ANL-HEP-TR-00-16

GAP-99-046

OAK GROVE TECHNOLOGIES, INC. TECHNICAL EVALUATION

PURIFIED WATER QUALITY STUDY

Prepared for:

Mr. Hal Spinka
Argonne National Laboraotry
9700 S. Cass Ave.
Bldg. 362-HEP
Argonne, IL 60439

(630)-252-7058
FAX (630)-252-5782

December 8, 1999

Paul Jackowski
Oak Grove Technologies, Inc.
975 Campus Drive
Mundelein, Illinois 60060
(847) 918-5470

Work supported by the U.S. Department of Energy, Division of High Energy Physics, Contract W-31-109-ENG-38.

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

1.0 Overview

1.1 Purpose of Study

Argonne National Laboratory (HEP) is examining the use of purified water for the detection medium in cosmic ray sensors. These sensors are to be deployed in a remote location in Argentina. The purpose of this study is to provide information and preliminary analysis of available water treatment options and associated costs. This information, along with the technical requirements of the sensors, will allow the project team to determine the required water quality to meet the overall project goals.

1.2 Goals of Study

The goals of this study are:

- Provide analysis of proposed water supply
- Propose treatment options and system configurations based on expected field conditions
- Provide water quality vs. cost analysis
- Identification of issues associated with the intended use of the product water

2.0 Background

2.1 Review of Water Supply

The proposed water supply is to be taken from the Rio Malargue.

Date	06/01/94	09/05/94	01/09/94	12/29/94	12/95	04/96
			Values			
Conductivity	486	785	812	557	514	850
Ph	7	7.6	8.4	7.9	7.8	8.1
Solid Materials mg/l	400	860	650	340	372	680
Chlorides mg/l	9	13	12.9	16	4.9	9.5
Sulphates mg/l	214	337	325.1	208	170	331
Alkalinity CO3/l	5	0	0	0	NR	NR
Alkalinity HCO3 /l	80	106	114.4	84	73	98
Sodium mg/l	7.46	12	13.4	7.7	5.6	9.2
Potassium mg/l	1.2	1.2	1.82	1.2	1.2	1.1
Calcium mg/l	81.5	135	110.8	74	73.4	127.2
Magnesium mg/l	4.25	9.2	4	4.44	4.3	7.5
Strontium mg/l	NR	NR	NR	.6	.72	1.32
Chromium mg/l	0	<0.01	NR	NR	NR	NR
Lead mg/l	<.1	<.01	<.1	NR	NR	NR
Cadmium mg/l	<.1	<.01	<.05	NR	NR	NR
Total Hydrocarbon	0	<.1	NR	<.1	<.1	<.1
Phenols	3.6	7.8	6.8	18.7	<3	<3

Based on the preceeding analysis, the following items are notable:

- Seasonal variations in water quality are significant; consequently analysis of treatment options will be based on the worst case for each of the listed constituents.
- Hardness (Ca and Mg) level is ~22 grains per gallon. This is a very high level and will need to be addressed if membrane processes are to be used. Hardness scaling may result.
- Sulphate levels are also high. Again, this will be an issue for membrane processes.
- Conductivity levels are relatively high at 850 μS/cm. For comparison, Chicago tap water conductivity is much lower at approximately 350 μS/cm.
- Iron levels have not been measured. However, as a surface water supply, we would not expect the level to be prohibitively high.
- Silica levels have not been identified. Silica can be detrimental to deionization process capacity.
- Turbidity and particulate counts are not provided. These levels will be assumed to be high due to the nature of the water source (Surface supply, no municipal treatment)

In general, while TDS (Total Dissolved Solids) and hardness levels are high, this does not appear to be an atypical surface water supply. At this time, there is no indication that this is an unacceptable feed source from the standpoint of treatment.

2.2 Review of Water Treatment Processes

2.2.1 Media Filtration

This process utilizes a filtration media such as sand, anthracite, or greensand to provide reduction in turbidity and iron levels. The filter is configured to allow periodic backwashing to remove the collected impurities and recondition the filter medium. This process may be used in conjunction with upstream flocculant injection to improve filtration efficiency.

2.2.2 Softening

This process utilizes sodium form ion exchange resin to selectively remove Ca and Mg ions and exchange them for Na. This has the effect of reducing water hardness. Water softeners are periodically regenerated with a concentrated NaCl solution to return the resin to the sodium form.

2.2.3 Reverse Osmosis

This process utilizes a semi-permeable membrane to remove dissolved solids. A feed pump pressurizes the water, which is then forced across the membrane. Due to the pore size of the membrane and surface charge effects, ionic contaminants are retained on the feed side of the membrane. A portion of the feed stream, with the rejected contaminants, is sent to drain in order to avoid precipitation of minerals on the membrane surface as saturation levels are approached. Due to the low solubility of Ca and Mg salts ($CaCO_3$, Ca SO_4, etc.) hardness levels in the feedwater need to be controlled.

2.2.4 Deionization

This process utilizes ion exchange resins in the H^+ and OH^- form to exchange impurities in the water for H^+ and OH^-. Deionizers are regenerated with concentrated acid and caustic solutions to return the resin to the H^+ and OH^- form. These units can be configured as on-site or off site regenerable units. For the purposes of this study, we are assuming that the off-site regenerable units will be utilized. (See explanation under section 3.1)

2.2.5 TOC (Total Organic Carbon) Control

This process uses UV lights (185 nm) to cleave carbon bonds in organic molecules in order to reduce them to CO_2 and H_2O. Addition of a strong oxidant such as ozone may also be used for this purpose.

2.2.6 UV sterilization

This process uses UV lights (254 nm) for microbiological control. UV light at this wavelength will destroy microorganisms that are present in the feed water.

2.3 Description of Water Quality Attributes

2.3.1 Total Dissolved Solids (TDS)

This is a measure of the dissolved impurities in the water. TDS is calculated by normalizing levels of specific ions to levels expressed as $CaCO_3$.

2.3.2 Conductivity (µS/cm)

Conductivity is a measure of the electrical conductivity of the subject water and is reported as microSiemens (µS/cm) Conductivity increases when dissolved ion levels increase. Resistivity is the inverse of conductivity and is normally expressed as ohms or Megohms. The theoretical purity limit of water is 18.3 MΩ (0.054 µS/cm).

2.3.3 Total Organic Carbon (TOC)

A measure of the amount of organic molecules present. In applications such as the manufacture of pharmaceuticals and semiconductors, TOC levels are minimized to reduce interference with manufacturing processes and to reduce possible food sources that could support microbiological activities.

3.0 Assumptions

3.1 Physical Plant / Sizing

Based on conversations with Hal Spinka, this study assumes the following:

- 1800 sensors
- 3000 gallons / sensor
- Sensors are deployed in a remote location.
- Capability to fill 2 sensors per day over a 3 year period (6000 gpd make up capacity)
- Water to be processed at central location with the ability to be transported to field.
- Minimal operator oversite of treatment systems.

In addition to the above, the intent is to fill the sensors once and not have to change water on a periodic basis. While the complete issue falls outside of the scope of this study, it is fairly clear that microbiological control will be a necessary part of any treatment system to reduce inoculation of the sensor tanks and ongoing biological growth.

Due to the remote location, issues relating to transport of concentrated Acid and Caustic, and the disposal of high TDS regenerant waste, all of the proposed system configurations assume the use of off-site regenerable DI units. These DI units are available in Argentina and a supplier for exchange and regeneration of the spent units can be identified. In addition, due to the low flow rate requirements (relatively), this approach will yield the benefits of lower capital cost and on-site maintenance.

3.2 Cost Structure

The following cost structure is assumed. As more detailed information regarding the site becomes available, the cost spreadsheets may be modified accordingly.

- Electrical Cost: $0.17/KW hr (Note: Electrical power costs for the region are unknown at this time. The selected cost is based on experience in the United States.)
- Water Cost: n/a
- Waste Water Disposal cost: n/a
- Salt (NaCl): $0.05/lb
- Capital amortized over 3 year period
- DI exchange Service: $200/ 3ft^3 bottle. (Note: DI Exchange costs for the region are unknown at this time. The selected cost is based on experience in the United States.)

Note: Because we are examining off-site regenerable DI systems, water usage over the various options will be similar. Since no data is available on water cost or disposal cost, it is treated as a constant that will not affect the relative cost/kgal.

4.0 System Configurations

Due to the possibility of microbiological growth, each of the following systems includes a 6000 gallon storage tank with recirculation loop, UV sterilizer, and sub-micron filtration. This system will allow the control of the water as it is produced and stored. See attached system drawing.

Capital costs are based on purchase of the equipment, and piping of the treatment equipment. There is no allowance for a building or the running of support utilities.

Required utilities:

- Electrical Power (single and 3-phase)
- Water Supply
- Drains
- Heating and cooling as required to maintain an ambient temperature of 50-90^{0}F

4.1 Softening

This configuration assumes that the only treatment processes will be media filtration to reduce turbidity and softening for hardness reduction.

Projected Product Water Conductivity: **800-1000 μS/cm**
Hardness level (Product): <15 ppm (as $CaCO_3$)
Process configuration: Media Filter⇒Softener⇒Storage Loop

Feed Water Rate	4.2 gpm
Gallons/day (Feed)	
Gallons/day (product)	6000 gpd
Feed Water Hardness	22 gr/gal

Softener	
Softener Grain Capacity	20000 gr/ft3
Softener Resin Capacity	5 ft3
Salt Dosage/ft3 resin	10 lbs.
Regeneration	1.32 per day
Salt Usage	66 lb/day
Water Usage (regen)	190 gal/regen
Water Usage (Total/day)	250.8 gpd

Media Filter	
Filter Service Rate	4.2 gpm
Backwash Cycles	2 per day
Water Usage (backwash)	84 per backwash
Water Usage (total/day)	168 gpd
Storage Loop	
Recirculation Pump	13.7 kw/day
UV Light	6 kw/day
Total	19.7 kw/day
Capital	
Budgetary Capital	$50,000
Water Usage	
Drain	418.8 gpd
Product	6000 gpd
Total	6418.8 gpd
Totals	
Salt	$0.55 /1000 gal
Power	$0.56 /1000 gal
Operating Cost	$1.11 /1000 gal
Total (including capital)	$8.72 /1000 gal

4.2 RO

This configuration assumes that RO will be used after the softeners in order to further reduce TDS and conductivity. The RO will operate at 75% recovery, which means that a 6000 gpd (product) RO will need 8000 gpd feed water with the additional 2000 gpd to go to drain.

Projected Product Water Conductivity: **10µS/cm (10 ppm TDS)**
Hardness level (Product): <1 ppm (as $CaCO_3$)
Process configuration: Media Filter⇒Softener⇒RO⇒Storage Loop

Feed Water Rate	5.5 gpm
Gallons/day (Feed)	8000 gpd
Gallons/day (product)	6000 gpd
Feed Water Hardness	22 gr/gal
Feed Water TDS	860 ppm (CaCO3)

Softener

Softener Grain Capacity	20000 gr/ft3
Softener Resin Capacity	5 ft3
Salt Dosage/ft3 resin	10 lbs.
Regeneration	1.76 per day
Salt Usage	88 lb/day
Water Usage (regen)	247.5 gal/regen
Water Usage (Total/day)	435.6 gpd

Media Filter

Filter Service Rate	5.5 gpm
Backwash Cycles	2 per day
Water Usage (backwash)	110 per backwash
Water Usage (total/day)	220 gpd

RO

RO prefilters	2 10" Elements
Change frequency	2 weeks
Cost/10" Element	$2.75 per 10" Element
RO Power	48 kw/day
Water Usage (Drain)	2000 gpd

Storage Loop

Recirculation Pump		13.7 kw/day
UV Light		6 kw/day
	Total	19.7 kw/day

Capital

Budgetary Capital	$80,000

Water Usage

Drain		2655.6 gpd
Product		6000 gpd
	Total	8655.6 gpd

Totals

Salt	$0.73 /1000 gal
Power	$1.92 /1000 gal
Filters	neg. /1000 gal
Operating Cost	$2.65 /1000 gal
Total (including capital)	$14.83 /1000 gal

4.3 RO / DI

This system is basically the same as the previous except for the addition of mixed bed deionizer tanks after the RO. This will polish the RO permeate and significantly reduce the dissolved solids.

Projected Product Water Conductivity: **.2-.1 μS/cm (5-10 MΩ)**
Hardness level (Product): <1 ppm (as $CaCO_3$)
Process configuration: Media Filter⇒Softener⇒RO⇒DI⇒Storage Loop

Feed Water Rate	5.5 gpm
Gallons/day (Feed)	8000 gpd
Gallons/day (product)	6000 gpd
Feed Water Hardness	22 gr/gal
Feed Water TDS	860 ppm (CaCO3)
Softener	
Softener Grain Capacity	20000 gr/ft3
Softener Resin Capacity	5 ft3
Salt Dosage/ft3 resin	10 lbs.
Regeneration	1.76 per day
Salt Usage	88 lb/day
Water Usage (regen)	247.5 gal/regen
Water Usage (Total/day)	435.6 gpd
Media Filter	
Filter Service Rate	5.5 gpm
Backwash Cycles	2 per day
Water Usage (backwash)	110 per backwash
Water Usage (total/day)	220 gpd
RO	
RO prefilters	2 10" Elements
Change frequency	2 weeks
Cost/10" Element	$2.75 per 10" Element
RO Power	48 kw/day
Water Usage (Drain)	2000 gpd
DI	
RO Permeate TDS	5 ppm
RO Permeate TDS (Grains)	0.29 grains/gal
DI Capacity	25000 grains/tank
DI Run Time	14.25 days
DI Cost/1000gal	$2.34 /1000 GAL
Storage Loop	
Recirculation Pump	13.7 kw/day
UV Light	6 kw/day
Total	19.7 kw/day

Capital

Budgetary Capital		$85,000

Water Usage

Drain		2655.6 gpd
Product		6000 gpd
	Total	8655.6 gpd

Totals

Salt	$0.73 /1000 gal
Power	$1.92 /1000 gal
Filters	negligible /1000 gal
DI	$2.34 /1000 gal
Operating Cost	$4.99 /1000 gal
Total (including capital)	$17.93 /1000 gal

4.4 RO / DI / MB with TOC Control

This configuration adds TOC destruct UV to the Storage loop to reduce TOC levels. In addition, an additional polishing mixed bed DI is in the loop. Water quality from this type of system is very high.

Projected Product Water Conductivity: **15-18MΩ**
Hardness level (Product): <1 ppm (as $CaCO_3$)
TOC Level= <10ppb
Process configuration: Media Filter⇒Softener⇒RO⇒DI⇒Storage Loop (Polishing MBDI, TOC UV)

Feed Water Rate	5.5 gpm
Gallons/day (Feed)	8000 gpd
Gallons/day (product)	6000 gpd
Feed Water Hardness	22 gr/gal
Feed Water TDS	860 ppm (CaCO3)

Softener

Softener Grain Capacity	20000 gr/ft3
Softener Resin Capacity	5 ft3
Salt Dosage/ft3 resin	10 lbs.
Regeneration	1.76 per day
Salt Usage	88 lb/day
Water Usage (regen)	247.5 gal/regen
Water Usage (Total/day)	435.6 gpd

Media Filter

Filter Service Rate	5.5 gpm
Backwash Cycles	2 per day
Water Usage (backwash)	110 per backwash
Water Usage (total/day)	220 gpd

RO

RO prefilters	2 10" Elements
Change frequency	2 weeks
Cost/10" Element	$2.75 per 10" Element
RO Power	48 kw/day
Water Usage (Drain)	2000 gpd

DI

RO Permeate TDS	5 ppm
RO Permeate TDS (Grains)	0.29 grains/gal
DI Capacity	25000 grains/tank
DI Run Time	14.25 days
DI Cost/1000gal	$2.34 /1000 GAL
Polishing DI Feed TDS	<1 ppm
DI Capacity	25000 grains/tank
DI Run Time	45 days
DI Cost/1000gal (Polishing)	$0.74 /1000 gal

Storage Loop

Recirculation Pump		13.7 kw/day
UV Light		6 kw/day
TOC UV		20 kw/day
	Total	39.7 kw/day

Capital

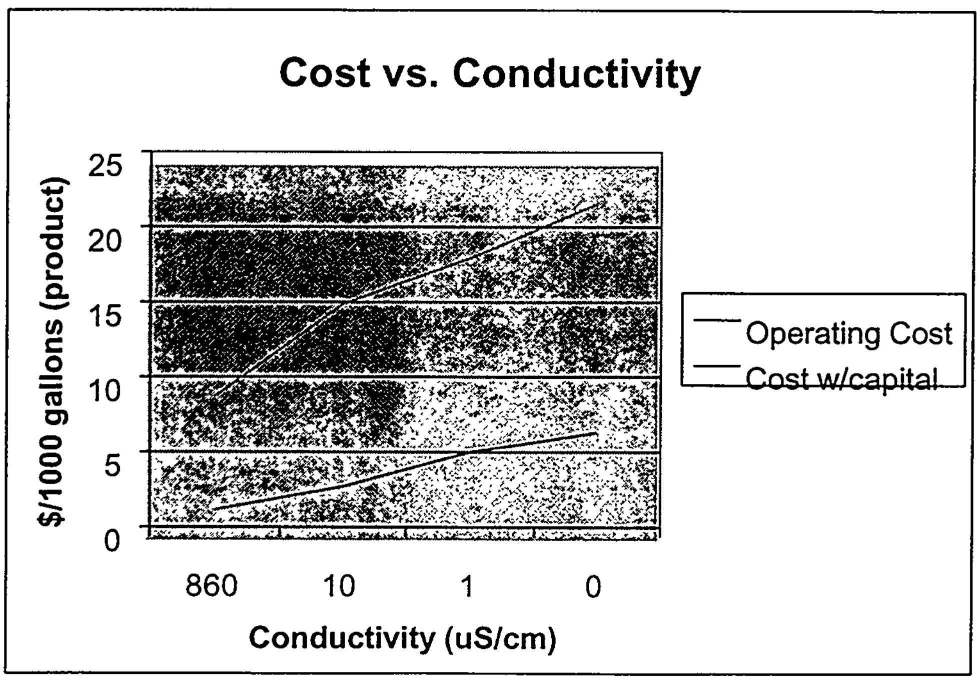
Budgetary Capital	$100,000

Water Usage

Drain		2655.6 gpd
Product		6000 gpd
	Total	8655.6 gpd

Totals

Salt	$0.73 /1000 gal
Power	$2.48 /1000 gal
Filters	negligible /1000 gal
DI	$3.08 /1000 gal
Operating Cost	$6.30 /1000 gal
Total (including capital)	$21.52 /1000 gal



5.0 Summary

As can be seen from the cost vs. conductivity chart, we should not be surprised to discover that the better the water quality, the more expensive it is to own and operate a treatment system.

The configurations described above represent a reasonable approach based on the facts as they stand today. Obviously, changes in the expected operating parameters, most notably the water source, would dramatically affect the cost per 1000 gallons. However, the relative costs between the various treatment strategies should be fairly stable.

It has been explained that the sensor storage vessel may be a polymer material of some kind. Please note that even if TOC treatment is indicated, TOC may still be leached over time from the storage vessel. In addition, most polymer vessels (polyethylene for instance) has a certain degree of porosity that may allow a biological organism to take hold.

In regard to the expected use of the purified water, it is outside of the scope of this study to speculate on the implementation of the sensor storage system. However, it is probably safe to assume that one of the key issues will be the biological stability of the purified water over time.

Should biological growth occur in the sensor, it is possible that a biofilm will form, obstructing the ability of light to pass through the storage vessel. Unfortunately, in order to have some relative assurance of biological control, it is necessary to remove or destroy any colony forming organisms, as well as reducing the food supply (TOC). This does not mean that the chemical purity (TDS) must necessarily be low. In fact, if the chemical purity of the water is not an issue, and appropriate biocide may be employed to reduce the threat of biological growth.