West Assiut Power Plant Revers Osmoses' Rejected Water Environmental Impact Reduction

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Abstract

As there are a highly increase in the interest in environmental issues in recent years, and in accordioning to this desire for reduction of the pollution load to the environmental, the problem of the ROC amount that be released to the neighbor environment of the West Assiut Combined Cycle Power Plant (WACCPP), needs to be solved. The main goal of this article is the trials that will reduce volume of ROC effluent that seeps to the environment, and also those will improve its quality will be studied.

Keywords: Reverse Osmoses, Concentrate, Total dissolved Salts, Electrocoagulation, Deep well, Evaporation Pond.

Introduction

Water is being used for electric power generation and different purposes nowadays from traditional sources as Rivers and, non-traditional water sources such as seawater, excessively hard or brackish groundwater, poorer quality surface waters, and wastewater. All of these sources commonly require treatment with high quality technologies before use. In West Assiut Combined Cycle Power Plant (WACCPP) groundwater is used as the main source for demineralized water production across Revers Osmoses treatment units, for this purpose, 37 wells were drilled there. In this paper we will examine the RO rejected water [1]. The chemical composition of Reverse Osmosis Concentrate (ROC) or reject is a reflective for the raw water source chemistry, RO pretreatment, and the mode of RO system operation. For inland brackish water RO plants, the concentration and type of different ions vary depending on the process chemicals and the constituents of the different geological regions and layers containing water and owing to differences in the solubility of minerals. ROC represents 10-30% of the feed water flow for brackish and underground waters, salts in ROC could be concentrated for 4 to7 times.The viable options for ROC management often dictate whether or not a project progresses past the planning stages, therefore, it may be the most critical consideration in many situations [2].

Reverse Osmoses Reject Characterization

ROC disposal environmental adverse effects and its associated costs are reduced by reducing the volume and/ or by diminishing the pollutant load of the concentrates. Converting it from a waste to a resource through treatment and beneficial use minimize both environmental impacts and costs. The physical parameters and chemical composition of the concentrate is presumably related to feed water characteristics and variable plant operational parameters such as membrane selection and flux. Depending on regional geochemistry, groundwater RO plants concentrate dissolved minerals such as calcium, magnesium, sodium, potassium, chloride, sulfate, silica, fluoride, nitrate and iron. The data had shown a concentration factor (CF) of about 4 for most constituents, but some parameters do not follow this pattern as: total iron (CF=2.3); calcium (CF=6.6); magnesium (CF=0.1). The average chemical composition of brines produced from inland brackish water RO plants on Australia and the Arabian Peninsula (Oman, United Arab Emirates, and Saudi Arabia) have been compiled as shown in Table (1). The data indicate that plants in this region tend to produce more concentrated brines with respect to conductivity and total dissolved solids [3].

The water recovery of seawater reverse osmosis (SWRO) systems varies between 40% and 50% [4], this means that 60–50% of the feed stream is wasted as concentrate. While brackish water reverse osmosis (BWRO) recovery is from 75% to 85%, but reduced to only 50–60% due to

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scaling or energy saving considerations[5]. The amount of contaminants could increase by 4-10 times and potentially reaching toxic level in the ROC concentrate, these contaminants areas; nitrate, naturally occurring radioactive materials, arsenic, and other heavy metals introduced by natural dissolution of rocks, and agricultural runoff, so it requires treatment before beneficial use or discharge.

Table (1): ROC variety parameters' concentrations

Item	pH	EC X100 μS/cm	T H ppm CaCO3	T Alk. ppm CaCO3	SiO2 ppm	Fe ppm	Mn ppm	Ca ppm	Mg ppm	Na ppm	K ppm	SO4 ppm	Cl ppm	NO3 ppm	PO4 ppm	Tem H. ppm CaCO3	HCO3 alk. ppm CaCO3	TDS X 100 ppm
Australia	8	104	1650	1480	133	0.09	0.01	650	5.7	2180	10.4	453	3080	29.1	1.04	1480	1480	74.4
Arab. Peni.	8	1274	4041	945	—	65.5	22.6	923	510	6206	264	4197	8946	143	—	—	—	803

ROC Treatment

The RO concentrate treatment is considered the key barriers that need to be overcome for a broader use of desalination processes in inland applications and includes; treatment, disposal and beneficial uses of ROC.RO feed water pretreatment (physio-chemically pretreatment), quality improvement, feed water pH adjusting, membrane scale control and, using RO new technologies are used for improve water recovery consequently, RO permeate volume increase. Also, reducing the ROC volume to be disposed is by; revers osmoses units permeate production improvement, concentrate treatment for improvement water recovery when pass in another RO unit, and reduction of contaminants before beneficial uses or discharge. Technologies have been proposed for ROC treatment, that could be viable options to be used to diversify available freshwater resources, provide newly recognized value and thus facilitate the more expensive means for treatment of ROC for beneficial use. ROC volume reduction is by; intermediate physio-chemically treatment, using a second reverse osmosis stage, new technologies (non-traditional reverse osmosis (VSEP & EMS), electrodialysis (ED), electrodialysis reversal (EDR) Zero Liquid Discharge Technologies. Disposal methods depend on concentrate quantity and quality, permitting requirements, geography and geology (e.g., accessibility to different receivers, appropriate geological formation for deep well injection, land availability), costs, and potential environmental impacts. Traditional concentrate disposal methods as evaporation, discharge to surface water, discharge to municipal treatment plants, and deep well injection, also, controlled by environmental impacts, lack of dilution of the receiving water bodies, and by the required physical footprint. As there is no one treatment method fits all scenarios, however, the more that the reject volume can be reduced, the better the choices for final disposal. ROC of brackish water desalination may be disposed to some of the common methods adopted for disposal as; evaporation ponds, deep wells, disposal to sanitary sewers, storm drains, irrigating salt tolerant species, mechanical evaporation, carting away from site by vendors [6]. Direct discharge in place of the ROC source is by blending with power plant cooling water, and land applications (evaporation ponds, deep well injection, infiltration, constructed wetlands and injection to petroleum old wells (used as disposal wells). Beneficial use of the ROC represents a more concentrate disposal and treatment as a sustainable alternative to the traditional disposal and treatment options, and the concentrate becomes a resource rather than a pollutant, as long as there is a value for this recovered resource. The viability of beneficial and nontraditional uses of concentrate are depended on a number of critically important site-specific factors, including costs, climate, markets, regulatory issues, and ecological risks. There are a lot of technologies for beneficial reuse of ROC, converting it from a waste to a resource minimize both costs and environmental impacts. Also, ROC byproducts are studied, recovering commercial byproducts from ROC would be the optimum treatment option, as it solves the environmental problem of concentrate disposal, as well as the economic profitability of reverse osmosis is improved at the same time. Generally, all these methods need to consider the environmental impacts, costs, complexity of permitting and regulations, site requirements and footprint, energy use, reliability, ease of implementation, and operation of the processes involved. In recent years there a lot of researches about finding substance that could absorb salts and minimize the TDS, they use aluminum electrodes in a process called electrocoagulation (EC), they found that the TDS removal is about 90%, and factors affect the removal of salts process are current density (I), reaction time (RT), pH, temperature of the solution (T), distance between the electrodes (IED) and stirrer speed (rpm) [7].

Environmental Impact

The environmental impacts associated with concentrate disposal is related to its elevated salinity, ion imbalance-related toxicity as well as toxicity due to elevated concentrations of anthropogenic contaminants. The disposal of untreated concentrate from high-pressure membrane plants presents a number of environmental issues; It can potentially cause severe damages to marine, freshwater and terrestrial environments, each receiving environment is unique. The untreated ROC has impacts other than direct changes in salinity, it was reported that the high salinity associated with reject brine discharges has detrimental effects on the aquatic life, sea grass structure and vitality as well as the quality of the seawater available for desalination in the area (Sánchez-Lizaso et al. 2008). It adversely affects the water and sediment quality of receiving water bodies, reduce dissolved oxygen levels impairs marine life as well as functioning and intactness of coastal ecosystems, also the indigenous aquatic species in the area of discharge vary in their susceptibility to deleterious effects. Many aquatic organisms are highly sensitive to variations in salinity, as cell dehydration occurs with increased salinity, and as salinity rises the number and diversity of species falls. High salinity also causes ion imbalance – triggered toxicity to aquatic flora and fauna. Disposal into open land, unlined ponds or pits have significant environmental impacts, potential for polluting the underground water (increase hardness) resources, risk of soil salinization and profound effects on subsurface soil physical properties. Water logging, formation of crusts and reduce soil permeability causing great reduction in infiltration rate thereby preventing plants or crops from accessing enough water for good growth. While specific constituents, such as heavy metals, can present significant environmental concerns, which was confirmed hydrochemically and chemically for the raw water used in WACCPP [8].

Specification of West Assiut Combined Cycle Power Plant (WACCPP)

West Assiut power plant is divided into two stages the simple cycle and the combined cycle, shows the main specifications. The simple cycle consists of 8 similar gas turbine units each with a combustion chamber contains14 cans, with a maximum power of 125 MW, with a total maximum power 1000 MW, each unit is equipped with wet-de NOX system. The combined cycle consists of 2 similar units each unit is composed of 4 heat recovery steam generators (HRSG) (each is on one gas turbine, and with a 210 m3/hr steam production capacity and the steam have a 540ºC) with a maximum power of 2X250 MW =500MW. And with a total power for both stages 1500MW. Burn of natural gas as the main fuel and light distillate oil as the alternative fuel.

Water Treatment in West Assiut Combined Cycle Power Plant

Water treatment depends on the purpose for which water is used and its source. In UEEPC, power plants use the demineralized water for different purposes such as: Steam generation, cooling, sealing, de- NOx, washing and so on. In old plants the traditional treatment means used is; clarifiers, gravity filters, activated carbon filters for pre-treatments and ion exchangers for desalination. In the modern power plants; self-cleaning filters and ultra-filtrations systems are used for pre-treatments and reverse osmosis and electrodialysis for demineralization. Water treatment reverse osmosis units that fed by a ground water as a raw water from, result in a huge amount of the reject water that is normally viewed as a severe environmental threat.

West Assiut Power Plant Location

Assiut is the largest town in upper Egypt and lies about 234 miles south of Cairo. City of Assiut is located at 27°11`00N, 31°10`00E and spread across 26,000km2. West Assiut power plant as shown in image (1c), is located at the northern west of Assiut city in Assiut governorate in Upper Egypt, and allocated from Assiut city by 25km and at about 5km from Bany Ghalleb and about 3.43km from the nearest village Jhdum as in Image (1). The site located between the petroleum company in the north and cement company in the south as shown in image (1b), it is on a 33.6 acres area, the whole WACCPP view as in Image (2), also wells are used as a raw water source.

Experimental

Sampling

Water samples from raw water tank in WACCPP and ROC water sample were withdrawn and analyzed using standard procedures for determining its physical and chemical constituents. The sample's bottles were prepared according the ASTM standards and the water samples were taken under almost careful conditions.

Instrumentation

the samples were analyzed for determining its content of; PH, hardness, alkalinity, TDS. The measurements were conducted according the standard specification, where; potential of Hydrogen (pH) and Electrical Conductivity (EC), were measured by HANA (HI9811-5) instrument directly in the field. While the total hardness was analyzed by the volumetric method (APHA 2017).

Laboratory work

In this work the ROC solution was subjected to an electrocoagulation by applying a potential about 12 volt and 3.3 A, in a container with 600 ml volume, the applied potential is on 2electrodes (Al & stainless steel) for a 4h the pH, TDS, and T were tapped, then the reduction in the TDS was calculated at 25ºC [9,10].

Physical Specifications Results

Raw and RO reject water TDS change with hypochlorite and SMBS dosing (with controlling residual chlorine at RO inlet does not exceed 0.0 ppm).

Results and Discussion

In our way to treat the high TDS in ROC, as the main goal is changing the concentrate from a waste to a resource through treatment and beneficial use, which minimize both costs and environmental impacts. And as the RO permeate increasing, ROC volume reduction will lead to a reduction in the volume of wastewater to waste water treatment plant and finally reduction of the volume of treated waste water needs to be discharged. We found that the following means could be used to treat ROC (240m3/h) in WACCPP as an inland case. Quality improvement by reduction of TDS in RO's feed water (treatment scenario) which could increase the RO units permeate, consequently decreasing the RO reject water volume, that was obtained by changing the disinfection mode from continuous to a shock mode; as by injecting the disinfecting agent (NaOCl) on a shock mode the amount of Na^+ and Cl^- ions added Eqs. (1,2), where, HOCl, and OCl^- is referred to as free available chlorine or free residual chlorine, expressed as ppm Cl_2.

And consequently SMBS (Na, HSO_3 and SO_4), commonly used for removal of free chlorine, when dissolved in water, sodium bisulfite (SBS) is formed from SMBS, then SBS reduces hypochlorous acid Eqs. (3,4):

Finally, a significant reduction in TDS of both RO feed and RO reject water by about 7% as appears in and Figure (1).

Figure(1): Satellite image of WACCPP at Jhdum village (APHA (2017).

RO concentrate disposal (direct disposal scenario), as disposal methods depends on concentrate quantity and quality, permitting requirements, geography and geology, costs, and potential environmental impacts, after all these issues were taken in consideration;

Evaporation ponds were used; by constructing a 6 evaporation ponds by a total capacity reach to 500000m3 as a traditional ROC disposal method.

Deep well injection was used; by digging 5 deep wells, especially after add on the combined cycle extension.

By RO concentrate volume reduction (ROC volume reduction scenario) in WACCPP is by:

As by change the fuel used from heavy oil, which requires a 175m3 (21.8 m3/h for each unit) service water for de-NOx, as the main fuel in combustion in the gas turbines in the simple cycle, to the natural gas, which does not require this quantity, consequently, led to a reduction in ROC by about 105m3.

As by change the fuel used from heavy oil to natural gas as the main fuel, the heavy fuel oil washing water (about 35m3/h) was not going be used ever again as the fuel water treatment units not used again, this will lead to a reduction in ROC by about 21m3. Then the total reduction in demineralized water is by about 210m3 due to using natural gas instead of HFO which led to a reduction in the ROC by about 126m3, i.e. reduced to about the half of the total amount of the planned ROC effluent. Experimental work for ROC quality improvement in the laboratory using Al electrodes for TDS reduction from ROC in a process called electrocoagulation (EC) was succeed to reduce the TDS from 6512.3 to 1832.9 ppm by about 71.85 % (25 ºC) and even decreased less than that for feed water (2638 ppm) as shown in Figure (2,3)

Figure (2): West Assiut combined cycle power plant

Conclusion

In accordance to the desire for reduction of the pollution load to the environmental, the ways used to reduce the amount of ROC that seeps to the neighbor environment of the WACCPP are; the managing the injection of disinfecting agent resulted in increases of the RO permeate consequently, reduces the rejected water (ROC). While the use of natural gas reduced the ROC by about 126 m3 i.e. to half of the total rejected water (240m3), also, the quality improvement treatment process as electrocoagulation treatment process for ROC using Al electrodes led to reduction of TDS to less than that for RO feed water.

Figure (3): West Assiut combined cycle power plant's evaporation ponds

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