# THE USE CONSTRUCTED WETLANDS TO OPTIMIZE THE REVERSE OSMOSIS (RO)

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*Recibido 13 de Noviembre de 2012 . Aceptado 11 de Marzo de 2013 / Received: November 13, 2012 Accepted: March 11, 2013*

## Abstract

This study describes an alternative to improve the reverse osmosis (RO). Every membrane process must use a pre-treatment to eliminate some particles such as SST, heavy metals, material organic. The membranes are very sensitive with these parameters. This study uses constructed wetlands as pre-treatment phase. It is well known wetlands can treat wastewater and stormwater in different phases. Furthermore, wetlands can treat many parameters of the water such as DBO, solid suspend total (SST), nitrogens, phosphates, heavy metals and pathogens. However, it has to compare and analyse different types of wetland to determine which one is the most suitable as pre-treatment due to RO. Besides, to study the plants which are tolerated salinity conditions. Finally, to research if the plants can be used in constructed wetlands.

***Key words:*** : reverse osmosis (RO), DBO, SST, constructed wetlands, plants.

## 1. INTRODUCTION

### *1.1 Background*

In many countries desalination is the only process to get fresh water. Countries such as Australia, Saudi Arabia or United Arab Emirates adopted Reverse Osmosis (RO) as an alternative technology to treatment the sea water.

However, as a desalination process RO is an expensive system. Therefore, to optimize the process would reduce the cost of treatment. Furthermore, it would facilitate to implant the technology in poor countries.

To determine which part of the process may be able to improve it is essential for developing this report. The attention will be focus to use wetlands as pre-treatment. Because of that, the report will study different types of wetlands and plants. In particular plants, they are the main of component of the treatment.

## 2. LITERATURE REVIEW

To reference in reverse osmosis (RO) it is essential to talk about desalination and its process.

### *2.1 Desalination*

Desalination is a water process which is allowed to obtain fresh water from a brine solution. The definition of this process is very simple. However, to think about its process is more complicated. Anyone with basic knowledge should know how to separate salt and water the process is called evaporation. Nevertheless, in a huge demand the main idea is to recollect the fresh water and use this for humans consume.

There are different methods of desalination and all of them need a fundamental requirement: energy. There are several issues about the amount of energy and the cost which are necessary due to start and maintain in function the desalination plant. Distillation and membrane technologies are widely used around the world. A briefly resume of every treatment is explained below.

### 2.1.1 Multi – effect distillation (MED)

The distillation process is the oldest one about desalination. The method consists in inducing heat in the brain solution. Consequently, the water is evaporated and the steam can be transported by collectors or pipe which can condense the water by low temperature and high pressure. Because of the high temperature (120˚C) and the brine this system is highly corrosive on the environment. Although, nowadays there are some materials which can resist the corrosion is not economically viable to do that. (Bruggen, Vandecasteele 2002).

### 2.1.2 Multi stage flash (MSF) distillation plant

Basically, the method has a first step where the solution of saline and water is heated by steam. Thus, the pressure around the container becomes lower. After this first step it may not put more temperature. The steam is recollected in tubes which are going to the next stage. As long as there are more stage the system's efficiency is better. The corrosion is easy to control. Nonetheless, this method requires a large quantity of energy, which means the treatment, is very expensive. (Segal 2004).

### 2.1.3 Electrodialysis

Comparing with the others this is the newest technology and it has not used in municipal plants but the concept of electrodialysis is not new. The fundaments of electrodialysis are based in the terms anionic and cationic. An electrical current makes to move the ions in opposite direction. Next, there are two membranes (cationic and anionic) which separate. The process produces fresh water stream in one side and a high concentrate of brine stream in another side. This process depends on concentration of salt in the solution (salty water). It is not economically viable especially if this treats seawater (high concentration of salt). However, some samples and industries have demonstrated electrodialysis as one of the most efficient method about obtaining fresh water from saline water. (Segal, 2004).

### 2.1.4 Other methods

There are others methods such as vapour compression, solar distillation, hybrids (distillation and osmosis), membranes distillation, so on. However, they are not allowed to use in communities as well as they have not developed yet.

### 2.2 Reverse osmosis (RO)

If two solutions have different concentration they can be separated by a semi permeable membrane. The process is called Osmosis. Furthermore, if an external pressure is applied on the solution with higher concentration the name of the process is reverse osmosis (RO) (Bergman, 2007).
Every year this method gets more popular between desalination plants. The reason for that is this technique has improved very fast in the last years. This system does not use heat. However, it needs pressure for working the range of pressure. On the other hand, this pressure has been reduced in the recent years (Bruggen, Vandecasteele 2002)

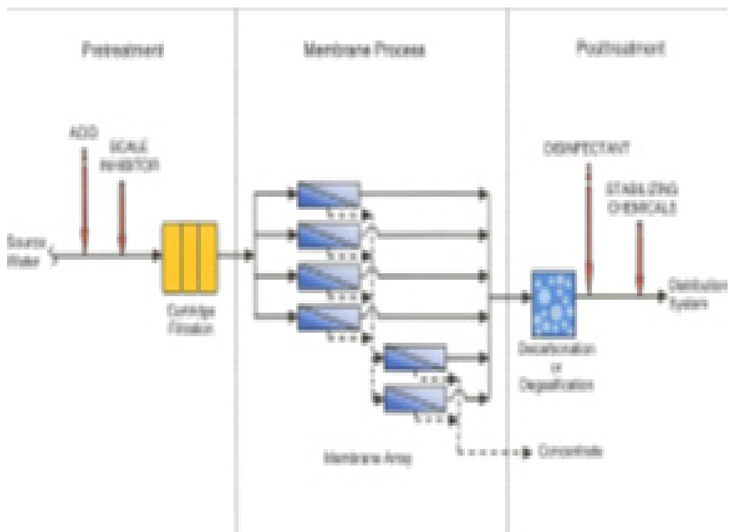

Figure 1. Typical RO membrane system (Bergman 2007)

The figure1 illustrated the process of the reverse osmosis. In the first stage the raw water needs a pre-treatment. The most common pre-treatment is filtration. Sand filtration is a popular treatment to reduce SST and other particles. After that, the water is passed through the semi permeable membrane. During this process the water is separated in two solutions. The first solution (without salty particle) goes to the descarbonation or desgasification camera. Finally, the disinfection process (chlorine) and stabilizing chemicals (pH, hardness, and alkalinity). The second solution (brine) is a very highly salinity concentration which is return to sea. (Bergman 2007).

### *2.3 Constructed wetlands*

Wetlands use natural energy for operating such as solar, organic matter and so on. Treatment wetland means low cost and low maintenance of the process. The interest in artificial wetlands has been raised for the last two decades. As a result, the development of new technology, design, studies, researches. Wetlands can treat many contaminants and transform into harmless by-products. They do not need to use high concentrations of fossil fuel energy (gas or diesel). (Sartoris et al., 1999) (Kadlec and Wallace, 2009).

Furthermore, animals and plants can use the artificial wetland as wildlife habitat. This is a significant point while the reduction or disappearance of natural wetland has been increased every year. The expansion of agricultural and urbanization have a negative impact on wetlands (Mc Gauley and Erin K 2008).

### *2.3.1 Classification*

Kallace and Wallace (2009, p.5) claim that there are three types of wetlands: Free water surface (FWS), horizontal subsurface flow (HSSF), vertical flow (VF).

Free water surface (FWS): This type of wetland shape is similar to natural wetlands. They operate of open water. Because of that, wild life can adapt very easily in this environment (Kadlec and Wallace, 2009). It transports the water a low velocity and shallow depth (Jadhav and Buchberger, 1995). The shallowed water layer is normally between 0.2m and 0.4m. The minimum period of the time is 10 days. The wastewater is combined with the surface water or stormwater in many cases. The typical plants are helophytes such as phragmites and scirpus spp. (Verhoeven and Meuleman, 1999).

Horizontal subsurface flow (HSSF): This system uses a gravel bed and the water is passed through from inlet to outlet (Jadhav and Buchberger, 1995). The reed Phragmites australis is often used in this type of wetland (Lesage et al, 2007).

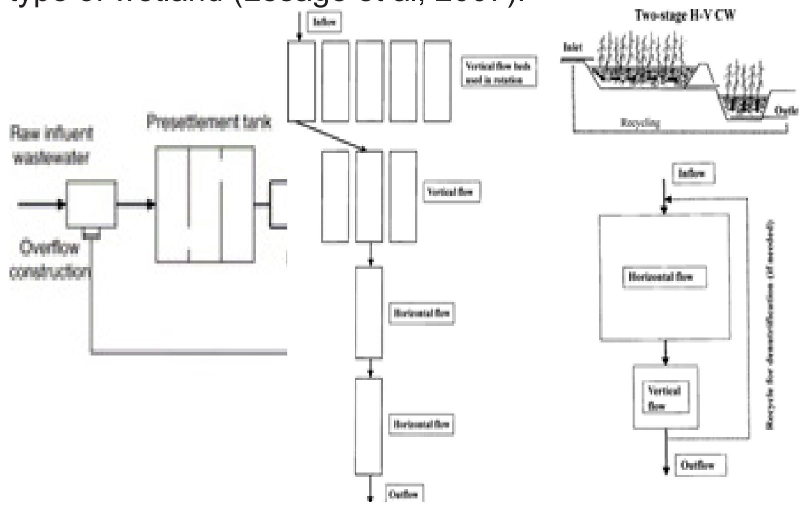


Figure 1. A process of HSSF and sampling locations of the wastewater, sediment and Phragmites australis biomass (Lesage et al, 2007)

The figure shows a process of HSSF where the influent comes to presettlement tank and after this is carried by pumps to two reed bed (Phragmites australis). Within the bed is seen the distances between the reed and sediment as well as the biomass production. Finally, the effluent is mixed with surface water.

Vertical flow (VF): In this method the wastewater is loaded on the surface and it is fallen down and collected by pipe. The area between surface and the pipe collector is called filter. The filter should have an area around 3.2 m2/PE and total depth is 1.4m (this specification is for a household). However, before the wastewater reaches the surface it should be deposited by container. In the unit (household) the tank must be 2 m3. Figure 2 below shows the structure of VF where most of the grid system is located underground as well as the system use a Phragmites australis as common specie. Some specifications must be considered for household units such as: the grid pipe should have a diameter between 32 -45 mm and should have between 5 – 7 mm holes. The systems must have a recirculation system where the effluent returns to sedimentation tank. This can be done by gravity or pump if the conditions are not favourable for gravity. (Brix and

Arias, 2005).

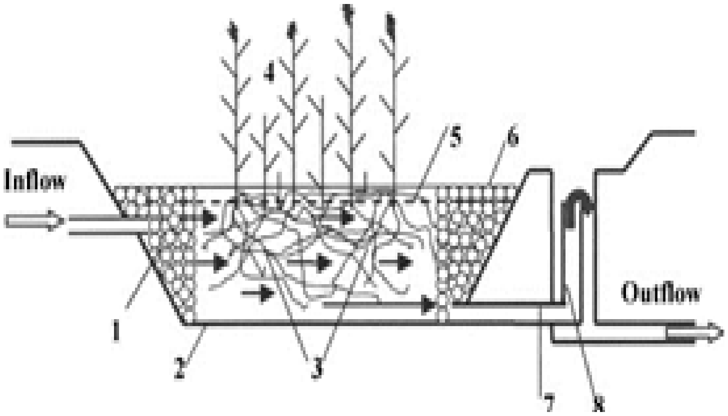


Figure 2. Schematic representation of a constructed wetland with horizontal sub-surface flow. 1, distribution zone filled with large stones; 2, impermeable liner; 3, filtration medium (gravel, crushed rock); 4, vegetation; 5, water level in the bed; 6, collection zone filled with large stones; 7, collection drainage pipe; 8, outlet structure for maintaining of water level in the bed. The arrows indicate only a general flow pattern (Vymazal 2005)

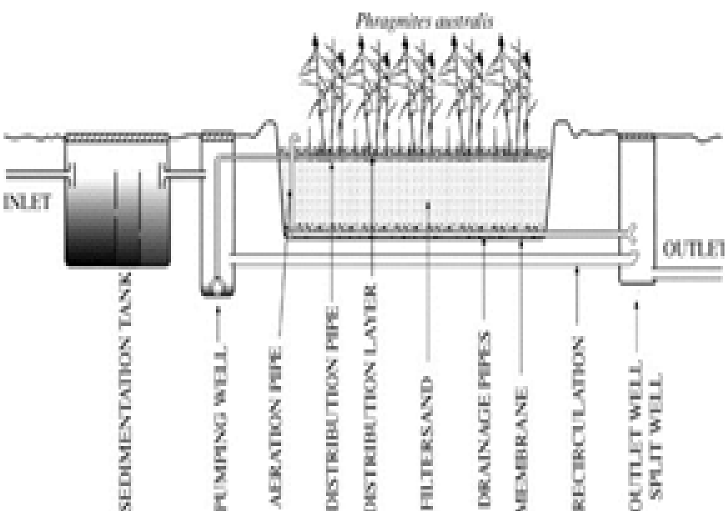


Figure 3. Layout of a vertical flow constructed wetland system for a single household (Brix and Arias, 2005).

Hybrids: Another type of artificial wetland is named hybrids. This method combines the horizontal subsurface flow (HSSF) with vertical flow (VF). The design consists in using VF as first step and the second step HSSF. The mean of the idea is to cover the two weakness points in each system and improve the process (Cooper et al, 1999).

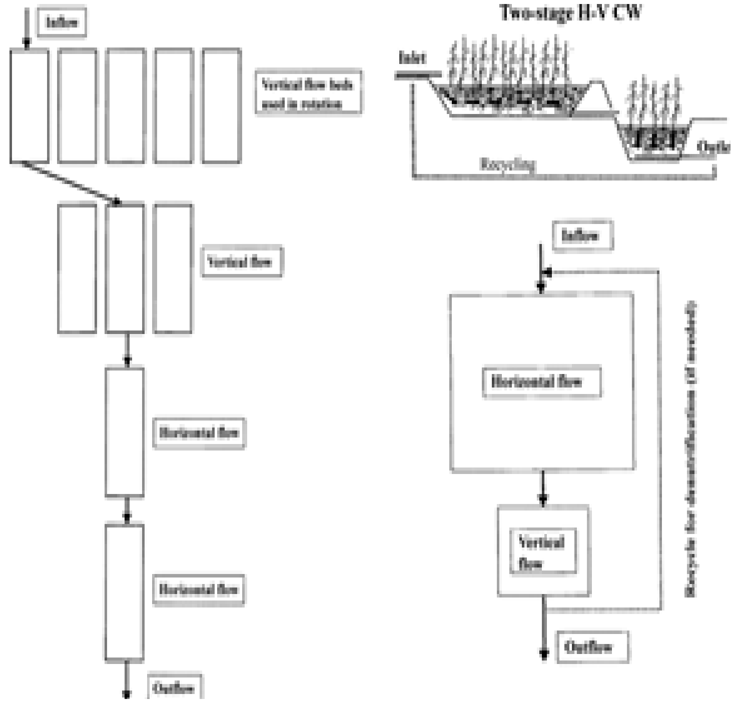


Figure 4. Hybrid construct wetland (Vymazal, 2005)

## 3. SYSTEM DESCRIPTION

### *3.1 Performance of RO*

The performance of the membrane depends on the condition of the raw water. For example, if the pre-treatment removed heavy metals (iron, manganese) or chlorine they can then removed by a single fibre filter. This formula calculates the performance of RO:

$R= 100(1- Cp/Cr)\%$

Where

R= Solute retention

Cp= is the solute concentration of the permeate.

Cr= is the solute concentration in the retentive.

Particles with sizes 0.00001-0.003µm are perfectly removed by RO. Some previous studies demonstrated the efficient of RO when they use a properly pre-treatment. For example, activated carbon and catalysed manganous dioxide membrane. (Gray 2010)

Following with the formula this is possible to use if the pre-treatment may reduce the salinity concentration.

Basically, the idea is to use the constructed wetland as pre-treatment in reverse osmosis process.

### *3.2 Type of plants*

Three types of wetlands were indentified in the literature review. None of these are the perfect to remove. However, the key of the process is the type of plants which reduce the TSS as well as they can tolerate salinity conditions.

There are some plants which have tolerance to the salinity conditions such as mangroves and halophytes.

Mangroves: consist in different type of vegetation which can survive in salinity conditions. There are more than 80 species of mangroves in the world. Most of them are in tropical and sub-tropical regions (Mangrove management in the Northern Territory 2002).

Stafford-Deistsch identified 5 characteristics which are mentioned below:

1. "Complete fidelity: That means the plants are only in the mangrove system and not other places.
2. A major role: They are the principal structure of the ecosystem.
3. Morphological specialization: They are completely adapted with the environment for example aerial roots and reproduction.
4. Salt exclusion: the tolerance of salinity which is obvious to see on leafs.
5. Taxonomic isolation: The total independence in structure and environment from terrestrial relatives. Strict mangroves have the own characteristics from others (Stafford-Deitsch 1996, p. 29,30).

However, there is no study about mangroves as constructed wetlands to use a reference. The point of view of this one is Mangroves are trees which spend years to reach the perfect shape. So, that would take time to investigate these types of plants as treatment wetland.

Halophytes: are marshal plants which are tolerated high salinity concentrations. However, these plants only represent the 2% of total of the plans on the earth. These plants are extremely rare compare with the normal plants. The taxonomy showed a widely range of plants which some of them tolerate more salinity that others. (Gleen and Brown, 1999)
3.3 Case study

Klomjek and Nitisoravut 2004 studied of eight plants under salinity conditions. They found out some plants can resist more than others. Even some of them was died during the process or in the end of that. The list of the plants can be seen in table 1:

***Table 1. List of tested emergent plants***

| **Scientific name** | **Common name** | **Basis of selection** |
|---|---|---|
| 1. T. angustifolia Linn. | Cattail | Prominent plant in brackish as well as freshwater marshes ( [29] , [Whigham et al., 1989] and [Glenn, 1995] ) |
| 2. C. corymbosus Rottb. | Sedge | Grows well in coastal areas and can be used in coastal treatment wetlands (Sripen et al., 2000) |
| 3. E. cordifolius (Linn.) Griseb | Amazon | Grows well in flood conditions and survives in the area affected by intermittent seawater intrusion (Sripen et al., 2000) |
| 4. B. mutica (Forssk.) Stapf | Paragrass, Water grass, Mountain grass, Buffalo grass | Can be found in coastal areas and commonly used for animal feeding |

| | | |
|---|---|---|
| 5. D. bicornis | Asia crabgrass | Has invaded into coastal treatment wetlands (Tudsri et al., 2000) |
| 6. V. zizaniodes Nash 'Indonesia' | Vetiver grass | Can be found in salt-affected soil and generally used for soil erosion protection (Office of the Royal Development Project Board, 1993) |
| 7. S. patents | Salt meadow cordgrass, Georgia | Can be found in upper salt marsh zone of eastern seaboard of USA and used for salt-affected soil improvement (Arunin, 1999) |
| 8. L. fusca (Linn.) Kunth | Kallar grass | Survives in salt-affected soil (12–14 dS m−1) and coastal treatment wetlands ( [Bhatti, 1983] and [23] ) |

In the end of the research Cattail sedge, Asia crabgrass showed the best performance and also they can process Nitrogen intake, BOD, even Asia crabgrass showed assimilation with SST. Salt meadow cordgrass and kallar grass survived in the experiment. The rest of plant could not tolerant the salinity conditions and they were dead. (Klomjek and Nitisoravut 2004)

Kadlec and Wallace 2009 p. 84 claim other type of plant can tolerate some salinity. Nervertheless, they do not specified the type of environment. These are the name of them: Typha, Phragmites, spartina and Juncus maritimus.

## 4. CONCLUSIONS

To reduce the concentration of salinity helps to improve the performance of the reverse osmosis.
The use constructed wetlands for pre-treatment can be an optional to replace traditional methods.
The type of wetland depends on characteristic of the raw water. However, if the main of the treatment is eliminate SST. Horizontal subsurface flow (HSSF) can be a good option

Base on the previous the halophytes (Asia crabgrass) can be the best option to use as sample.

## 5. ACKNOWLEDGEMENT

I would like to thank Dr Ljubo Vlacic for his advices during each presentation as the professor of the curse "Dissertation and Project Preparation". His feedbacks were essential to address the topic of this report.

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