

Brackish Water Purification Systems

(7/4/2007)

How does one set up an emergency water purification system that uses minimum power to work with brackish water after a PS? What does one need to know? What strategy does one use to pull together the components in a short period of time? How can it all be made cost effective so the common man can afford it? How much preparation is needed? These and more questions will be attempted to be addressed in the following write-up.

Distillation is an excellent method of producing good water and is highly recommended. It is very expensive in terms of the amount of energy used. Distillation was well covered earlier. Separation by freezing will not be covered in this report. Portable hand operated methods to the extent they are usefully have been previously covered. What will be covered now are ways of filtering and purifying water using about 200 to 400 times less energy than distillation for use at a base site.

Many may not have the energy available for doing distillation. So alternatives become appropriate. A good energy efficient brackish water purification system will have the following minimum components.

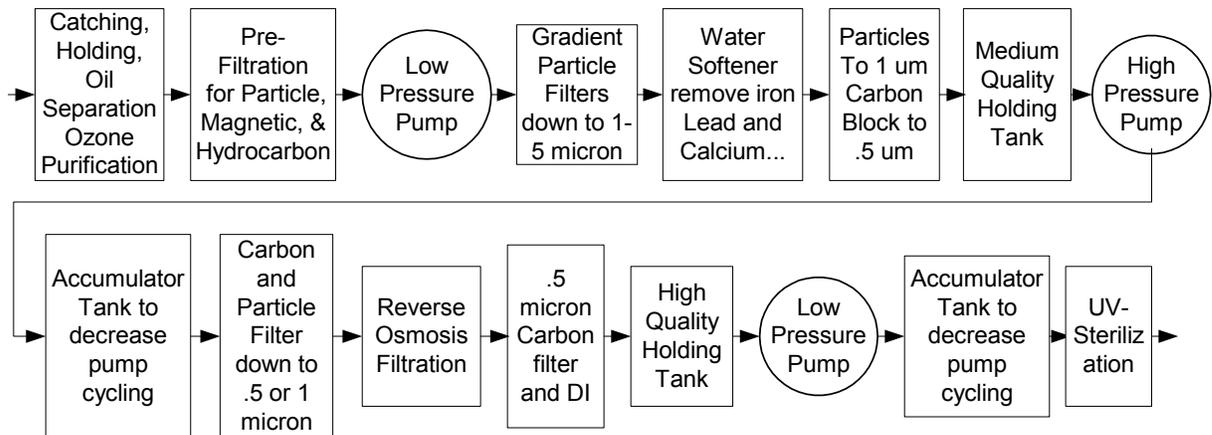
- Container(s) to collect and hold rain or run off water (plastic garbage cans, hole in ground lined with plastic, 55 gallon tanks, etc)
- Strong magnet to attract iron and other ferromagnetic metals and pull them out of solution.
- Ozone bubbled through the water to kill pathogens and reduce heavy metals.
- Settling tank to separate oil and dirt. Oil floats to top and runs out an over flow. Dirt and heavy particles settle on the bottom of the tank. Good water is drawn out from in-between.
- Gradient particle filters down to about .5 micron. Gradient mesh cloths could be stuffed into a 4" pipe as one example. A sand filter or a commercial filter element could be used.
- Method of moving water (gravity, electric pump or hand pump)
- Way to precipitate small or dissolved unwanted heavy metals. (water softeners, ion exchange, Ozone, and Magnets)
- Way to bring the pH back in range if very different from neutral especially if acid. (if acid add ashes, or use Ozone)
- Way to remove very-very small particles out of the water. (ceramic filters, reverse osmosis, DI demineralization resins filters, and distillation)
- Way to remove hydro carbons (oil etc) and bad smells. A Carbon filter elements, or could be as simple as a plastic garbage can full of crushed charcoal that the water is run slowly though. Ozone bubbled through water will also remove smells.
- Sterilization or killing of parasitic organisms like bacteria, viruses, etc (passed by UV-light source, or add an item like chlorine, iodine, colloidal silver, Grape fruit seed extract or bubbling ozone gas through the water).
- Container to collect the output, so the process can be done slowly or at its own best most efficient rate yet water can be easily obtained from it.

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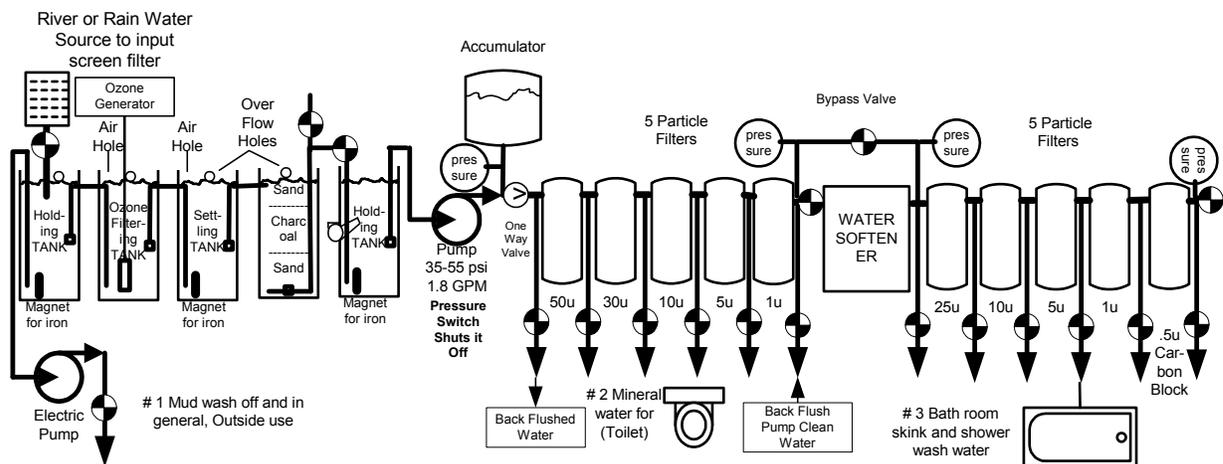
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A block diagram of the major functional components would look like:

Functional Flow of Needed Water Purification Items



In more detail it might look like the following:



Water flows in from an up hill source and is controlled by a ball valve. The planned near continuous over flowing of the settling tank allows for the removal of floating oil and debris. Magnets are used to help remove Iron. Ozone is bubbled as needed to kill pathogens and remove heavy metals. An alternative to this would be to run the water through a UV-light filter to kill pathogens between tank one and two.

Sand and ground charcoal is used to remove small partials and hydrocarbons (oils). Commercial 10" filter elements are used to remove small partials and more hydrocarbons and some lead. The water softener removes more Iron, and hardness (calcium). This is to make the RO process more efficient. Three types or qualities of water can be taped off as needed.

The pressure gauges are used to tell when the filters need to be back washed. The many valves or water faucet tap off points allow for bypassing (skipping filters or components not needed)

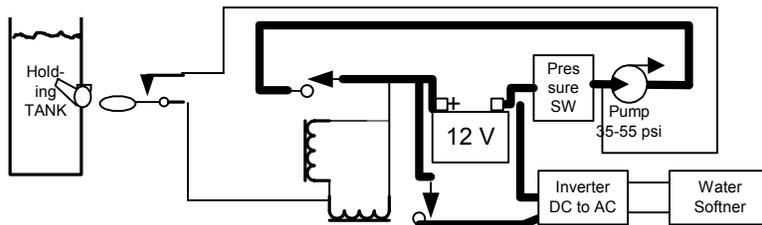
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and allow for backwashing of each filter element independently without removing it from the cartridge. It also allows for many different qualities of water to be used as needed.

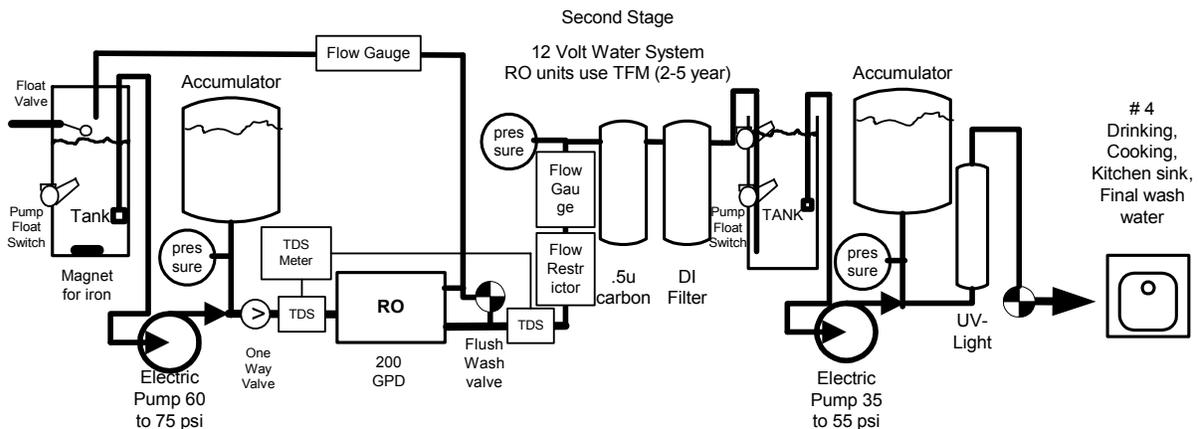
For the holding tanks use 55 gallon containers, trash cans, or 5 gallon buckets depending on scale of operation. Grind or pound up raw wood barbeque charcoal to small chunks. Don't get brickets (they have a non-charcoal binder) or any charcoal that is presoaked with hydrocarbons to make it easy to light. Put a separating cloth between the sand and ground charcoal. Put some sand under and then on top to hold the carbon down from floating. This is set up so it can be backwashed as needed.

Electrical diagram for the first pump is:



The Ozone generator is hooked up to a separate inverter and is turned on by hand. As power permits it is run nearly consciously. The 12 Volt Relay is normal open with no power applied and typically is a DPDT (double pole/double throw). The tank float switches were boat bilge pump switches (15 amp max). The pressure switch comes with the pump.

Plumbing diagram for the Reverse Osmosis (RO) or second half is:



Multiple RO membranes can be put in parallel to get the desired GPD. The "flush wash" valve is used to flush buildup on the membrane to waste. It is used as often as needed to keep the membrane from clogging up. The flow restrictor size is matched to the GPD rating for the membrane (see below for more explanation). A flow restrictor and flow volume measurement gauges help keep the ratio of good water to waste water at about 22% or 1:3.5. The total dissolved solids (TDS) meter helps keep track of the efficiency of the process.

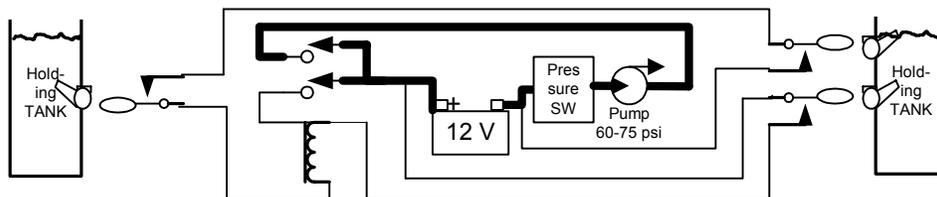
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The carbon filter removes any hydrocarbons that have made it to this point. The DI or demineralization resin bead filter takes out any remaining dissolved minerals and takes the PPM to zero. The result is stored in a tank and pumped on demand for drinking and food preparation. The UV-Light does a final sterilization of pathogens.

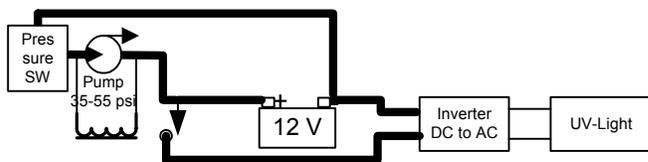
The good news is that off the shelf house hold RO units have gone down in price and up in GPD over the last number of years. In many cases one can get a replacement membrane that brings the old 10-15 GPD unit up to 75 or 100 GPD rate. The price of the membrane is about \$30-\$40. Household RO systems that produce 100 to 200 GPD now cost about the same as the 10-15 GPD units of 5 years ago. Searching on eBay is a good way to find these. Start with a good basic RO unit and add up front more items as described in this report. If one wants to venture into new territory's there is even a 700 GPD tankless Merlin Reverse Osmosis Water Filter that sells for about \$375.

Electrical for the RO Pump:



The 12 Volt Relay is normal open with no power applied and typically is a SPST (single pole/single throw). Once turned off the water has to go down to the lower tank float switch (tank on the right) to turn on the unit. Then it won't turn off until the tank is full or the source tank (one on left) is down to its switch.

Pump wiring for the last or delivery pump:



The pressure is adjusted on all of the pumps to be as big a range as possible to minimize on/off cycling. The Accumulator tanks are as big as possible considering cost. Bladder tanks are preferred however one can use the typical 2-5 gallon water pressure tanks supplied with some RO units. I suggest one use several in parallel to compensate for the slow flow through the small inlet tank fittings.

For water delivery and all but to drive RO we ended up choosing Shurflo 12 volt Industrial pump part number 8000-443-236 about \$60/each. Flow rate of 1.25 GPM at 60 psi and 7.2 amps or 1.4 GPM at 35 psi and 5.2 amps. http://www.shurflo.com/pages/gen/site_map.htm

For water delivery to the membrane one can use Aquatec 5800 (at .25 to 1.5 GPM, 25W to 100W, Up to 130 psi) or equivalent depending on intended GPD flow rate.

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For various RO piece parts or components check out:

<http://airwaterice.com/>

<http://www.waterfiltersonline.com/parts-department.asp>

<http://stores.ebay.com/H20-Science>

For a source of cost effective filter elements to include .5 um Carbon Block at about \$6.00/each in quality including the price of shipping and sediment filters for about \$1.20/each down to 1 um see: <http://stores.ebay.com/H2O-SPLASH>

BILGE PUMP FLOAT SWITCH see

<http://stores.ebay.com/Stuff4boats>

Water Softener

The water softener can be as simple as a holding tank where the water flows through the resin beads (like for charcoal filter only smaller). One can buy the resin on-line eBay for about \$100/1cuft or 50 lbs. One could take the container off-line and back flush with salt once in a while to regenerate it. One would fill the container with a high concentration of salt and let it sit for about 30-40 min while stirring it up occasionally. Then one would wash the salt off the resin beads and put the filter back on-line. From time to time testing the TDS of the input and output would determine how often regeneration would be needed. When the TDS starts to go up on the output one would know it's time to regenerate.

A small version of a rebuildable cartridge that fits within a 10" cartridge filter can be purchased. It is a plastic container that one can replace the beads in and put it back in the filter cartridge. See <http://stores.ebay.com/H20-Science> for where to get this rebuildable removable cartridge. They are made primary for DI and Carbon replacement particles. However there is no reason why one couldn't use water softener resin beads. These beads can last up to 10 years of regeneration as long as you have salt available. Non-reusable cartridges can be purchased at <http://www.filterwater.com/showproduct.aspx?productid=101&affiliateid=10050>

Water Hardness: Calcium and magnesium are two minerals which make water "hard." Both of these minerals are classed as "contaminants," but that's a poor choice in terminology, for calcium is essential in our diet! A softener merely exchanges one group of non-toxic elements for another group of non-toxic elements. Water hardness is measured either in grains per gallon (GPG) or as calcium hardness in milligrams per liter (mg/l) or parts per million (ppm). GPG is based on calcium hardness. To convert from calcium hardness ppm, just divide by a factor of 17.2 and this gives you hardness in GPG. A soft or slightly hard water has up to 3.5 GPG; moderately hard water runs from 3.5 to 10.5 GPG; and very hard water is greater than 10.5 GPG. Metro water is on the low side of moderately hard at 4.1 GPG (that is 70 mg/l of calcium hardness. Purchase a TDS hand held meter to measure your Hardness.

Water softeners resin beads use about 1 lb of salt to regenerate for about 3,800 gal of good water produced. This is depending on hardness of the water. Non-electric water softeners do not have the problem electric ones have. When the electricity goes off, the electric softeners loose track

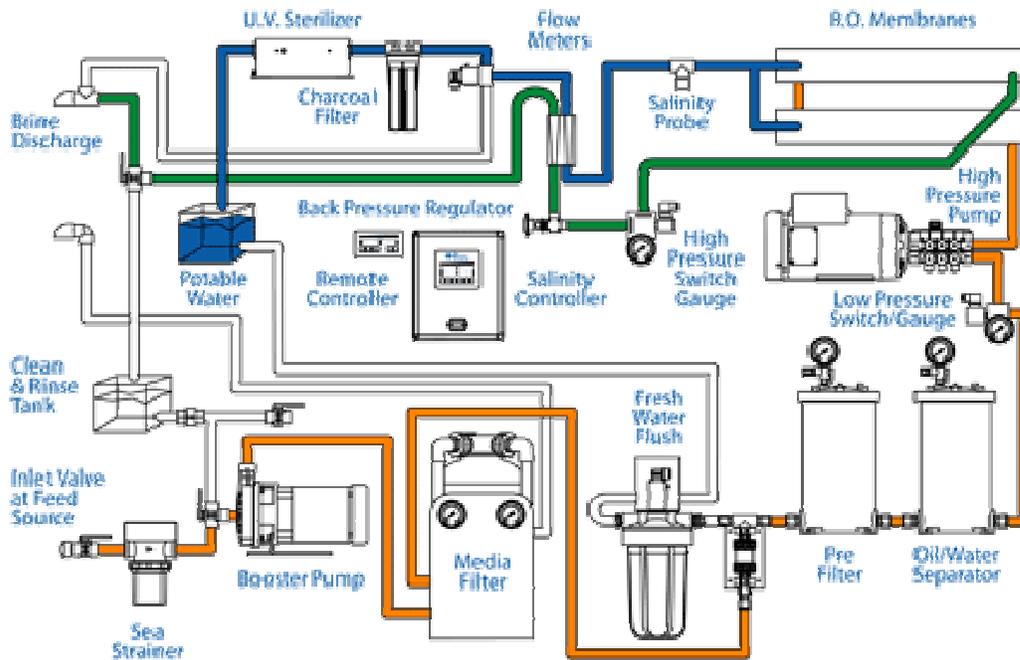
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of the amount of water volume that has flowed since the last regeneration cycle. When the electricity comes back on they do an automatic regeneration cycle. The bottom line is to make your own or purchase a non-electric type of water softener.

Sea Water RO

A RO unit that works for making fresh water out of salt water operates at a much higher pressure (600 to 1000 psi) and might look like the following. These are usually rather pricy.



For the type of salt water systems available and how they work see:

<http://www.cruisingworld.com/article.jsp?ID=44957&typeID=397&catID=572>

Ventura 150 is a very efficient fresh water maker and produces 150 gal/day at 17 watt-hr/gal running off 12 Volt DC. Also check out the Aquifer 150. It is a portable rugged water maker engineered for the mobile conditions in remote areas where good water is essential. The Aquifer 150 system makes 150 gallons of purified fresh drinking water every day in almost any climate. Both of these have a much lower cost than most marine RO units.

<http://www.spectrawatermakers.com/>

Ozone Water Treatment

This is done by bubbling Ozone Gas made from air passing over a strong UV light source through water. This is not to be confused with passing water over a UV light source to kill water born pathogens. Both have their place in water purification. Ozone Gas bubbled through water will kill pathogens and also it will take out heavy metals and bad smells.

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Municipal water companies have used ozone technology to treat large quantities of water for many years because of its effectiveness in purifying and conditioning water. California state law now requires ozonation as the final step before bottled drinking water is packaged. The International Bottled Water Association also requires ozonation prior to bottling.

The Benefits of bubbling Ozone through water are:

- Kill bacteria on contact thousands of times faster than chlorine or bromine.
- Kill virus on contact.
- Kill algae spores, fungus, mold and yeast spores.
- Precipitate heavy metals.
- Remove excess iron, manganese, and sulfur by a process known as micro-flocculation, thus conditioning the water naturally without chemical additives.
- Remove color and odor, leaving a fresh, healthy bouquet.
- Reduce scale build-up on equipment such as pipes

The level of contaminants that can be removed by use of Ozone in a single tank is typically: Iron to ~10ppm, Manganese to ~1ppm, Hydrogen Sulfide up to ~25ppm. Twin tanks in service have successfully removed Iron to ~55ppm, Manganese to ~16ppm, H₂S to over ~100ppm. It will also raise the PH of your water if it is in the acidic range (below a PH of 7.0) and stabilize the PH in the 7.5 range.

Ozone is made up of 3 atoms of oxygen and is unstable soon to become O₂. This makes it one of nature's very powerful disinfecting and deodorizing agents. The Half life of Ozone in air is on the order of hours and the order of minutes when dissolved in water. Ozone Dissolves over 12 times more readily into water than pure oxygen. The result of this decay is much higher than normal concentrations of pure Oxygen dissolved in water.

Use a holding tank size such that as a rule, the maximum usage per day will never exceed 25% of the tank capacity. Ozone gas is heavier than air and will accumulate around the holding tank. Do not breathe the accumulated Ozone gas for an extended period of time.

Ozone will not remove nitrates (typical when water is contaminated by fertilizer run off), sodium, sulfates, total dissolved solids, chlorides, and fluoride. These contaminants can be removed by reverse osmosis or distillation. Pre-treating the water with the Ozone will dramatically reduce the maintenance required on the reverse osmosis.

A typical unit that performs this function can be found at <http://www.tripleo.com/default.htm>. Once one understands how it works. It can be made simply by passing air over a UV-light germicidal lamp light source. A small fish tank pulse pump can be used to supply the air.

Things to be aware of

Maximum PSI for Filmtec RO Membrane 50, 75, or 100 GPD is about 90 PSI. Optimal PSI is 65 to 72 PSI and a temperature of 70 degrees. Ozone and chlorine will harm and degrade the RO Membrane.

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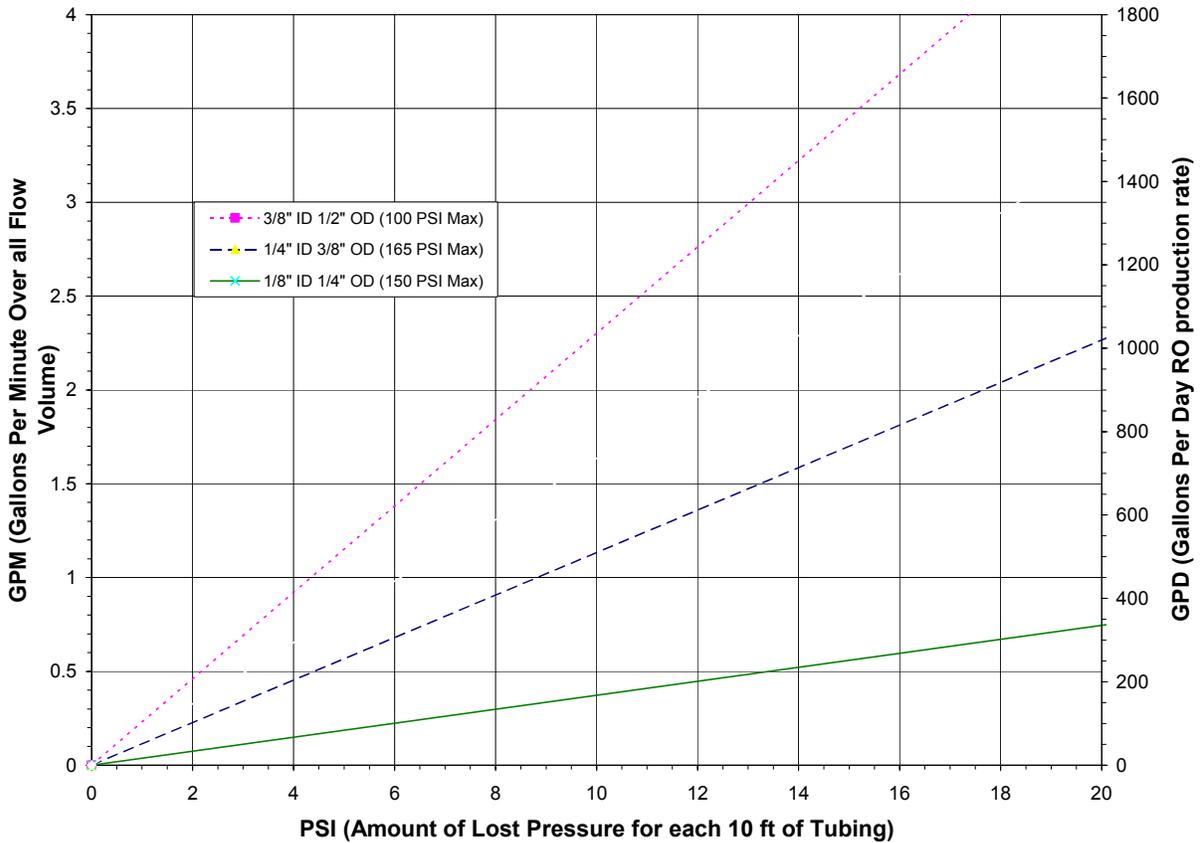
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DI stands for Demineralization by Ion Exchange. It is a mixed bed of beads of Anion and Cation resins. Ions, salts or minerals can be entirely removed from water to near 0 PPM. Typical capacity of a Vertical 10" filter cartridge is 6,800 ppm. If TDS (total dissolved solids) out of the membrane measure 20 ppm then $6,800 \div 20 \text{ ppm} = 340$ gallons before it runs out of capacity to take minerals out of water. A DI can be used stand alone without a RO unit in front of it; however, it will not last very long depending on the TDS PPM. As far as I know this resin can not be recharged like water softener beads. However water softener beads can be used in the same rebuildable cartridge to make a rechargeable reusable water softener filter.

Choosing Tubing Size

How to determine the size tubing to use based on expected flow rate: As an example say one is building a 200 GPD RO unit. Can .25 inch OD (outside dimensions) tubing be used? We can see from the chart below that for every 10 ft of tubing used the pressure will drop by 12 PSI. So the answer is yes we can as long as one keeps the over all length of this size tubing short. We can also compensate for tubing pressure drop by boosting the pump pressure by 1.2 psi/ft of length used. Any flow greater than this and one should use the next size bigger tubing or 3/8" OD.

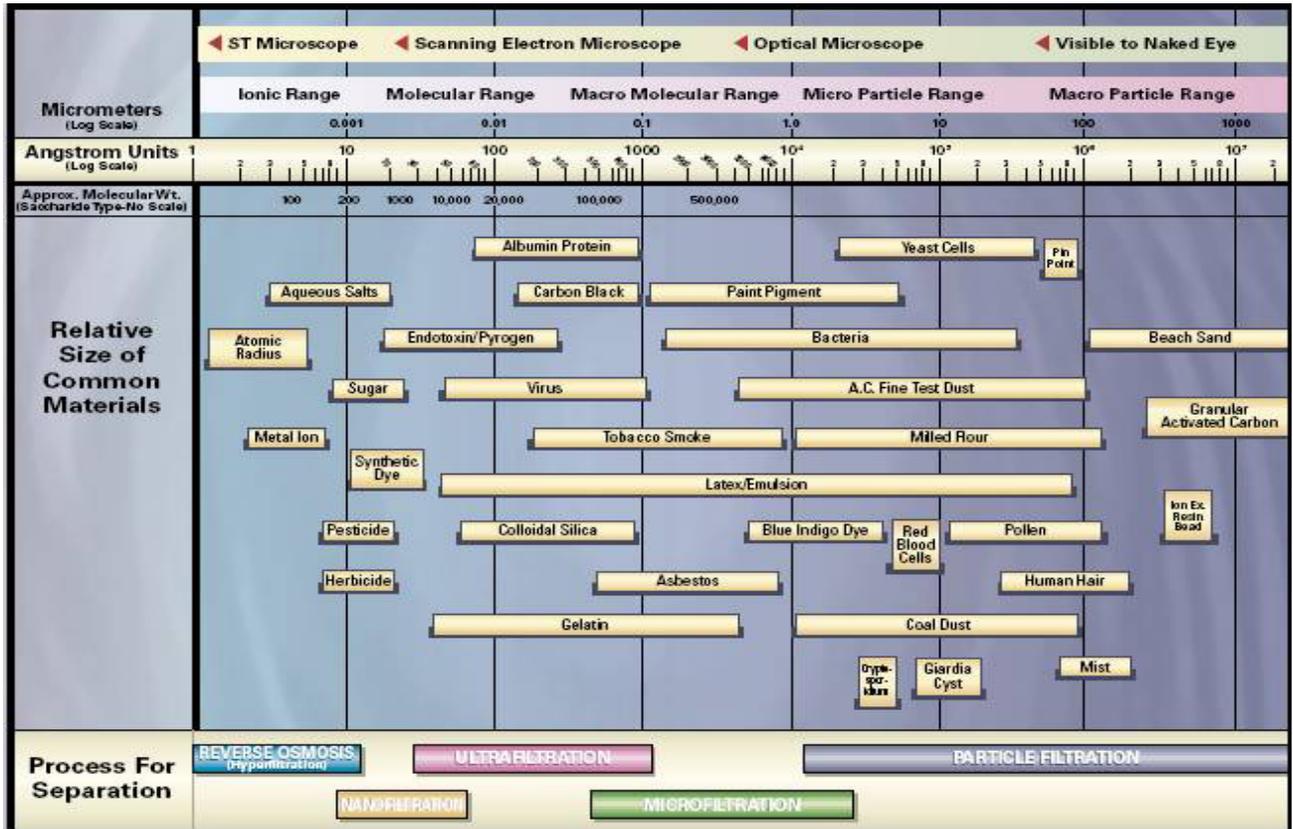
Amount of Lost Pressure Due to Plastic Tubing Friction



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The following illustrates where reverse osmosis membranes (.0001 to .0015 micron) fits in the relative size of common materials. From http://www.hfpurewater.com/reverse_osmosis.htm Don't get thrown off by the word "reverse" in the name of "reverse osmosis". The bottom line is it is a material that has very small holes and one needs to use a high pressure to get the water separated from the dissolved larger particles. The holes are just a bit bigger than water molecules. RO is just like any other particle filter only with smaller holes.



In practice, a fraction of the living bacteria can and do pass through RO membranes through minor imperfections, or bypass the membrane entirely through tiny leaks in surrounding seals. Thus, complete RO systems should include additional water treatment stages that use ultraviolet light or ozone to prevent microbiological contamination. For more info see http://en.wikipedia.org/wiki/Reverse_osmosis

Tribal knowledge

Chlorine and Ozone gas will degrade membranes and a lot of both is not good for water softener resin. Remove them if present in water before the RO membranes, water softeners and carbon filters. Carbon filters and/or "UV-Light with water passing by it" will take ozone and chlorine out of water solution. The carbon get hot as the Ozone reacts with it. Letting the water with Ozone sit while going from one holding tank to another will allow the Ozone to change to normal oxygen due to its short half life of minutes. If needed passing Ozone water through a

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UV-Light filter will remove chlorine and ozone from the water rendering it harmless. For more info see http://www.daytonwatersystems.com/productsHTML/L1_TechInfo.htm near the end of the page.

The reason for doing sterilization up front is to avoid growth in down stream filters and tanks. In general if possible use the UV-Light or ozone sterilization again at the end of the process. Light in the range of 200nm to 300nm (nanometer) is used for UV-Light germicidal sterilization disrupting metabolism and reproduction by altering the DNA.

Very high or very low pH can degrade the membrane. Low or acid pH will bring the water softening process to a halt. Bring the pH of the water close to between normal 7 or a bit basic before filtering. Ozone bubbling through the water will help do this.

Iron Bacteria (not to be confused with dissolved iron) causes water softeners problem. Kill it up front with Ozone or UV-Light before it gets to the water softener.

For a simple description of how reverse osmosis filters work see: <http://www.aquamarineinc.net/content/ROtheory.html> or http://www.fresh-water-filters.com/reverse_osmosis.html

All RO systems use some type of flow restricting device to apply pressure to the membrane. By restricting the flow rate to the drain the system applies proper pressure to the membrane. RO process doesn't work below about 40 PSI. In this case all the water is dumped to waste water. Storage of RO filter elements should be done in a sealed air free bag. There are solutions that can be purchased from marine manufactures that will put it into storage while wet.

Flow restrictor size list:

Reverse Osmosis Membrane Size	ML Per Minute	Approximate Ratio- Waste/Product (Home Use)
8 - 20 GPD	150	4:1
25 GPD	250	3.5:1
36 GPD	350	3.5:1
50 GPD	500	3.5:1
75 GPD	750	3.5:1
100 GPD	1000	3.5:1
150 GPD	1,200	3.5:1

An adjustable flow restrictor can be made by using a T-valve and adjusting the flow through to get approximately 3.5 to 1 water flow ratio for waste water to good water.

Water Well Problems and their Cure:
http://www.water-treatment.org.uk/well_water.html

Water Treatment Processes:

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http://www.water-treatment.org.uk/swimming_treatment_processes.html

The following are useful Conversions when working with water purification:

General:	
Conversions	Abbreviations
ppm = mg/L	ppm = parts per million
1mg/L = 1,000 microgram/L	mg/L = milligrams per liter
1ppm = 1,000ppb	ppb = parts per billion
cc = ml	cc = cubic centimeters
1ml = 1g water	g = gram
1% = 10,000ppm	ml = milliliters
1% = g/100mL	ppt or 0/00 = parts per thousand
1ppt = 1,000ppm	ppb = parts per billion
1% = 10ppt	ug/g = microgram/gram
0.1% = 1g/L	1ug/g = 1ppm
1000ppb = 1ppm	g/L = gram per liter

Hardness:	
Conversions	Abbreviations
1gpg = 17.1ppm CaCO ₃	gpg = grains per gallon
	CaCO ₃ = calcium carbonate

Alkalinity:	
Conversions	Abbreviations
1dKh = 17.9ppm CaCO ₃	dKh = German degrees of hardness (also shown as Kh)
1 meq/L = 50ppm CaCO ₃	meq/L = milli equivalents per liter

Conductivity/TDS (total dissolved solids):	
Conductivity Units:	
uS = microSiemens = mhos/cm = micromhos per centimeter	
mS = milliSiemens = mmhos/cm = millimhos per centimeter	
(mhos and Siemens are the same)	
TDS Units:	
ppm = parts per million	
ppt = parts per thousand	

Weight:	
Conversions	Abbreviations
16oz = 1lb	7000 grains = 1lb
0.454kg = 1lb	kg = kilograms
454g = 1lb	mg = milligrams
1kg = 1000g	g = grams
1g = 1000mg	28.349g = 1oz

Conductivity/TDS Conversions:	
1mS = 1,000uS	
1ppt = 1,000ppm	
uSiemens x 0.7 = ppm	

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Temperature:

$$(1.8 \times ^\circ\text{C}) + 32 = ^\circ\text{F}$$

$$(^{\circ}\text{F} - 32) \times 0.56 = ^\circ\text{C}$$

Volume:

$$15\text{ml} = 1/2\text{oz}$$

$$250\text{ml} = 8\text{oz}$$

$$3800\text{ml} = 1 \text{ gallon}$$

$$30\text{ml} = 1\text{oz}$$

$$500\text{ml} = 1\text{pint}$$

$$60\text{ml} = 2\text{oz}$$

$$1000\text{ml} = 1\text{quart}$$

$$120\text{ml} = 4\text{oz}$$

$$2000/2500\text{ml} = 1/2 \text{ gallon}$$

$$3.78\text{L} = 1\text{gal}$$

$$128\text{oz} = 1\text{gal}$$

$$2\text{pt} = 1\text{qt}$$

$$4\text{qt} = 1\text{gal}$$

$$\text{qt} = \text{quart}$$

$$\text{pt} = \text{pint}$$