosis membrane can remove arsenic at a percentage of more than 99%.

Brief Description of the Drawings

10

FIG. 1 shows a schematic view of a system (100) for treating wastewater containing heavy metals by a low energy reverse osmosis membrane.

Detailed Description of The Invention

15

One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The embodiment described herein is not intended as limitations on the scope of the invention.

20

The present invention discloses a method for treating wastewater containing heavy metals comprising directing the wastewater across a reverse osmosis aromatic polyamide membrane at low pressure ranging from 40-120psi, the membrane being capable of removing at least 90% of the target heavy metals from the wastewater.

25

By using the low energy reverse osmosis membrane which will be operated at a low pressure range, the operational and maintenance costs of a wastewater treatment system can be reduced. The low energy membrane shall have a longer lifespan of within 3-5 years than a conventional reverse osmosis membrane that operates at a higher pressure.

30

In the present invention, the reverse osmosis aromatic polyamide membrane has high salt rejection and high water or permeate flux. A preferred embodiment of the present invention has claimed that the reverse osmosis aromatic polyamide membrane can remove at least 90% target heavy metals from the wastewater, particularly removal of
5 more than 99% arsenic at optimum operating conditions of pressure 80psi or 552kPa and pH ranges from 3.4 to 7.6 at room temperature.

Moreover, the reverse osmosis aromatic polyamide membrane can also remove other metals including cadmium, chromium, copper, iron, nickel, zinc, manganese,
10 magnesium and the like. In a preferred embodiment of the present invention, the aromatic polyamide membrane has high heavy metal rejection particularly of at least 99% arsenic, at least 98% nickel, at least 97% manganese and 99.9% magnesium, 94% chromium, and at least 80% rejection of cadmium, copper and zinc from the wastewater.

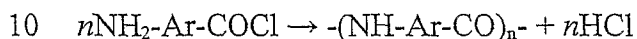
15 Besides, the present invention has described the reverse osmosis aromatic polyamide membrane shall provide a high sodium chloride rejection to at least 98% when tested with 500mg/L sodium chloride at pressure 552kPa, pH7 and room temperature. In the present invention, the membrane shall have a molecular weight cut-off of above 100
20 and reject particles with size of less than 2nm.

As claimed in the present invention, the aromatic polyamide membrane shall contain size pores of less than 2nm and water flux or permeate flux ranges $0.005\text{m}^3/\text{m}^2\cdot\text{h}$ to $0.025\text{m}^3/\text{m}^2\cdot\text{h}$, depending on the operating conditions and types of feed water. The
25 preferred water or permeate flux of the membrane is $0.013\text{m}^3/\text{m}^2\cdot\text{h}$.

In a comparison with a conventional cellulose acetate membrane, an aromatic polyamide membrane improves membrane technology by offering better rejection towards salts and water soluble organics, providing a better resistance against
30 hydrolysis and biological attack, withstanding higher temperatures and operating over

a wide pH range of 2-10.

The aromatic polyamide has better salt rejection than cellulose acetate membrane due to lower diffusivity of NaCl but higher permeability, solubility and diffusivity of water across the aromatic polyamide membrane. The present invention has described that the aromatic polyamide membrane is an ultra-low pressure reverse osmosis membrane which has a corrugated film layer. Generally, the aromatic polyamide is prepared by the reaction between an amide group and a carboxylic acid halide group, to be shown as below:



wherein n is a number or ratio; subscript n is a number or ratio; and Ar is aromatic radicals.

As disclosed in the present invention, a system (100) for treating wastewater containing heavy metals comprising a multilayer thin flat sheets of aromatic polyamide membrane framed inside a cell (102), a feed tank (101), a low pressure pump (106), pressure gauges (105), a permeate tank (103), flow control valves (104) and flow meters (107). The circulating or transporting pipelines of the system (100) are preferably made from stainless steel and/or high quality plastic.

In the present invention, the membrane cell (102) is preferably a cross flow module enclosing a multilayer flat sheets of aromatic polyamide membrane by upper and lower cell frames. The cross flow module has an active membrane surface area of 60cm^2 and operates at maximum pressure and temperature of 130psi and 40°C as respectively.

The multilayer flat sheets of aromatic polyamide membrane can operate at a wide range of pH from 2 to 10. Due to the membrane layer which is presented with charged chemical groups of carboxyl and amine groups, the membrane will be negatively charged at a pH above 5 as a result from dissociation of the carboxyl groups; and

positively charged at a pH below 5 as a result from dissociation of the amine groups.

High quality glass is utilized to construct the cross flow membrane module for preventing contamination of feed solutions by corrosive materials. The membrane
5 module shall further consisting components such as a feed water spacer preferably with 0.7mm spacing, two permeate spacers preferably with 0.3mm and 1.25mm spacing each, a plate ring and O-ring for fixing the membrane layer and preventing the system (100) from leakage.

10 The dimensions of membrane module or framed membrane cell (102) are preferably 80mm in width, 210mm in length and 82mm in height. However, the framed membrane cell (102) has inner dimensions of 46mm in width, 180 in length and 82mm in height to fit in all the parts or components comprising the flat aromatic polyamide membrane, feed water and permeate spacers, plate ring and O-ring.

15

In a system (100) for treating wastewater containing heavy metals, the feed tank (101) is preferably filled with 2 liters in capacity of wastewater. As described in a preferred embodiment of the present invention, the source of wastewater containing heavy metals is collected from a mining pool or synthetically produced into polluted water
20 by dissolving magnesium sulfate and copper chloride in distilled water.

The feed solutions of wastewater will be drawn from the feed tank (101) and pumped by the low pressure pump (106) across the membrane cell (102) at a specified range of low pressure. The permeate or purified water obtained is collected in a permeate
25 tank (103) whereas the retentate or concentrate is returned or circulated back to the feed tank (101) for maintaining its volume and solute concentration at constant.

Hereinafter, as discussed in the present invention, the feed solution treated in the system (100) is maintained at a temperature of $25\pm 2^{\circ}\text{C}$. The system (100) is installed
30 with pressure gauges (105) to record pressure of the feed and concentrate, flow meters

(107) to record flow rate of feed and concentrate, flow control valves (104) to regulate the flow of concentrate and permeate and pH probes (108) to record pH value of the feed solution in the feed tank (101) or permeate tank (103).

5 Examples

Example 1

The removal of various metals in percentage from a wastewater sample is shown in a table as below:

Metals/ Parameters	Percentage of Removal (%)
Arsenic	99.4
Cadmium	80.2
Chromium	94.0
Copper	81.4
Iron	51.5
Nickel	98.8
Zinc	86.0
Manganese	96.7
Magnesium	99.9

From the table, the percentage of removal for the metals in average is calculated as 87.5.

15 Example 2

In the present invention, a method for treating wastewater which may be obtained from a mining pool wherein the wastewater is estimated to have the composition indicated as below:

Metals/ Parameters	Concentration (mg/L) \pm 0.05
Arsenic	0.52
Cadmium	0.33
Chromium	0.01
Copper	0.42
Iron	0.33
Nickel	0.10
Zinc	0.56
Magnesium	2.34

The present invention has described a method for treating the wastewater by using a low energy reverse osmosis aromatic polyamide membrane. As shown in a table below, heavy metal particularly arsenic can be removed in an amount of at least 90% at a different low operating pressure and pH:

Run Code	1	2	3	4	5	6
Operating Pressure (psi)	51.7	108.3	51.7	108.3	40.0	120.0
pH	3.4	3.4	7.6	7.6	5.5	5.5
Flux ($\times 10^{-3} \text{m}^3/\text{m}^2 \cdot \text{h}$)	8.5	20.5	7.7	19.3	6.1	21.8
Arsenic Removal (%)	99.15	99.70	99.68	98.72	98.02	99.72

Example 3

10 For testing the treated water samples, permeates are collected in every 30 minutes from the permeate tank (103). The permeate flux and concentration are measured until obtaining a stable permeate to evaluate the rejection of reverse osmosis membrane.

15 Distilled water flux data shall be determined by passing distilled water across the reverse osmosis membrane for four hours at a pressure of 80psi or 552kPa and a pH of 7 at a constant recovery rate ranges from 60% to 65%. The membrane efficiency will be tested by using 500mg/L NaCl solution to acquire the minimum time for the

wastewater treatment system (100) which is operated at a steady state.

The operating conditions for rejection of sodium chloride are at pressure of 552kPa, pH7 and with concentration of 500mg/L. The data regarding permeate flux of NaCl collected in every 30 minutes for a period of 240 minutes with the replication of eight samples is shown in a table:

Time	Permeate Flux (m ³ /m ² .h)								
Minutes	F1	F2	F3	F4	F5	F6	F7	F8	F _{Ave}
30	0.0114	0.0112	0.0113	0.0110	0.0115	0.0116	0.0116	0.0115	0.0114
60	0.0115	0.0114	0.0115	0.0113	0.0116	0.0117	0.0118	0.0116	0.0116
90	0.0124	0.0120	0.0120	0.0123	0.0120	0.0120	0.0118	0.0127	0.0122
120	0.0124	0.0123	0.0119	0.0125	0.0120	0.0120	0.0120	0.0123	0.0122
150	0.0120	0.0119	0.0119	0.0123	0.0119	0.0119	0.0120	0.0120	0.0120
180	0.0120	0.0123	0.0124	0.0125	0.0120	0.0123	0.0120	0.0120	0.0122
210	0.0124	0.0123	0.0125	0.0125	0.0120	0.0123	0.0120	0.0120	0.0123
240	0.0124	0.0120	0.0120	0.0125	0.0120	0.0123	0.0120	0.0120	0.0122

The data of NaCl removal in percentage collected in every 30 minutes for a period of 240 minutes with replication of eight samples is also shown in a table:

Time	Removal (%)								
Minutes	R1	R2	R3	R4	R5	R6	R7	R8	R _{Ave}
30	98.0	98.0	99.4	98.0	98.4	98.2	98.6	99.0	98.5
60	98.0	98.1	98.0	98.0	98.2	98.5	98.0	98.2	98.1
90	97.9	97.9	99.0	99.0	98.7	99.0	99.0	99.5	98.8
120	97.6	97.6	97.6	96.7	97.6	97.6	96.5	96.1	97.2
150	98.1	98.2	98.0	98.0	97.0	97.6	96.9	96.5	97.5
180	97.0	96.0	97.0	97.5	96.7	97.0	96.0	96.0	96.7
210	96.0	96.8	97.6	95.6	96.8	96.0	96.0	95.9	96.3
240	97.5	97.1	97.5	96.5	96.0	96.0	94.5	95.5	96.3

Example 4

The rejection of heavy metals in wastewater especially copper, magnesium and arsenic is investigated under various influent concentrations of copper chloride and magnesium sulfate at 1.00mg/L, 2.00mg/L, 3.00mg/L, 4.0mg/L and 5.0mg/L at various pressure conditions of 40psi, 60psi, 80psi, 100psi and 120psi with different pH range of feed solutions at 2.5, 4.5, 6.5 and 8.5 and a constant recovery rate ranges from 60% to 65%.

- 10 The data regarding permeate flux of copper removal (%) is determined from a 20-runs experiment, which is shown in a table below:

Run Order	Permeate Flux (m ³ /m ² .h)								
	F1	F2	F3	F4	F5	F6	F7	F8	F _{Ave}
1	12.3	12.3	12.5	12.5	12.5	12.5	12.5	12.5	12.5
2	25.0	25.0	26.5	26.4	25.5	26.5	25.8	25.8	25.8
3	13.5	13.8	13.8	13.8	13.5	13.5	13.0	13.8	13.6
4	25.5	25.5	25.5	28.0	28.0	27.7	27.7	27.7	27.0
5	10.0	10.8	11.0	10.5	10.5	10.5	10.5	10.5	10.5
6	20.0	25.0	25.0	24.0	23.5	23.5	23.5	23.5	23.5
7	10.5	10.4	10.3	10.8	10.8	10.5	10.5	10.5	10.5
8	27.4	27.8	27.0	27.5	27.5	27.5	27.5	27.5	27.5
9	3.5	3.3	3.3	3.4	3.3	3.3	3.3	3.3	3.3
10	30.0	31.5	35.0	35.0	33.0	33.0	34.0	32.5	33.0
11	12.5	15.3	15.8	15.8	15.8	15.8	15.8	15.3	15.3
12	15.0	15.3	15.5	15.2	15.2	15.8	15.5	15.5	15.4
13	18.5	19.8	21.0	21.0	20.0	20.0	20.0	20.0	20.0
14	16.0	16.5	16.8	16.8	16.5	16.5	16.5	16.5	16.5
15	20.0	20.0	20.8	21.5	21.5	20.8	20.8	20.8	20.8
16	15.3	15.5	16.0	16.0	16.0	15.4	15.0	15.0	15.5
17	20.0	20.0	20.8	21.5	21.5	20.8	20.8	20.8	20.8

18	16.3	16.3	16.3	17.0	16.8	16.3	16.5	16.8	16.5
19	15.3	15.3	16.5	16.5	17.0	17.5	16.3	16.3	16.3
20	17.5	18.0	17.5	17.5	18.0	17.5	17.5	16.8	17.5

Another table showing the data percentage of copper removal for a 20-runs experiment is indicated as below:

Run Order	Removal (%)								
	R1	R2	R3	R4	R5	R6	R7	R8	R _{Ave}
1	86.1	83.7	84.9	84.4	85.1	84.1	84.7	84.8	84.7
2	94.3	93.6	91.9	89.4	91.9	92.0	79.3	85.0	89.7
3	98.9	99.5	99.8	98.6	98.7	99.5	99.5	99.7	99.3
4	88.5	88.3	89.4	89.9	89.6	89.6	89.6	89.6	89.3
5	96.6	96.3	96.3	96.6	96.5	96.5	96.2	96.2	96.4
6	96.2	96.7	97.0	96.7	96.8	96.8	96.8	96.8	96.7
7	96.5	96.4	96.1	96.4	96.4	97.7	96.0	96.0	96.4
8	99.1	97.8	99.5	99.6	99.6	99.8	96.5	99.6	98.9
9	92.6	92.4	95.1	92.6	92.5	92.4	92.4	92.9	92.9
10	98.4	98.2	98.4	98.2	98.1	98.1	98.1	98.1	98.2
11	90.8	86.3	73.9	72.8	66.6	69.1	66.8	66.9	74.2
12	89.0	89.5	89.2	89.8	89.9	89.7	89.6	89.7	89.6
13	72.0	70.5	70.5	70.0	72.0	69.5	68.9	70.5	70.5
14	98.1	98.1	97.6	97.6	97.6	97.9	97.9	97.9	97.8
15	98.8	98.3	98.2	98.1	98.1	98.1	98.3	98.3	98.3
16	98.8	98.4	97.2	98.0	98.6	98.6	98.6	98.6	98.4
17	98.8	98.3	98.2	98.1	98.1	98.1	98.3	98.3	98.3
18	97.0	97.6	95.5	96.0	98.6	98.6	99.2	99.7	97.8
19	96.8	96.2	97.7	96.9	96.6	96.8	98.4	98.4	97.2
20	99.0	99.6	99.5	99.8	98.5	99.3	99.2	99.2	99.3

Example 5

To optimize the process of heavy metals removal by the low energy reverse osmosis membrane, a response surface methodology is implemented to identify the significant and interactive factors quantitatively. The response surface methodology is designed statistically using response surface design, in particular, Central Composite Rotatable Design.

Besides, the Central Composite Rotatable Design facilitates the detection of non-linear behavior of effect and determination of the best setting of the experimental factors which can produce the maximum outcome.

The synergistic effect of the factors is determined based on Hadamard matrix and centre point runs whereas the non-linear response behavior is analyzed using start point and centre point runs. The centre point run is repeated six times in order to allow a better estimate of the experimental error. The runs are carried out in randomized order and this will reduce the effect of time-dependent factors not included in the study.

A table below showing the value of permeate flux and percentage of heavy metal removal obtained from an experiment runs for rejection of micro-pollutants not in random order at a constant recovery rate ranges from 60% to 65%:

^a Run Code	Operating Pressure, psi (^b)	pH (^b)	Concentration, mg/L (^b)
1	56.2 (-1)	3.7 (-1)	1.8 (-1)
2	103.8 (+1)	3.7 (-1)	1.8 (-1)
3	56.2 (-1)	7.3 (+1)	1.8 (-1)
4	103.8 (+1)	7.3 (+1)	1.8 (-1)
5	56.2 (-1)	3.7 (-1)	4.2 (+1)
6	103.8 (+1)	3.7 (-1)	4.2 (+1)

7	56.2 (-1)	7.3 (+1)	4.2 (+1)
8	103.8 (+1)	7.3 (+1)	4.2 (+1)
9	40.0 (-1.682)	5.5 (0)	3.0 (0)
10	120.0 (+1.682)	5.5 (0)	3.0 (0)
11	80.0 (0)	2.5 (-1.682)	3.0 (0)
12	80.0 (0)	8.5 (+1.682)	3.0 (0)
13	80.0 (0)	5.5 (0)	1.0 (-1.682)
14	80.0 (0)	5.5 (0)	5.0 (+1.682)
15	80.0 (0)	5.5 (0)	3.0(0)
16	80.0 (0)	5.5 (0)	3.0 (0)
17	80.0 (0)	5.5 (0)	3.0 (0)
18	80.0 (0)	5.5 (0)	3.0 (0)
19	80.0 (0)	5.5 (0)	3.0 (0)
20	80.0 (0)	5.5 (0)	3.0 (0)

From the table, ^abased on standard order designed by Central Composite Rotatable Design and; ()^b is coded value as assigned by Central Composite Rotatable Design.

5

10

15

Claims

1. A method for treating wastewater containing heavy metals comprising:
directing the wastewater across a reverse osmosis aromatic polyamide membrane at
5 low pressure ranging from 40-120psi, the membrane being capable of removing at
least 90% of the target heavy metals from the wastewater.

2. A method as claimed in claim 1, wherein said membrane has pore size for rejecting
particles of less than 2nm.

- 10 3. A method as claimed in claim 1 or claim 2, wherein said membrane has a water flux
ranges from $0.005\text{m}^3/\text{m}^2.\text{h}$ to $0.025\text{m}^3/\text{m}^2.\text{h}$.

4. A method as claimed in claim 1, wherein said membrane has heavy metal rejection
15 of at least 99% arsenic.

5. A method as claimed in claim 1, wherein said membrane also has a rejection of at
least 98% nickel, at least 97% manganese, 99.9% magnesium, 94% chromium and at
least 80% rejection of cadmium, copper and zinc from the wastewater.

20

25

30

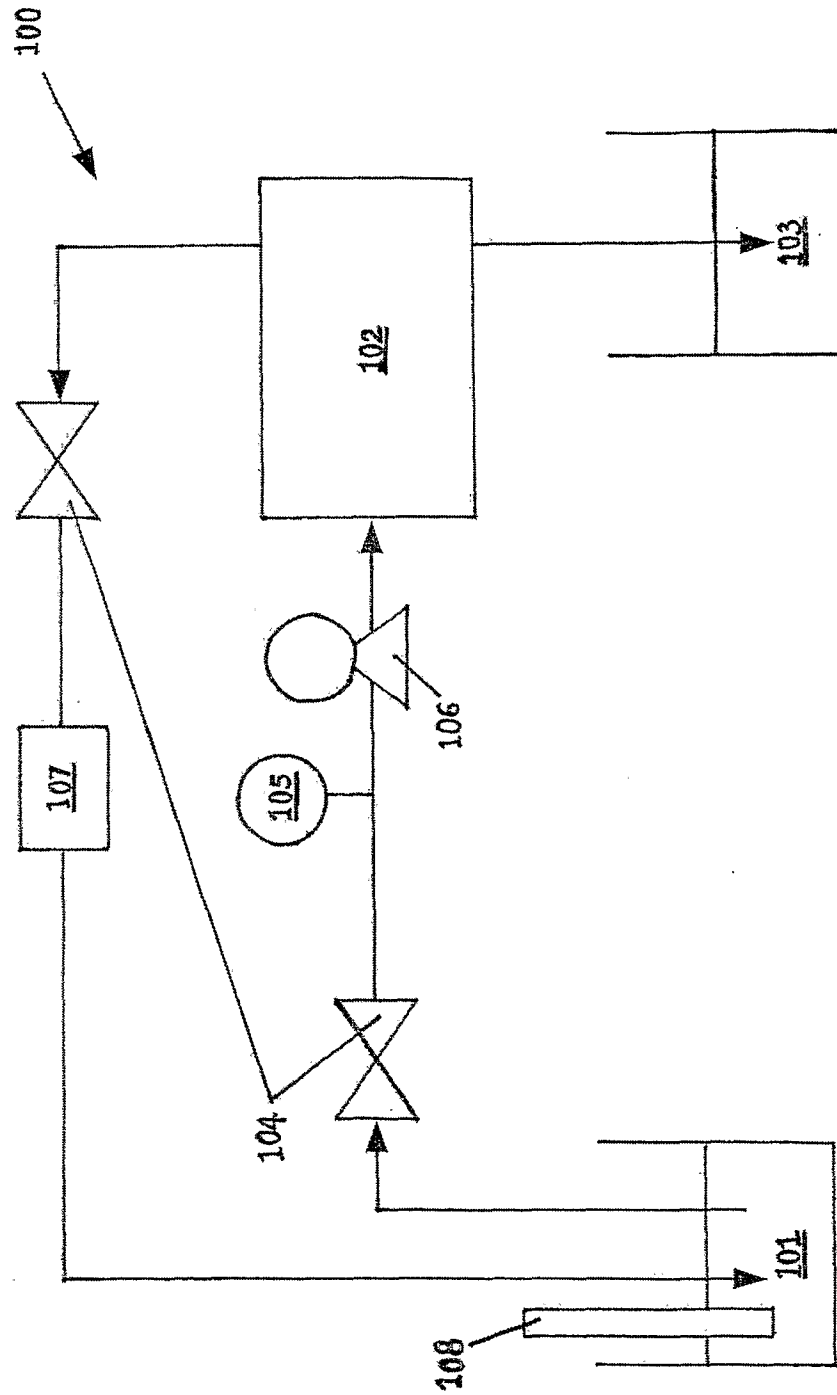


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/MY2010/000085

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

C02F 1/44 (2006.01) *B01D 71/56* (2006.01) *C02F 101/20* (2006.01)
B01D 61/02 (2006.01) *B01D 71/64* (2006.01)
B01D 71/28 (2006.01) *C02F 1/62* (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)
 EPODOD AND WPI WITH IPC (C02F1/44/IC/EC, C02F1/62/LOW/IC/EC, C02F101/20/LOW/IC/EC, B01D61/02/IC/EC, B01D71/28/IC/EC, B01D71/56/IC/EC, B01D71/64/IC/EC) AND KEYWORDS (+AMIDE?, NI, MG, CD, CO, ZN, AS, HG, PB, CU, PRESS+ AND SIMILAR TERMS); GOOGLE PATENT WITH KEYWORDS (POLYAMIDE; WASTEWATER, OSMOSIS, HEAVY METAL, AND SIMILAR TERMS); ESPACE WITH KEYWORDS (AMIDE, WASTEWATER, OSMO+, AND SIMILAR TERMS)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7186344 B2 (HUGHES) 6 March 2007 Column 8 lines 29 – 35; column 9 line 56 – column 10 line 64	1, 2, 4, 5
X	US 4812270 A (CADOTTE ET AL) 14 March 1989 Column 1 line 55 – column 2 line 2; Examples 1 – 7, 12 – 15; Table I and Table II	1, 3
X	US 5269919 A (VON MEDLIN) 14 December 1993 Column 4 line 67 – column 5 line 2; column 7 line 38 – column 8 line 5; Figure 3	1
A	US 4046686 A (GOLDSTEIN) 6 September 1977 Whole document	1 – 5

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	"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	
"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
17 August 2010

Date of mailing of the international search report
19 AUG 2010

Name and mailing address of the ISA/AU
 AUSTRALIAN PATENT OFFICE
 PO BOX 200, WODEN ACT 2606, AUSTRALIA
 E-mail address: pct@ipaustralia.gov.au
 Facsimile No. +61 2 6283 7999

Authorized officer
 MILKA WENAS
 AUSTRALIAN PATENT OFFICE
 (ISO 9001 Quality Certified Service)
 Telephone No : +61 2 6283 2593

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/MY2010/000085

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					
US	7186344	AU	2003222626	US	2003196955	WO	03089119
US	4812270	AU	21437/88	CN	1040745	EP	0355188
		US	4765897	US	4824574	WO	9001980
		ZA	8806244				
US	5269919	NONE					
US	4046686	NONE					
<p>Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.</p> <p style="text-align: right;">END OF ANNEX</p>							