concentrations, flowrate or operational problems and inefficiencies associated with the "solids" precipitation equipment.

## SUMMARY ~~OF THE INVENTION~~

It is an object of the ~~invention~~disclosure to provide an improved process for the treatment of small and large flowrates of Influent Water from natural sources or wastewater containing "sparingly soluble" inorganic scale-forming compounds.

It is another object of the ~~invention~~disclosure to provide an improved process using a single stage or 2-stage membrane process to purify the Influent Water and recover 67% - 99.9% of the water as purified water without incurring the risk of precipitation of scale-forming compounds on the surface of the membranes which reduces the life of the membranes.

It is still another object of the ~~invention~~disclosure to prevent precipitation of scale-forming compounds on the membrane surface by chemically precipitating said compounds from the membrane concentrate in an external recycle loop by adding a suitable alkali compound, followed by coagulating, flocculating and removing said precipitated compounds thereby producing a chemically softened membrane concentrate for further water recovery and recycling.

Yet it is another object of the ~~invention~~disclosure to enhance the membrane concentrate softening process by removing residual hardness and silica from said chemically softened membrane concentrate, using an ion exchange softening resin, a silica sequestering media or both, to ensure consistent and almost complete removal of said scale-forming compounds from the membrane concentrate, thus preventing deposition on the membrane surface, preventing permeate flux loss and preventing premature cleaning and/or membrane replacement.

These and other objects of this ~~invention~~disclosure will become clear from the specification, claims and drawings appended hereto.

In a first aspect, there is provided an improved enhanced two-stage high recovery membrane process for the economical operation of semi-permeable reverse osmosis (RO) membranes which are used to purify water containing soluble and sparingly soluble inorganic compounds and achieve high recoveries of purified water in the range 67% - 99.9% of the Influent Water without precipitation of sparingly soluble inorganic scale compounds on the surface of the membrane, as illustrated in Figure 1 , comprising:

a) pretreatment of the Influent Water, containing soluble and sparingly soluble inorganic compounds by filtration to separate suspended solids using a suitable filtration means and preconditioning by adding acid and antiscalant to produce a preconditioned Influent Water;

b) introducing said preconditioned Influent Water into the high pressure side of a first stage RO membrane system (R01 ) and pressurizing said preconditioned Influent Water to produce purified water permeate on the low pressure side that is substantially free of said inorganic compounds;

c) removing first stage R01 membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds from the high pressure side of said R01 membrane system without precipitation of said preconcentrated sparingly soluble inorganic compounds on the R01 membrane;

d) recovering the bulk of purified water permeate on the low pressure side of the R01 membrane at a rate at least 50% of the rate of introducing said water containing soluble and sparingly soluble inorganic compounds to the high pressure side of said RO membrane;

e) blending the R01 membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds with a large fraction of the softened high TDS second stage RO membrane (R02) concentrate recycle stream producing a blended high TDS stream containing elevated sparingly soluble inorganic compounds;

f) introducing said blended high TDS stream containing said elevated sparingly soluble inorganic compounds into a well-mixed chemical precipitation tank wherein the pH is raised by adding an alkaline solution to provide a precipitate of the insoluble inorganic compounds;

g) removing the well-mixed suspension containing chemically-precipitated inorganic compounds from the chemical precipitation tank;

h) introducing the well-mixed suspension containing chemically-precipitated inorganic compounds into a clarifier to produce a supernatant solution at the top of the tank which is substantially (but not completely) free from suspended solids and a slurry phase at the bottom containing most of the suspended solids;

i) removing the bulk solids from the bottom of the clarifier as a small slurry reject stream containing high TDS in the range 1 % - 5% and high Total Suspended Solids (TSS) in the range 2% - 5%;

j) removing the supernatant from the top of the clarifier, containing high TDS in the range 1 % - 5% and low TSS in the range 50 - 250 mg/L;

k) reducing the pH of the supernatant removed from the top of the clarifier to a pH in the neutral range of 6 - 9 by adding a suitable mineral acid;

l) introducing the pH-adjusted supernatant from the clarifier into a suitable filtration means in order to provide a "blended, softened and suspended solids-free" concentrate stream;

m) introducing said "blended, softened and suspended solids-free" concentrate stream into a suitable ion exchange softening means to provide a "blended, softened, suspended solids-free and hardness-free" concentrate stream;

n) introducing said "blended, softened, suspended solids-free and hardness-free" concentrate into the high pressure side of a second stage RO membrane system (R02) and pressurizing said blended, softened, suspended solids-free and
hardness-free concentrate to produce purified water permeate on the low pressure side of said R02 membrane system that is substantially free of said inorganic compounds;

o) removing R02 membrane concentrate containing concentrated soluble and "under-saturated" sparingly soluble inorganic compounds from the high pressure side of said R02 membrane system without precipitation of said sparingly soluble inorganic compounds on the surface of the membrane;

p) recovering the remaining purified water permeate on the low pressure side of said R02 membrane system at a rate at least 5% and up to 50% of the rate of Influent Water;

q) combining the purified water permeate from said R01 membrane system with purified water from said R02 membrane system to provide the final purified water stream at a rate ranging from 67% - 99.9% of the rate of the Influent water;

r) splitting said R02 membrane concentrate into a large R02 membrane concentrate recycle stream which is recycled and blended with said R01 membrane concentrate, and a small R02 membrane reject stream;

s) Adjusting the fiowrates of said small slurry reject stream from the bottom of the clarifier and said small R02 membrane reject stream to control the concentration of soluble inorganic compounds and hence the osmotic pressure;

t) removing said small slurry reject stream and said small R02 membrane reject stream from the process as final rejects for disposal or further treatment.

In a second aspect, there is provided an improved enhanced two-stage high recovery membrane process for the economical operation of semi-permeable reverse osmosis (RO) membranes which are used to purify water containing soluble and elevated concentrations of sparingly soluble inorganic compounds and achieve high recoveries of purified water in the range 67% - 99.9% of the Influent Water without precipitation of sparingly soluble inorganic scale compounds on the surface of the membrane, as illustrated in Figure 3, comprising:

a) blending of the Influent Water, containing soluble and elevated levels of sparingly soluble inorganic compounds with first stage R01 membrane concentrate recycle stream to provide a blended Influent Water with elevated levels of sparingly soluble inorganic compounds;

b) introducing said blended Influent Water into a well-mixed chemical precipitation tank wherein the pH is raised by adding an alkaline solution to provide a precipitate of the insoluble inorganic compounds;

c) removing the well-mixed suspension containing chemically-precipitated inorganic compounds from the chemical precipitation tank;

d) introducing the well-mixed suspension containing chemically-precipitated inorganic compounds into a clarifier to produce a supernatant solution at the top of the tank which is substantially (but not completely) free from suspended solids and a slurry phase at the bottom containing most of the suspended solids;

e) removing the bulk solids from the bottom of the clarifier as a small slurry reject stream containing high TDS in the range 1% - 5% and high Total Suspended Solids (TSS) in the range 2% - 5%;

f) removing the supernatant from the top of the clarifier, containing high TDS in the range 1% - 5% and low TSS in the range 50 - 250 mg/L;

g) reducing the pH of the supernatant removed from the top of the clarifier to a pH in the neutral range of 6 - 9 by adding a suitable mineral acid;

h) introducing the pH-adjusted supernatant from the clarifier into a suitable filtration means in order to provide a softened and suspended solids-free Influent Water;

i) preconditioning of said softened and suspended solids-free Influent Water by adding acid and antiscalant to produce a preconditioned Influent Water;

j) introducing said preconditioned Influent Water into the high pressure side of a first stage RO membrane system (R01) and pressurizing said preconditioned Influent Water to produce purified water permeate on the low pressure side that is substantially free of said inorganic compounds;

k) removing first stage R01 membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds from the high pressure side of said R01 membrane system without precipitation of said preconcentrated sparingly soluble inorganic compounds on the R01 membrane;

l) recovering the bulk of purified water permeate on the low pressure side of the R01 membrane at a rate at least 50% of the rate of introducing said water containing soluble and sparingly soluble inorganic compounds to the high pressure side of said RO membrane;

m) splitting said R01 membrane concentrate into an R01 membrane concentrate recycle stream which is recycled and blended with said Influent Water and an R01 membrane concentrate stream for further softening and purified water recovery in the second stage membrane system (R02);

n) blending said R01 membrane concentrate with a large fraction of the softened high TDS second stage RO membrane (R02) concentrate recycle stream producing a blended high TDS stream containing elevated levels of sparingly soluble inorganic compounds;

o) introducing said blended, high TDS stream containing said elevated levels of sparingly soluble inorganic compounds into a suitable ion exchange softening means to provide a "blended, high TDS and hardness-free" concentrate stream;

p) introducing said "blended, high TDS and hardness-free" concentrate into the high pressure side of a second stage RO membrane system (R02) and pressurizing said blended, high TDS and hardness-free concentrate to produce purified water permeate on the low pressure side of said R02 membrane system that is substantially free of said inorganic compounds;

q) removing R02 membrane concentrate containing concentrated soluble and "under-saturated" sparingly soluble inorganic compounds from the high pressure side of said R02 membrane system without precipitation of said sparingly soluble inorganic compounds on the surface of the membrane;

r) recovering the remaining purified water permeate on the low pressure side of said R02 membrane system at a rate at least 5% and up to 50% of the rate of Influent Water;

s) combining the purified water permeate from said R01 membrane system with purified water permeate from said R02 membrane system to provide the final purified water stream at a rate ranging from 67% - 99.9% of the rate of the Influent water;

t) splitting said R02 membrane concentrate into a large R02 membrane concentrate recycle stream which is recycled and blended with said R01 membrane concentrate, and a small R02 membrane reject stream;

u) Adjusting the flowrate of said small R02 membrane reject stream to control the concentration of soluble inorganic compounds and hence the osmotic pressure;

v) removing said small slurry reject stream and said small R02 membrane reject stream from the process as final rejects for disposal or further treatment.

In a third aspect, there is provided an improved enhanced two-stage high recovery membrane process for the economical operation of semi-permeable reverse osmosis (RO) membranes which are used to purify water containing soluble and low concentrations of sparingly soluble inorganic compounds and achieve high recoveries of purified water in the range 67% - 99.9% of the Influent Water without precipitation of sparingly soluble inorganic scale compounds on the surface of the membrane, as illustrated in Figure 5, comprising:

a) pretreatment of the Influent Water, containing soluble and low concentrations of sparingly soluble inorganic compounds by filtration to separate suspended solids using a suitable filtration means and preconditioning by adding acid and antiscalant to produce a preconditioned Influent Water;

b) introducing said preconditioned Influent Water into the high pressure side of a first stage RO membrane system (R01 ) and pressurizing said preconditioned
Influent Water to produce purified water permeate on the low pressure side that is substantially free of said inorganic compounds;

c) removing first stage R01 membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds from the high pressure side of said R01 membrane system without precipitation of said preconcentrated sparingly soluble inorganic compounds on the R01 membrane;

d) recovering the bulk of purified water permeate on the low pressure side of the R01 membrane at a rate at least 50% of the rate of introducing said water containing soluble and sparingly soluble inorganic compounds to the high pressure side of said RO membrane;

e) blending said R01 membrane concentrate with a large fraction of the softened high TDS second stage RO membrane (R02) concentrate recycle stream producing a blended high TDS stream containing elevated levels of sparingly soluble inorganic compounds;

f) introducing said blended, high TDS stream containing said elevated levels of sparingly soluble inorganic compounds into a suitable ion exchange softening means to provide a "blended, high TDS and hardness-free" concentrate stream;

g) introducing said "blended, high TDS and hardness-free" concentrate into the high pressure side of a second stage RO membrane system (R02) and pressurizing said blended, high TDS and hardness-free concentrate to produce purified water permeate on the low pressure side of said R02 membrane system that is substantially free of said inorganic compounds;

h) removing R02 membrane concentrate containing concentrated soluble and "under-saturated" sparingly soluble inorganic compounds from the high pressure side of said R02 membrane system without precipitation of said sparingly soluble inorganic compounds on the surface of the membrane;

i) recovering the remaining purified water permeate on the low pressure side of said R02 membrane system at a rate at least 5% and up to 50% of the rate of Influent Water;

j) combining the purified water permeate from said R01 membrane system with purified water permeate from said R02 membrane system to provide the final purified water stream at a rate ranging from 67% - 99.9% of the rate of the Influent water;

k) splitting said R02 membrane concentrate into a large R02 membrane concentrate recycle stream which is recycled and blended with said R01 membrane concentrate, and a small R02 membrane reject stream;

l) Adjusting the flowrate of said small R02 membrane reject stream to control the concentration of soluble inorganic compounds and hence the osmotic pressure;

m) removing said small R02 membrane reject stream from the process as final rejects for disposal or further treatment.

In a fourth aspect, there is provided an improved enhanced two-stage high recovery membrane process for the economical operation of semi-permeable reverse osmosis (RO) membranes which are used to purify water containing soluble and sparingly soluble inorganic compounds and achieve high recoveries of purified water in the range 67% - 99.9% of the Influent Water without precipitation of sparingly soluble inorganic scale compounds on the surface of the membrane, as illustrated in Figure 7, comprising:

a) pretreatment of the Influent Water, containing soluble and sparingly soluble inorganic compounds by filtration to separate suspended solids using a suitable filtration means and preconditioning by adding acid and antiscalant to produce a preconditioned Influent Water;

b) introducing said preconditioned Influent Water into the high pressure side of a first stage RO membrane system (R01 ) and pressurizing said preconditioned Influent Water to produce purified water permeate on the low pressure side that is substantially free of said inorganic compounds;

c) removing first stage R01 membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds from the high pressure side of said R01 membrane system without precipitation of said preconcentrated sparingly soluble inorganic compounds on the R01 membrane;

d) recovering the bulk of purified water permeate on the low pressure side of the R01 membrane at a rate at least 50% of the rate of introducing said water containing soluble and sparingly soluble inorganic compounds to the high pressure side of said RO membrane;

e) blending the R01 membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds with the high TDS, hardness-free R02 concentrate recycle stream, producing a blended high TDS stream containing reduced concentrations of sparingly soluble inorganic compounds;

f) introducing said blended high TDS stream containing said reduced concentrations of said sparingly soluble inorganic compounds into the high pressure side of a second stage RO membrane system (R02) and pressurizing said blended, high TDS stream to produce purified water permeate on the low pressure side of said R02 membrane system that is substantially free of said inorganic compounds;

g) removing R02 membrane concentrate containing concentrated soluble and "under-saturated" sparingly soluble inorganic compounds from the high pressure side of said R02 membrane system without precipitation of said sparingly soluble inorganic compounds on the surface of the membrane;
h) recovering the remaining purified water permeate on the low pressure side of said R02 membrane system at a rate at least 5% and up to 50% of the rate of Influent Water;

i) combining the purified water permeate from said R01 membrane system with purified water from said R02 membrane system to provide the final purified water stream at a rate ranging from 67% - 99.9% of the rate of the Influent water;

j) splitting said R02 membrane concentrate into a large R02 membrane concentrate recycle stream which is recycled after softening, and a small R02 membrane reject stream;

k) introducing said R02 membrane concentrate recycle stream into a well-mixed chemical precipitation tank wherein the pH is raised by adding an alkaline solution to provide a precipitate of the insoluble inorganic compounds;

l) removing the well-mixed suspension containing chemically-precipitated inorganic compounds from the chemical precipitation tank;

m) introducing the well-mixed suspension containing chemically-precipitated inorganic compounds into a clarifier to produce a supernatant solution at the top of the tank which is substantially (but not completely) free from suspended solids and a slurry phase at the bottom containing most of the suspended solids;

n) removing the bulk solids from the bottom of the clarifier as a small slurry reject stream containing high TDS in the range 3% - 10% and high Total Suspended Solids (TSS) in the range 2% - 5%;

o) removing the supernatant from the top of the clarifier, containing high TDS in the range 3% - 10% and low TSS in the range 50 - 250 mg/L;

p) reducing the pH of the supernatant removed from the top of the clarifier to a pH in the neutral range of 6 - 9 by adding a suitable mineral acid;

q) introducing the pH-adjusted supernatant from the clarifier into a suitable filtration means in order to provide a "high TDS, chemically softened and suspended solids-free" R02 concentrate stream;

r) introducing said "high TDS, chemically softened and suspended solids-free" R02 concentrate stream into a suitable ion exchange softening means to provide a "high TDS, hardness-free" R02 concentrate recycle stream which is recycled and blended with said R01 membrane concentrate, as described earlier;
s) adjusting the flowrates of said small slurry reject stream from the bottom of the clarifier and said small R02 membrane reject stream to control the concentration of soluble inorganic compounds and hence the osmotic pressure;

t) removing said small slurry reject stream and said small R02 membrane reject stream from the process as final rejects for disposal or further treatment.

In a fifth aspect, there is provided an improved enhanced two-stage high recovery membrane process for the economical operation of semi-permeable reverse osmosis (RO) membranes which are used to purify water containing soluble and sparingly soluble inorganic compounds and achieve high recoveries of purified water in the range 67% - 99.9% of the Influent Water without precipitation of sparingly soluble inorganic scale compounds on the surface of the membrane, as illustrated in Figure 9, comprising:

a) pretreatment of the Influent Water, containing soluble and sparingly soluble inorganic compounds by filtration to separate suspended solids using a suitable filtration means and preconditioning by adding acid and antiscalant to produce a preconditioned Influent Water;

b) introducing said preconditioned Influent Water into the high pressure side of a first stage RO membrane system (R01 ) and pressurizing said preconditioned Influent Water to produce purified water permeate on the low pressure side that is substantially free of said inorganic compounds;

c) removing first stage R01 membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds from the high pressure side of said R01 membrane system without precipitation of said preconcentrated sparingly soluble inorganic compounds on the R01 membrane;

d) recovering the bulk of purified water permeate on the low pressure side of the R01 membrane at a rate at least 50% of the rate of introducing said water containing soluble and sparingly soluble inorganic compounds to the high pressure side of said RO membrane;

e) blending said R01 membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds with the high TDS, hardness-free and silica-free R02 membrane concentrate recycle stream, producing a blended high TDS stream containing reduced concentrations of sparingly soluble inorganic compounds;

f) introducing said blended high TDS stream containing said reduced concentrations of said sparingly soluble inorganic compounds into the high pressure side of a second stage RO membrane system (R02) and pressurizing said blended, high TDS stream to produce purified water permeate on the low pressure side of said R02 membrane system that is substantially free of said inorganic compounds;
g) removing R02 membrane concentrate containing concentrated soluble and "under-saturated" sparingly soluble inorganic compounds from the high pressure side of said R02 membrane system without precipitation of said sparingly soluble inorganic compounds on the surface of the membrane;

h) recovering the remaining purified water permeate on the low pressure side of said R02 membrane system at a rate at least 5% and up to 50% of the rate of Influent Water;

i) combining the purified water permeate from said R01 membrane system with purified water from said R02 membrane system to provide the final purified water stream at a rate ranging from 67% - 99.9% of the rate of the Influent water;

j) splitting said R02 membrane concentrate into a large R02 membrane concentrate recycle stream which is recycled after softening, and a small R02 membrane reject stream;

k) introducing said R02 membrane concentrate recycle stream into a suitable ion exchange softening means to provide a "high TDS, hardness-free" R02 concentrate recycle stream;

l) introducing said "high TDS, hardness-free" R02 concentrate recycle stream from said ion exchange softening means into a silica sequestering unit (SSU) containing granualr activated alumina or other selective silica removing material to produce a "high TDS, hardness-free and silica-free" R02 concentrate recycle stream which is recycled and blended with said R01 membrane concentrate, as described earlier;

m) adjusting the flowrates of said small R02 membrane reject stream to control the concentration of soluble inorganic compounds and hence the osmotic pressure;

n) removing said small R02 membrane reject stream from the process as final rejects for disposal or further treatment.

In a sixth aspect, there is provided an improved enhanced single stage high recovery membrane process for the economical operation of semi-permeable reverse osmosis (RO) membranes which are used to purify water containing soluble and sparingly soluble inorganic compounds and achieve high recoveries of purified water in the range 67% - 99.9% of the Influent Water without precipitation of sparingly soluble inorganic scale compounds on the surface of the membrane, as illustrated in Figure 10, comprising:

a) pretreatment of the Influent Water, containing soluble and sparingly soluble inorganic compounds by filtration to separate suspended solids using a suitable filtration means and preconditioning by adding acid and antiscalant to produce a preconditioned Influent Water;
b) blending said preconditioned Influent Water with suspended solids-free, high TDS and hardness-free RO membrane concentrate recycle stream to provide a blended stream containing elevated TDS and reduced concentration of hardness and silica;

c) introducing said blended stream containing said elevated TDS and said reduced concentration of hardness and silica into the high pressure side of the reverse osmosis (RO) membrane system and pressurizing said blended stream containing said elevated TDS to produce purified water permeate on the low pressure side of said RO membrane system that is substantially free of said inorganic compounds;

d) removing high TDS RO membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds from the high pressure side of said RO membrane system without precipitation of said preconcentrated sparingly soluble inorganic compounds on said RO membrane;

e) recovering purified water permeate on the low pressure side of said RO membrane at a rate ranging from 67% - 99.9% of the rate of the Influent water;

f) splitting said high TDS RO membrane concentrate into a large RO membrane concentrate recycle stream and a small RO membrane reject stream;

g) introducing said large RO membrane concentrate recycle stream containing elevated concentrations of sparingly soluble inorganic compounds into a well- mixed chemical precipitation tank wherein the pH is raised by adding an alkaline solution to provide a precipitate of the insoluble inorganic compounds;

h) removing the well-mixed suspension containing chemically-precipitated inorganic compounds from said chemical precipitation tank;

i) introducing said well-mixed suspension containing said chemically-precipitated inorganic compounds into a clarifier to produce a supernatant solution at the top of the tank which is substantially (but not completely) free from suspended solids and a slurry phase at the bottom containing most of the suspended solids;

j) removing the bulk solids from the bottom of the clarifier as a small slurry reject stream containing high TDS in the range 3% - 10% and high Total Suspended Solids (TSS) in the range 2% - 5%;

k) removing the supernatant from the top of the clarifier, containing high TDS in the range 3% - 10% and low TSS in the range 50 - 250 mg/L;

l) reducing the pH of the supernatant removed from the top of the clarifier to a pH in the neutral range of 6 - 9 by adding a suitable mineral acid;

m) introducing the pH-adjusted supernatant from the clarifier into a suitable filtration means in order to provide a "high TDS, softened and suspended solids-free" O membrane concentrate recycle stream;

n) introducing said "high TDS, softened and suspended solids-free" RO membrane concentrate recycle stream into a suitable ion exchange softening means to provide a "high TDS, hardness-free" RO membrane concentrate recycle stream;

o) Adjusting the flowrates of said small slurry reject stream from the bottom of the clarifier and said small RO membrane reject stream to control the concentration of soluble inorganic compounds and hence the osmotic pressure;

p) removing said small slurry reject stream and said small RO membrane reject stream from the process as final rejects for disposal or further treatment.

In a seventh aspect, there is provided an improved enhanced single stage high recovery membrane process for the economical operation of semi-permeable reverse osmosis (RO) membranes which are used to purify water containing soluble and sparingly soluble inorganic compounds and achieve high recoveries of purified water in the range 67% - 99.9% of the Influent Water without precipitation of sparingly soluble inorganic scale
compounds on the surface of the membrane, as illustrated in Figure 12, comprising:

a) pretreatment of the Influent Water, containing soluble and sparingly soluble inorganic compounds by filtration to separate suspended solids using a suitable filtration means and preconditioning by adding acid and antiscalant to produce a preconditioned Influent Water;

b) blending said preconditioned Influent Water with said high TDS, hardness-free and silica-free RO membrane concentrate recycle stream to provide a blended stream containing elevated TDS and reduced concentration of hardness and silica;

c) introducing said blended stream containing said elevated TDS and said reduced concentration of hardness and silica into the high pressure side of the reverse osmosis (RO) membrane system and pressurizing said blended stream containing said elevated TDS to produce purified water permeate on the low pressure side of said RO membrane system that is substantially free of said inorganic compounds;

d) removing high TDS RO membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds from the high pressure side of said RO membrane system without precipitation of said preconcentrated sparingly soluble inorganic compounds on said RO membrane;

e) recovering purified water permeate on the low pressure side of said RO membrane at a rate ranging from 67% - 99.9% of the rate of the Influent water;

f) splitting said high TDS RO membrane concentrate into a large RO membrane concentrate recycle stream and a small RO membrane reject stream;

g) introducing said large RO membrane concentrate recycle stream containing elevated concentrations of sparingly soluble inorganic compounds into a suitable ion exchange softening means to provide a "high TDS, hardness-free" RO membrane concentrate recycle stream;

h) introducing said "high TDS, hardness-free" RO membrane concentrate recycle stream from said ion exchange softening means into a silica sequestering unit (SSU) containing granular activated alumina or other selective silica removing material to produce a "high TDS, hardness-free and silica-free" RO membrane concentrate recycle stream;

i) Adjusting the flowrate of said small RO membrane reject stream to control the concentration of soluble inorganic compounds and hence the osmotic pressure;

j) removing said small RO membrane reject stream from the process as final rejects for disposal or further treatment.

In an eighth aspect, there is provided an improved enhanced single stage high recovery membrane process for the economical operation of semi-permeable reverse osmosis (RO) membranes which are used to purify water containing soluble and elevated concentrations of sparingly soluble inorganic compounds and achieve high recoveries of purified water in the range 67% - 99.9% of the Influent Water without precipitation of sparingly soluble inorganic scale compounds on the surface of the membrane, as illustrated in Figure 13, comprising:

a) pretreatment of the Influent Water, containing soluble and sparingly soluble inorganic compounds, soluble organic compounds and oil by using a suitable oil separation means, aeration and secondary treatment to biologically degrade the soluble organic compounds and prevent biological fouling of the membranes downstream;

b) blending of the pretreated Influent Water, containing soluble and elevated levels of sparingly soluble inorganic compounds and free from oil and soluble organic compounds, with high TDS RO membrane concentrate recycle stream to provide a blended pretreated Influent Water with elevated levels of sparingly soluble inorganic compounds;

c) introducing said blended pretreated Influent Water into a well-mixed chemical precipitation tank wherein the pH is raised by adding an alkaline solution to provide a precipitate of the insoluble inorganic compounds;

d) removing the well-mixed suspension containing chemically-precipitated inorganic compounds from the chemical precipitation tank;

e) introducing the well-mixed suspension containing chemically-precipitated inorganic compounds into a clarifier to produce a supernatant solution at the top of the tank which is substantially (but not completely) free from suspended solids and a slurry phase at the bottom containing most of the suspended solids;

f) removing the bulk solids from the bottom of the clarifier as a small slurry reject stream containing high TDS in the range 3% - 10% and high Total Suspended Solids (TSS) in the range 2% - 5%;

g) removing the supernatant from the top of the clarifier, containing high TDS in the range 3% - 10% and low TSS in the range 50 - 250 mg/L;

h) reducing the pH of the supernatant removed from the top of the clarifier to a pH in the neutral range of 6 - 9 by adding a suitable mineral acid;

i) introducing the pH-adjusted supernatant from the clarifier into a suitable filtration means in order to provide a softened and suspended solids-free blended Influent Water;

j) preconditioning of said softened and suspended solids-free blended Influent Water by adding acid and antiscalant to produce a preconditioned, softened and suspended solids-free blended Influent Water;

k) introducing said preconditioned, softened and suspended solids-free blended Influent Water into a suitable ion exchange softening means to provide a blended, preconditioned, hardness-free Influent Water;

I) introducing said blended, preconditioned, hardness-free Influent Water into the high pressure side of the single stage reverse osmosis (RO) membrane system
and pressurizing said blended, preconditioned, hardness-free Influent Water to produce purified water permeate on the low pressure side that is substantially free of said inorganic compounds;
m) removing RO membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds from the high pressure side of said RO membrane system without precipitation of said preconcentrated sparingly soluble inorganic compounds on the RO membranes;

n) recovering purified water permeate on the low pressure side of said RO membrane system at a rate ranging from 67% - 99.9% of the rate of the Influent water;

o) splitting said RO membrane concentrate into a large RO membrane concentrate recycle stream which is recycled and blended with said pretreated Influent Water and a small RO membrane reject stream;

p) Adjusting the flowrates of said small slurry reject stream from the bottom of the clarifier and said small RO membrane reject stream to control the concentration of soluble inorganic compounds and hence the osmotic pressure;

q) removing said small slurry reject stream and said small RO membrane reject stream from the process as final rejects for disposal or further treatment.

In a ninth aspect, there is provided an improved enhanced single stage high recovery membrane process for the economical operation of semi-permeable reverse osmosis (RO) membranes which are used to purify water containing soluble and elevated concentrations of sparingly soluble inorganic compounds and achieve high recoveries of purified water in the range 67% - 99.9% of the Influent Water without precipitation of sparingly soluble inorganic scale compounds on the surface of the membrane, as illustrated in Figure 15, comprising:

a) pretreatment of the Influent Water, containing soluble and sparingly soluble inorganic compounds, soluble organic compounds and oil by using a suitable oil separation means, aeration, secondary treatment to biologically degrade the soluble organic compounds and prevent biological fouling of the membranes downstream, filtration to separate suspended solids using a suitable filtration means and preconditioning by adding acid and antiscalant to produce a preconditioned Influent Water;

b) blending of the preconditioned Influent Water, containing soluble and elevated levels of sparingly soluble inorganic compounds and free from oil and soluble organic compounds, with high TDS RO membrane concentrate recycle stream to provide a blended preconditioned Influent Water with elevated levels of sparingly soluble inorganic compounds;

c) introducing said blended preconditioned Influent Water into a suitable ion exchange softening means to provide a blended, preconditioned, hardness-free Influent Water;

d) introducing said blended, preconditioned, hardness-free Influent Water from said ion exchange softening means into a silica sequestering unit (SSU) containing granualr activated alumina or other selective silica removing material to produce a "blended, preconditioned, hardness-free and silica-free" Influent Water

e) introducing said blended, preconditioned, hardness-free and silica-free Influent Water into the high pressure side of the single stage reverse osmosis (RO) membrane system and pressurizing said blended, preconditioned, hardness-free and silica-free Influent Water to produce purified water permeate on the low pressure side that is substantially free of said inorganic compounds;

f) removing RO membrane concentrate containing preconcentrated soluble and sparingly soluble inorganic compounds from the high pressure side of said RO membrane system without precipitation of said preconcentrated sparingly soluble inorganic compounds on the RO membranes;

g) recovering purified water permeate on the low pressure side of said RO membrane system at a rate ranging from 67% - 99.9% of the rate of the Influent water;

h) splitting said RO membrane concentrate into a large RO membrane concentrate recycle stream which is recycled and blended with said preconditioned Influent Water and a small RO membrane reject stream;

i) Adjusting the flowrates of said small RO membrane reject stream to control the concentration of soluble inorganic compounds and hence the osmotic pressure;

j) removing said small RO membrane reject stream from the process as final rejects for disposal or further treatment.

In accordance with these objects, there is provided an improved membrane process for the treatment of water from natural sources or wastewater containing "sparingly soluble" inorganic scale-forming compounds wherein very high permeate recoveries in the range 67% - 99.9% are achieved in a reliable and consistent manner. The Influent Water, containing the inorganic scale-forming compounds as well as completely soluble inorganic and low concentrations of organic compounds is first pre-treated in order to separate virtually all of the suspended matter including oil and grease by using an oil separation device, followed by chemical coagulation, flocculation,

clarification and/or gravity settling, and multi-media filtration. Alternatively, the Influent Water is pre-filtered using micro-media (i.e. fine particle) filtration, micro-filtration membranes or ultra-filtration membranes to effectively separate all of the suspended solids and colloidal matter. If iron is also present in the Influent Water, the water must be aerated using appropriate in-tank air spargers before coagulation, flocculation and/or filtration.

The pre-treated Influent Water in the present ~~invention~~disclosure is purified by a 2-stage or single stage membrane system operating at suitable pressures depending on the concentration of soluble compounds in the Influent Water and the desired overall permeate recovery. In order to prevent formation of scale compounds on the membranes, the membrane concentrate (also known as retentate) is softened by adding a suitable alkali compound to raise the pH and precipitate the sparingly-soluble hardness compounds, followed by coagulating, flocculating and removing said precipitated compounds in a clarifier or settling tank.

The chemically softened membrane concentrate is further softened by using ion exchange (IX) water softening resins, silica sequestering media or a combination of both to ensure almost complete removal of residual cationic scale precursors (i.e. calcium, maagnesium, barium, iron, aluminum, amongst other sparingly soluble multi-valent ions) which will otherwise cause scale formation on the membranes and reduce the process reliability and its ability to consistently achieve the desired permeate recoveries in the range 67% to 99.9%. The completely softened membrane concentrate will contain a high concentration of soluble ions, also known as the total dissolved solids (TDS). The softened membrane concentrate is recycled and blended with the Influent Water in the case of the single-stage process, or blended with the first stage membrane concentrate in the case of the 2-stage pocess to undergo further purification. A small volume of concentrate is removed from the system upstream from the IX water softening resin, combined with a small slurry reject stream from the bottom of the clarifier and disposed of as an overall process reject stream, in order to control the membrane's osmotic pressure, prevent precipitation and control the overall membrane system's permeate recovery in the range 67% - 99.9%.