Evaluation of a Report on Receiving Water Chemistry and Quality Issues Related to the Operation of a Reverse Osmosis Desalination Facility at the Huntington Beach Power Generating Station

by

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Summary

This report evaluates the recently completed analysis of how operation of a reverse osmosis (RO) desalination facility at the Huntington Beach Power Generating Station (HBGS) will affect the chemistry of the receiving waters. The analysis compared eleven trace elements and other water parameters [pH (an index of water acidity), dissolved oxygen concentration, suspended solids, and turbidity] in the Huntington Beach source water and in the concentrated seawater exiting a demonstration RO facility currently operating at Carlsbad CA.

RO requires the pumping of seawater through membrane filters that remove its salts. For each volume of freshwater formed by RO an approximately equal volume of doubly concentrated (2x salinity) seawater is also formed. The mass balance analysis of the proposed RO operation at the HBGS requires integration of daily flow volumes through it [e.g., 50 million gallons per day (mgd) each of potable freshwater produced along with 50 mgd of 2x concentrate] and the mixing ratio of the latter with the HBGS cooling water flow (approximately 127 mgd). Because seawater that will undergo RO filtration is pre-treated with iron sulfate (or iron chloride, a chelating agent that coagulates organic solutes and other dissolved materials, and also precipitates a fraction of the trace elements), evaluation of seawater chemistry and physical properties is done before and after pre-treatment and following RO filtration. Another RO factor affecting mass balance and water chemistry is the volume of RO filter backwash water produced by the intermittent reverse-flow of seawater over the pre-treatment sand filters to flush way organic debris.

Chemical comparisons show that all of the trace elements considered in the discharge analysis already occur in the source water and they have the same concentration off Huntington Beach as they do in coastal oceans throughout the world. Chemical and physical factor comparisons between

the source water and the RO facility discharge stream demonstrate the "concentrating effect" of RO on the circuiting seawater but also show that the RO operation will not significantly affect water turbidity, suspended solids, pH, or oxygen levels.

Mass balance results were based on the assumption of a relatively low HBGS flow rate (127 mgd) and thus conservatively overestimate the amount of concentration that would be expected under normal station operation conditions. Nevertheless, the results show that while these trace elements will become slightly concentrated by RO, their discharge concentrations remain far below the numerical water quality standards established to protect aquatic marine life by the Environmental Protection Agency and by the State of California. The only change in discharge water chemistry resulting from the RO facility will be an elevation in dissolved iron. However, these concentrations are low and, like the salinity difference between the discharge and receiving waters, the iron concentration will be rapidly diluted to ambient levels. There are no numerical water quality standards governing the discharge of iron, which is usually present in low concentrations in seawater, and readily binds with the other elements in seawater and the sediments. Moreover, iron is an important ocean nutrient (essential for the growth of phytoplankton) and is likely to be biologically assimilated by primary producer organisms (mainly phytoplankton) in the discharge plume.

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Introduction

Poseidon Resources proposes to construct and operate a reverse osmosis (RO) desalination facility at the Applied Energy Sources Huntington Beach Power Generating Station (AES HBGS). The HBGS uses ocean water for the once-through cooling of its steam condenser units. The seawater intake is positioned in the Pacific Ocean approximately 1,840 ft offshore from the mean high tide line. After circuiting through Station condensers, the heated seawater exits through a discharge pipe that opens to the ocean 1,500 ft offshore.

The proposed desalination facility will convert a fraction of the Station's cooling-seawater return flow into freshwater. Approximately 100 mgd of the heated seawater (i.e., after it has passed through the condensers) will enter the RO system which, using high-pressure membrane filters, will produce about 50 mgd of freshwater. Also produced by RO will be about 50 mgd of twice-concentrated (2x) seawater, which will be returned to the cooling seawater outflow pipe downstream of the RO diversion point. Dilution of the 2x RO seawater by the cooling water will occur as both flow along the pipe leading to the offshore discharge site.

Reverse Osmosis Effects on Seawater Chemistry and Physical Factors

Planning for the proposed RO facility required description of the chemicals used in the preparation of seawater for the RO desalination process as well as an analysis of the fate of these and any other chemicals that will be returned to the receiving water in the combined RO concentrate and cooling water discharge.

I. Flow Stream Mass Balance: Combined RO and Generating station Cooling Operations

A. Generating Station Flow

HBGS has four power producing generator units, each of which has a separate cooling condenser and cooling-water pump. The pumps withdraw ocean water through the offshore intake. Total cooling-water pump rate depends on which units are operating. The maximum rated cooling-water flow for HBGS is about 514 mgd. Historical maximum flow rate is

507mgd. From 1979 to 2002, the Station's average flow rate was 234 mgd. Between 2002 to July 2003, when some retrofitted units went back on line, average Station flow was 265 mgd. Station flow never drops to below 127 mgd when power is being generated. After its intake seawater passes over the condensers where it is heated, and then piped 1,500 ft offshore where it enters the ocean through a vertically positioned subsurface discharge tower.

B. Flow to the RO Facility

The RO operation will take approximately 100 mgd of the warmed seawater flow stream. Of this, about 50 mgd will be turned into potable freshwater and return approximately 50 mgd doubly concentrated (2x) seawater to the HBGS discharge pipe and mix with the remaining cooling water prior to exiting to the ocean via the offshore discharge tower.

C. RO and Generating Station Flow Stream Mixing

The extent of dilution that the 2x RO discharge water will undergo in the discharge pipe depends upon the "in-pipe dilution ratio," which is:

$$\frac{\textbf{Total Generating Station Flow} - \textbf{RO Water Flow}}{\textbf{RO Concentrate Return Water Flow}}$$

A low generating station flow rate lessens the "in-pipe dilution," which means that the 2x RO stream will become less diluted during its transit to the discharge site. A minimum Generating Station flow rate of 127 mgd was assumed in all calculations in order to obtain estimates of the potentially most extreme situations (worst case) for discharge water physical parameters.

D. The Total Discharge Flow Budget

This budget has three flow components, intake, use, and discharge. Of the initial 127 mgd intake, 100 mgd enters the RO facility to make 50 mgd of freshwater At 127 mgd, the ratio is (127-100)/50=0.54

II. Discharge Water Content Analyses

Chemical analyses of 11 trace elements found in all ocean waters were carried out. Also measured were parameters of seawater quality, pH, dissolved oxygen level, suspended solids, and turbidity. Source water chemistry and other water data were obtained from samples taken near the HBGS. Data for RO water were obtained by sampling the discharge water (backwash and 2x concentrate) from the small demonstration RO facility operated by Poseidon at the Encina Power Plant, Carlsbad, CA.

A. Source and Discharge Water Comparisons.

Table 1 lists the measured source seawater values for the chemicals and conditions analyzed in the study. All of the chemical concentrations reported for the source water are consistent with levels reported for ocean water (Chester, 2000). This table also allows comparison of the physical and chemical features of the discharge water with the source water and further shows the effect of different steps in the preparation of water for the RO desalination process. The seawater flowing into the RO facility has either iron sulfate or iron chloride added to it. Iron added in this form acts as a chelating agent (i.e., a chemical, usually a metal, that coagulates dissolved organic material as well as a small percentage of the inorganic constituents including some of the trace elements in seawater) that binds many non-reactive molecules into larger aggregations that can be filtered out of the water). The chelated material is then collected on the pre-treatment filters and backwashed to the discharge. The % column Table 1 indicates the approximate quantity of each dissolved trace element subject to removal by chelation and filter washing. Note that up to 50% of some of the trace elements is removed by pre-treatment and the back wash and in the case of iron this is 99.5%. The "RO-In" and "RO-Out" columns (#2 in Table 1) detail the changes taking place in each seawater constituent or characteristic during the process of forming the freshwater and the 2x seawater concentrate. As could be expected, the "RO-Out" column shows the approximate doubling in the "concentration" of each element as a result of freshwater removal (filtration). This column also shows a small drop in water pH and dissolved oxygen.

The "Discharge" column (#3 Table 1) summarizes the changes occurring for the chemical constituents of the source water, all of which are returned to the ocean. Included in this is the approximately 2x RO concentrate resulting from desalination that mixes with the portion of the HBGS cooling water stream that entirely bypassed the RO system. Also added into the discharge is the pre-treatment filter wash. This wash contains

a large quantity of iron, the pre-treatment chelation agent. Table 1 shows that each liter of discharge water will contain 4.37 milligrams of iron/l, which is about 15 times greater than the normal seawater concentration (0.30 mg/l). However, this rate of iron addition amounts to only 1,831 lbs/24 hours and is likely to have a positive effect on local marine biology because iron is considered a limiting (i.e., never enough is present) nutrient that readily mixes with ocean water and is thus available for uptake by phytoplankton and other primary producers in the discharge area.

Most of the natural chemical constituents of seawater have numerical water quality standards for discharge that have been established by the Environmental Protection Agency and by the State of California to protect marine organisms and habitats. The OP/da column (#3 in Table 1) stands for "Ocean Plan, daily allowance" and it indicates the daily operational limit established by the Ocean Plan. Table 1 establishes that all of the trace elements in seawater are of natural origin and that, while the RO process will slightly concentrate them, the levels realized after concentration remain several times less than those deemed unsafe for marine organisms or habitats by the Ocean Plan. Iron, which is added in RO water pre-treatment, enters the discharge mainly through filter backwashing; although a smaller amount arises due to RO concentration. Iron concentrations in the discharge stream are therefore much higher than other elements. However, the excess iron will quickly equilibrate with ambient conditions by binding with other elements in the water column and with elements in the substrate. The disappearance of iron would thus parallel the dilution of excess salinity in the receiving water, as has been modeled by Jenkins and Wasyl (2004).

Table 1. Source-water levels of trace elements and other parameters reported in the analysis and the sequence of changes taking place as water moves through the steps of: 1) pre-treatment effects -reduces the % concentration of most constituents, 2) the RO in and out steps, concentrate most trace elements, and 3), the mass balance determination of discharge water contents and characteristics. [Note, unless otherwise specified trace element and other concentrations are given in micrograms (*u*g per liter); conversion from *u*g/l to mg/l is done by dividing *u*g by 1000.] The column designated "OP/da" stands for Ocean Plan daily allowance for the concentrations of the seawater constituents of the discharge or the extent of allowable change from source-water conditions (see text).

	Source Water	(#1) %	(#2)RO In	Out	(3) Discharge water	OP da
Chemical/condition						
Arsenic	1.67	8	1.6	3.1	2.65	32
Cadmium	0.30	35	0.2	0.4	0.48	4
Chromium	2.72	50	1.5	2.7	4.4	8
Copper	1.07	50	0.57	1.1	1.73	12
Lead	1.72	50	0.91	1.7	2.78	8
Mercury	0.05	50	0.03	0.1	0.08	0.2
Nickel	1.73	50	0.92	1.7	2.8	20
Selenium	0.05	0	0.05	0.1	0.08	60
Silver	0.28	0	0.297	0.6	0.44	2.8
Zinc	6.49	50	3.5	6.6	10.49	80
Iron	297.0	99.5	16.5	30	4367	--*
Suspended solids+	15.0				25	60
Turbidity (NTU)**	7.0	-	0.7	0.14	20	100***
pH	8.2			7.3	7.8	6-9

* no operational discharge limits exist
**nefelometric turbidity units
***weekly standard for turbidity
+mg/l

Applied to iron, the models indicate its concentration will approach that of the source water within a short distance of the discharge. Moreover, iron is an important nutrient for organisms based at the lower end of the food web (Turner and Hunter, 2001) and would likely be rapidly assimilated by primary producer organisms (mainly phytoplankton) living in the discharge plume.

B. Other Water Properties

Table 1 shows that the source water pH (an index of water acidity, with 7 equaling neutrality between acid ≤ 7 and alkaline >7) is near 8, which is typical of most coastal ocean surface waters (Millero and Sohn, 1991). The table also shows that RO processing does not affect discharge water pH, which remains well within the daily operational range established for marine organism and habitat protection.

Data in Table 1 show that the RO process will increase the discharge turbidity slightly above that of the source water. However, this increase is not sufficient to significantly affect water appearance or light transmission. It will not affect marine life in the area of the discharge plume and is far below daily operational discharge standards (Table 1). There are also minimal effects on suspended solid contents (Table 1).

The sulfuric acid (H_2SO_4) that is added after water pre-treatment will rapidly ionize ($2H^+$, SO_4^{2-}) and combine with salts in seawater and thus be neutralized. Sulfate (SO_4^{2-}) is the second most abundant anion (after chloride) in seawater and has an extremely low level of chemical activity. Thus, the quantity of sulfate added in the RO operation is insignificant relative to the vast amounts already present and understandably, there are no Ocean Plan standards for sulfate.

Conclusions

The seawater that is pumped through the HBGS and the RO facility has been evaluated for its physical characteristics and its concentration of 11 trace elements that occur in all ocean water. Chemical comparisons show that the trace element concentrations and values for pH, dissolved oxygen, suspended solids, and turbidity in the source water closely match values typical for ocean coastal zone waters throughout the world.

Analyses of the RO facility effects on the discharge water show that the RO operation will not significantly affect water turbidity, suspended solids, pH, or oxygen levels. Mass balance estimates for the fate of the trace elements (which are omnipresent in seawater) are based on a relatively low

total flow rate (127 mgd) for the HBGS and thus conservatively overestimate the concentrations that would be expected under normal RO station operation conditions. While these analyses show that RO will slightly "concentrate" the trace elements, Table 1 documents that the discharge concentrations of these elements will remain far below the numerical water quality standards established to protect aquatic marine life by the Environmental Protection Agency and by the State of California.

As a result of the pre-treatment step, the backwash and 2x concentrate RO water contains a much larger quantity of iron than does the source water (Table 1). The iron sulfate (or iron chloride) used in pre-treatment quickly dissociates in seawater to form iron hydroxide. This is the most common form of iron in seawater. While the iron content of the discharge is relatively high, the iron will be rapidly mixed with ocean water. There are no numerical water quality standards governing the discharge of iron, which is usually present in low concentrations in seawater, and readily binds with the other elements in seawater and the sediments. Moreover, iron is considered to be an ocean nutrient (essential for the growth of phytoplankton) and will be taken up by organisms in the discharge plume.

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