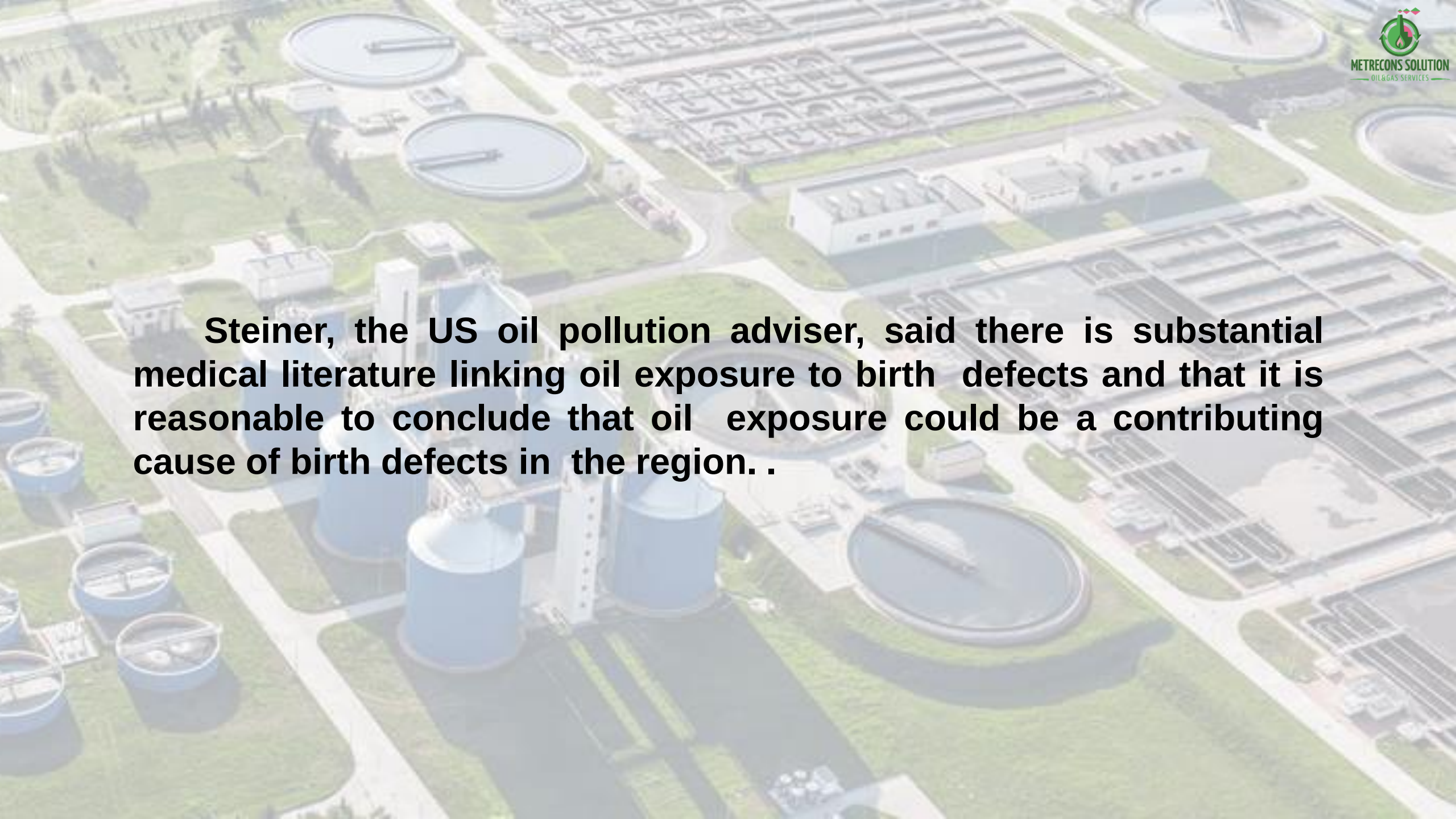
Produced water from oil extraction

Using Innovation To Meet The Water Needs



Steiner, the US oil pollution adviser, said there is substantial medical literature linking oil exposure to birth defects and that it is reasonable to conclude that oil exposure could be a contributing cause of birth defects in the region. .

Produced water from oil extraction

Some of the typical PW constituents are salts (expressed as salinity, total dissolved solids (TDS), or electrical conductivity), oil and grease, BTEX (benzene, toluene, ethylbenzene, and xylenes), PAHs (polycyclic aromatic hydrocarbons), organic acids, and phenols. In addition, chemical additives can be found that come from drilling, fracturing, or from operating the well.

Oil and fat concentrations in PW can range from 2 to 565 $mg \cdot L^{-1}$.

In general, PW discharges from offshore oil and gas platforms are a significant source of polycyclic aromatic hydrocarbons (PAHs) released into the ocean.

Produced water compositions range based on different oil production fields around the world

Parameter	Range of values (based on comparison worldwide)
pH	4.3 – 7.45
BOD (mg/L)	750 – 957
COD (mg/L)	1220 – 1910
TOC (mg/L)	491 - 1700
TN (mg/L)	34 - 647
TKN (mg/L)	83 - 155
BTEX (mg/L)	12.415 – 83.611
Phenol (mg/L)	11.5045 – 1000.001
Oil and grease (mg/L)	40.5 - 654
TSS (mg/L)	500.6 - 7820
TPH (mg/L)	45.00
Conductivity (µS/cm)	7200 – 87, 542
TDS (mg/L)	5189 – 400,000
Salinity (mg/L)	7165 – 100,000
Chloride (mg/L)	2265 – 250,000
Sodium (mg/L)	1030 – 150,000
Calcium (mg/L)	329 – 74,000
Sulfide (mg/L)	828.00
Magnesium (mg/L)	4.7943 – 12,341
Bromide (mg/L)	51.00
Bicarbonate (mg/L)	144.4176 – 15,000
Sulfate (mg/L)	54 – 15,000
Potassium (mg/L)	44 - 2162
Thiosulfate (mg/L)	14.00
Acetate (mg/L)	347.00
Ammonium (mg/L)	11 – 14.54
Ammonia (mg/L)	9.66 - 74
Nitrate (mg/L)	2.15 – 9.492
Nitrite (mg/L)	0.05
Total phosphorous (mg/L)	0.71

Concentrations of different metals in produced water based on oil production fields around the world

Metal	Concentrations range (mg/L)
Barium	0.058 - 850
Strontium	500.01 - 6250
Cadmium	0.0105 – 26.2
Chromium	0.1963 – 97.2
Copper	0.0613 - 89
Lead	0.1340 – 205.8
Nickel	0.0977 - 162
Zinc	0.255 – 113.4
Iron	0.7133 – 550.05
Manganese	0.0713 – 87.502
Arsenic	0.1525 – 5.2387
Boron	1.8873 - 50
Tin	0.68
Aluminum	205.2 - 360
Lithium	26.5 – 32.019
Titanium	0.36
Mercury	0.0015

Discharge limit according to the European standard
NTPA 001 - discharge into the river

Nr. crt.	Parameters	U.M.	Maxim accepted limits
Physical indicators			
1	Temperature	^0C	35
Chinical indicators			
2	pH	unitati pH	6,5-8,5
3	Suspended matter (MS)	mg/dm^3	35,0 (60,0)
4	BOD	$mg\ O2/dm^3$	20-25,0
5	COD	$mg\ O_2/dm^3$	70-125,0
6	(NH4+)	mg/dm^3	2,0 (3,0)
7	Total nitrogen (N)	mg/dm^3	10,0 (15,0)
8	(NO3)	mg/dm^3	25,0 (37,0)
9	$(NO2^-)$	mg/dm^3	1 (2,0)
10	Sulfur and hydrogen (S)	mg/dm^3	0,5
11	$(SO3^{2-})$	mg/dm^3	1,0
12	$(SO4^{2-})$	mg/dm^3	600,0
13	Fenols with water vapor (C6H5OH)	mg/dm^3	0,3
14	Extractable substrates with organic	mg/dm^3	20,0
15	Solvents Petroleum products	mg/dm^3	5,0
16	Total phosphorus	mg/dm^3	1,0 (2,0)
17	Synthetic detergents	mg/dm^3	0,5
18	Total cyanide (CN)	mg/dm^3	0,1
19	Free residual chlorine (Cl_2)	mg/dm^3	0,2

Nr. crt.	Parameters	U.M.	Maxim accepted limits
20	(Ca^{2+})	mg/dm^3	300,0
21	Fluoride (F^-)	mg/dm^3	5,0
22	Residue filtered at 105^0C	mg/dm^3	2.000,0
23	(As^+)	mg/dm^3	0,1
24	(Al^{3+})	mg/dm^3	5,0
25	Chloride(Cl^-)	mg/dm^3	500,0
26	(Pb^{2+})	mg/dm^3	0,2
27	(Cd^{2+})	mg/dm^3	0,2
28	$(Cr^{3+} + Cr^{6+})$	mg/dm^3	1,0
29	(Cr^{6+})	mg/dm^3	0,1
30	(Fe^{2+}, Fe^{3+})	mg/dm^3	5,0
31	(Cu^{2+})	mg/dm^3	0,1
32	(Ni^{2+})	mg/dm^3	0,5
33	(Zn^{2+})	mg/dm^3	0,5
34	(Hg^{2+})	mg/dm^3	0,05
35	(Ag^+)	mg/dm^3	0,1
36	(Mo^{2+})	mg/dm^3	0,1
37	(Se^{2+})	mg/dm^3	0,1
38	(Mn)	mg/dm^3	1,0
39	(Mg^{2+})	mg/dm^3	100,0
40	(Co^{2+})	mg/dm^3	1,0

Water reintroduction limit in the ground according to the European standard

Parameter	EU standards
pH (pH units)	6.5 – 9.5
EC (mS/cm)	2500
Turbidity	5 - 10
Aluminium (mg/l)	0.200
Ammonia/ammonium (mg/l)	0.50
Cadmium (mg/l)	0.0050
Chromium (mg/l)	0.050
Copper (mg/l)	2.0
Iron (mg/l)	0.200
Lead (mg/l)	0.010
Manganese (mg/l)	0.050
Nickel (mg/l)	0.020
Chloride (mg/l)	250
Nitrite (mg/l)	0.50
Sulfate (mg/l)	250
CaCO3 (mg/l)	300-600
Residual free Chlorine (mg/l)	0.200
Calcium (mg/l)	75 - 200
Nitrate (mg/l)	50
Fluoride (mg/l)	1.0 – 1.5
Mercury (mg/l)	0.001

Parameter	EU standards
Selenium (mg/l)	0.01
Arsenic (mg/l)	0.05
Cyanide (mg/l)	0.05
Zinc (mg/l)	5 - 15
Mineral oil (mg/l)	0.01 – 0.03
Pesticides (mg/l)	Absent – 0.001
Radioactive materials	Absent
Alkalinity (mg/l)	200 - 600
Boron (mg/l)	1 - 5
Colour (Hazen units)	5 - 25
Chlorides (mg/l)	250 - 1000
Nitrate (mg/l)	50
Phenolic compounds (mg/l)	0.001 – 0.002
Escherichia coli (E. coli)	Absent
Enterococci	Absent
Pseudomonas aeruginosa	Absent
Benzene (ug/l)	1
Tetrachloroethene and Trichloroethene (ug/l)	10
Trihalomethanes (ug/l)	100
Antimony (ug/l)	5

Pilot station to confirm the treatment solution

- Each project must have a customized solution.
- The proposed solution will be verified with the help of a pile station that will contain all the stages of the technological flow.
- The advantage of the pilot station is that it offers a wide range of adjustments as well as a high degree of adaptability.
- In this way, the final flow will be established in relation to the quality of the treated water and the operating cost.

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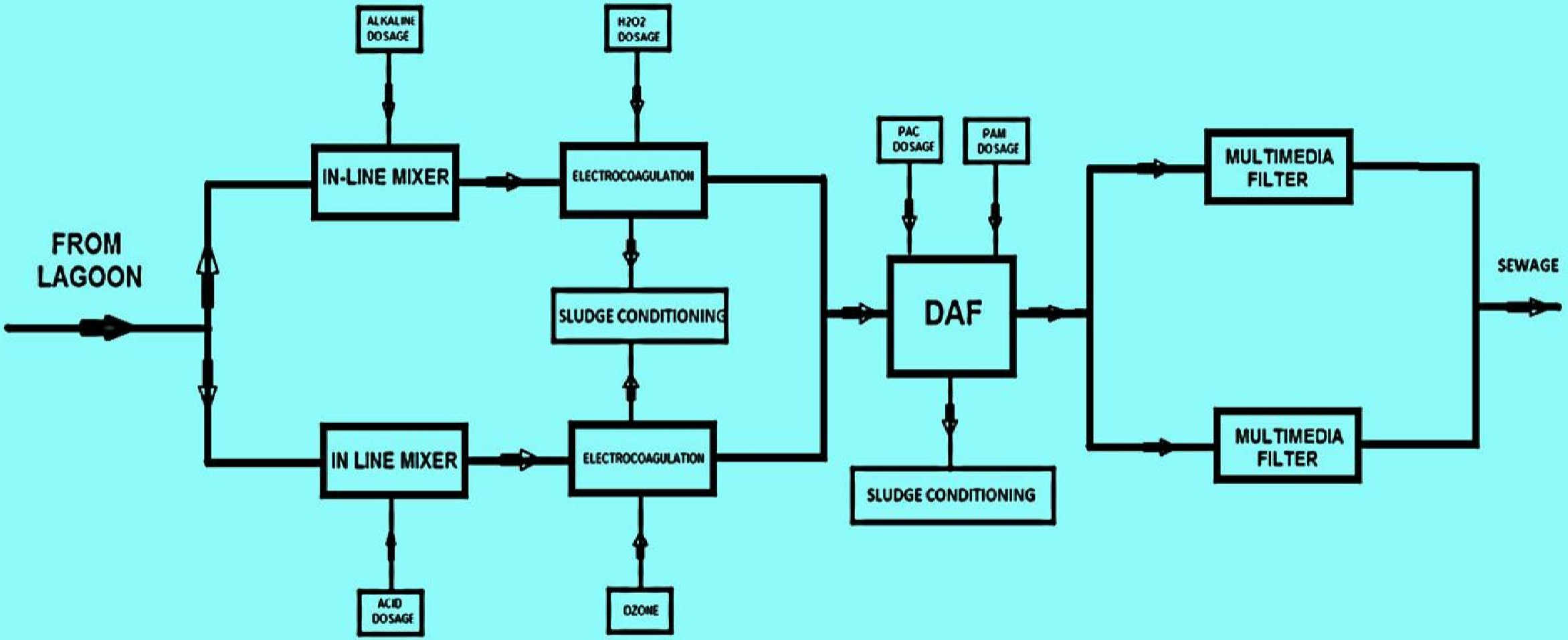

PUMP TREAT RE-INJECT FACIY PROCESS BLOCK FLOW DIAGRAM

AQUIFER-1/2 PRODUCTION WELLS | WATER STORAGE TANKS (A/B) | SAND FILTER UNIT NOTE 9 | ACTIVATED CARBON FILTER UNIT NOTE 9 | WATER HOLDING TANKS (A/B) | RO FEED PUMPS (A/B) | REVERSE OSMOSIS UNIT NOTE 9 | TREATED WATER TANKS (A/B)

INJECTION PUMPS (A/B) AQUIFER-1 | INJECTION PUMPS (A/B) AQUIFER-2 | INJECTION WELLS | BACKWASH SOLID/WATER SEPARATION UNIT | DISPOSAL DEEP WELL NOTE 5 | CIP SKID NOTE 20

NOTE 12 SODIUM HYDROXIDE/PH DOSING SYSTEM | NOTE 8 SODIUM HYPOCHLORITE SYSTEM | NOTE 6 FLOCCULANT DOSING SYSTEM

WELL PUMP A — AQUIFER-1 PRODUCTION WELL

WELL PUMP B — AQUIFER-2 PRODUCTION WELL

NOTE 2 → WATER STORAGE TANKS (A/B)

SAND FILTER UNIT NOTE 19: PUMPS (A/B) → SAND FILTERS (A/B) ↔ BACKWASH PUMP

ACTIVATED CARBON FILTER UNIT NOTE 19: PUMPS (A/B) → ACTIVATED CARBON FILTERS (A/B/C) ↔ BACKWASH PUMP

WATER HOLDING TANKS (A/B) → NOTE 3 → RO FEED PUMPS (A/B)

BACK WASH WATER + RINSING WATER + DRAIN WATER

BACKWASH SOLID/WATER SEPARATION UNIT NOTE 19: BACKWASH SOLID/WATER SEPARATOR → DISPOSAL PUMPS (A/B) → NOTE 14A CARTRIDGE FILTER (A/B) → DISPOSAL DEEP WELL NOTE 5

SLUDGE DISPOSAL BY ROAD TANKER

MAKEUP WATER BY ROAD TANKER 138m3/Day NOTE 18

NOTE 17 ~100 m NOTE 7 → WATER INJECTION PUMPS (A/B) AQUIFER-1 ← TREATED WATER TANK ← NOTE 4

TREATED WATER TANK → WATER INJECTION PUMPS (A/B) AQUIFER-2

INJECTION WELL-1 NOTE 11 | INJECTION WELL-2 NOTE 11 | INJECTION WELL-3 NOTE 11 | INJECTION WELL-4 NOTE 11 | INJECTION WELL-5 NOTE 11 — AQUIFER-2

NOTE 10 ~100 m NOTE 7

INJECTION WELL-1 NOTE 10 | INJECTION WELL-2 NOTE 10 | INJECTION WELL-3 NOTE 10 | INJECTION WELL-4 NOTE 10 | INJECTION WELL-5 NOTE 10 — AQUIFER-1

REVERSE OSMOSIS UNIT NOTE 19

NOTE 21 → HP BOOSTER PUMPS (A/B) → STAGE-III RO MEMBRANE → STAGE-II RO MEMBRANES → STAGE-I RO MEMBRANES

RO FEED PUMPS (A/B) → DIP NOTE 1 → ANTI-SCALANT DOSING SYSTEM | SULPHURIC ACID DOSING SYSTEM | SODIUM BI-SULFITE DOSING SYSTEM NOTE 22 → CARTRIDGE FILTERS (A/B) NOTE 9 → HIGH PRESSURE PUMPS (A/B)

CIP SKID NOTE 20: CIP TANK → CIP PUMP

UTILITIES / AUXILIARY SYSTEMS: DIESEL FUEL SYSTEM | POWER GENERATION SYSTEM | FIRE FIGHTING SYSTEM | FMS SYSTEM | CHEMICAL INJECTION SYSTEMS

NOTES

1. SINGLE UNIT DRP ANALYZER SHALL ALSO MONITOR THE FREE CHLORINE, PH, CONDUCTIVITY, TURBIDITY, TEMPERATURE AND FLOW RATE ETC.
2. INLET WATER QUALITY PARAMETERS ARE GIVEN BELOW:
   - TURBIDITY = 30 NTU (TO BE CONFIRMED)
   - PH = 7-7.5
   - SDI ≤ 5 (TO BE CONFIRMED)
   - TDS = 5900 mg/l
   - TPH = 0.48 mg/l (TO BE CONFIRMED)
   - FE = 9.35 mg/l
   - Mn = 9.5 mg/l
3. THE REQUIRED RO PROCESS INLET CONDITIONS AND QUALITY REQUIREMENTS ARE GIVEN BELOW:
   - FLOW = 54 m3/hr
   - PRESSURE = 195 Psig
   - SDI = 3
   - TPH (OIL & GREASE) = 0.1 ppm
   - METALS (Fe, Al and) = 0.05 ppm
   - TDS = 3000 ppm
4. TREATED WATER REQUIREMENTS ARE GIVEN BELOW
   - COLOUR = 15 TCU
   - ODOUR = 3 TON
   - TDS = 600 mg/l
5. DISPOSAL DEEP WELL DEPTH SHALL BE 150-200m.
6. FLOCCULENT SHALL BE COMPATIBLE TO REVERSE OSMOSIS MEMBRANE. THE PACKAGE PROCESS DETAILS SHALL BE CONFIRMED BY VENDOR.
7. THE WATER INJECTION PUMPS DISCHARGE LINE LENGTH IS 100m. IT SHALL BE FINALIZED LATER.
8. SODIUM HYPOCHLORITE SHALL BE INJECTED TO MAINTAIN CHLORINE OF 0.5ppm. THE PACKAGE PROCESS DETAILS SHALL BE CONFIRMED BY VENDOR.
9. SAND FILTER SHALL BE HORIZONTAL AND ACTIVATED CARBON FILTER SHALL BE DOWN FLOW. THE PARTICLE SIZE AT OUTLET OF CARTRIDGE FILTER IS 5 MICRONS.
10. AQUIFER-1 THE ACTUAL DEPTH IS 17-45m.
11. AQUIFER-2 THE ACTUAL DEPTH IS 50-100m.
12. SODIUM HYDROXIDE SHALL BE INJECTED TO ADJUST PH OF 7-8. THE PACKAGE PROCESS DETAILS SHALL BE CONFIRMED BY VENDOR.
13. FLOW METER SHALL BE PROVIDED TO MEASURE THE INJECTION FLOW RATES.
14. CARTRIDGE FILTER POROSITY IS 5 MICRONS.
15. THE EQUIPMENT, LINE SIZES AND PUMPS DIFFERENTIAL PRESSURE INCLUDING SHAFT RATING ARE INDICATIVE BASED ON PRELIMINARY DESIGN REPORT AND SHALL BE FINALIZED BY PROCUREMENT CONSTRUCTION CONTRACTOR IN CONSULTATION WITH WATER TREATMENT PACKAGER/SUPPLIER. THE LOCATION AND DEPTH OF PRODUCTION/INJECTION/DISPOSAL DEEP WELLS SHALL BE FINALIZED BY PROCUREMENT CONSTRUCTION CONTRACTOR.
16. THE STANDARD EQUIPMENT AND PACKAGE ITEMS SHALL BE CONTAINERIZED.
17. ELECTRICALLY OPERATED MOTORIZED VALVES WILL BE PREFERRED AGAINST PNEUMATIC OPERATING CONTROL VALVES. IN CASE OF UNAVAILABILITY OF ELECTRICALLY OPERATED MOTORIZED VALES THEN REQUIRED NECESSARY UTILITIES AS INSTRUMENT AIR AND OTHER UTILITIES SHALL BE PART OF ALL ASSOCIATED PACKAGE UNITS.
18. TREATMENT LOSS AT 10% OF 1380m3/Day WILL BE MAKEUP THROUGH ROAD TANKER.
19. ALL NECESSARY ITEMS AND SUB ITEMS WITHIN THE SKID INCLUDING EQUIPMENTS, INSTRUMENTS, PIPING, VALVES, UNIT CONTROL PANEL ETC. SHALL BE PART OF PACKAGE UNIT.
20. REVERSE OSMOSIS UNIT CLEAN IN PLACE (CIP) SKID.
21. DURING REVERSE OSMOSIS UNIT MEMBRANES CLEANING, TREATED AND REJECTED WATER SHALL BE TRANSFERRED TO DISPOSAL DEEP WELL.
22. FILTERED WATER SHALL BE CONDITIONED WITH ANTI-SCALANT, SULPHURIC ACID AND SODIUM BI-SULFITE WITHIN THE RO PACKAGE TO SAFEGUARD THE MEMBRANES.

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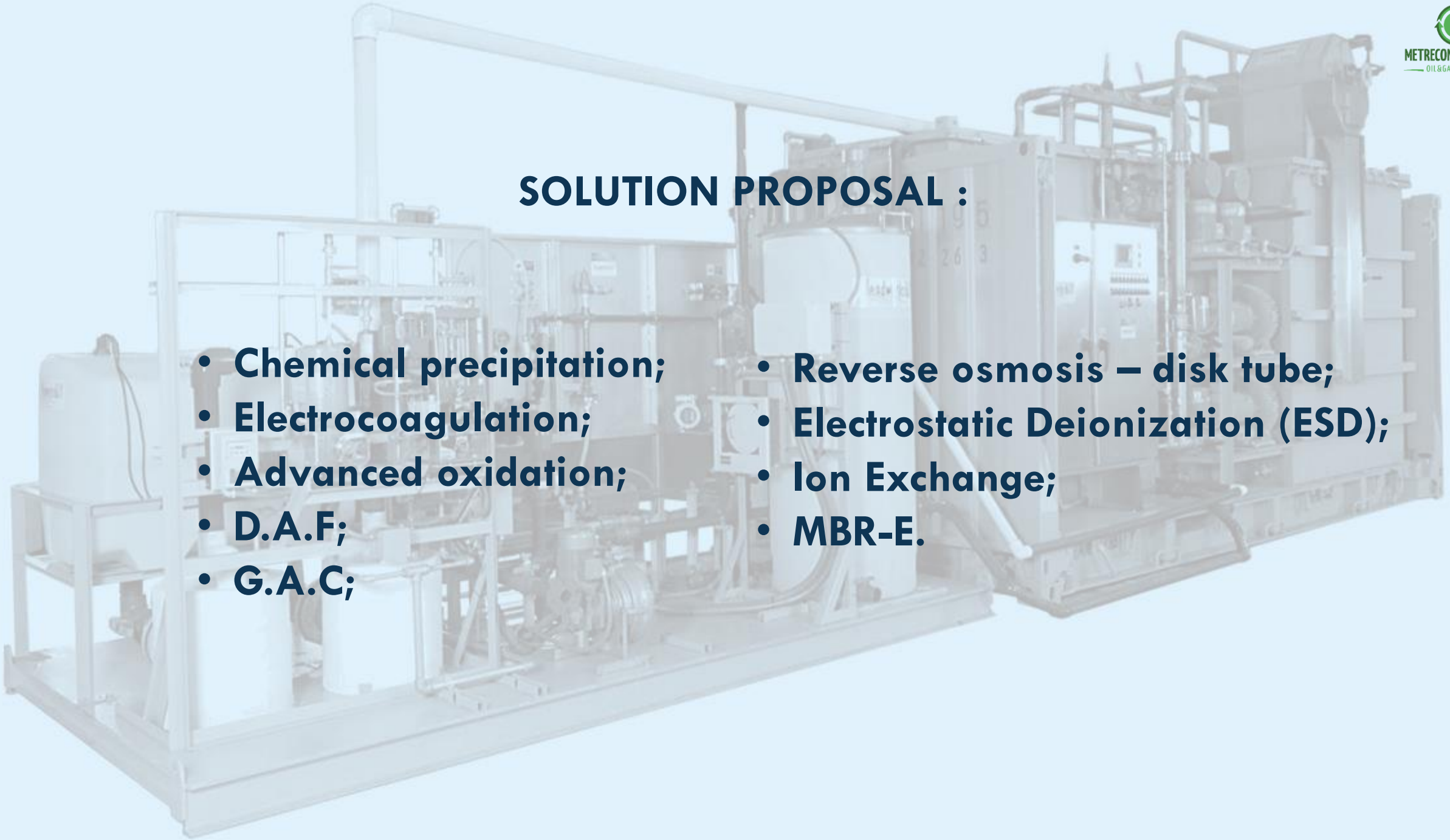


SOLUTION PROPOSAL :

- Chemical precipitation;
- Electrocoagulation;
- Advanced oxidation;
- D.A.F;
- G.A.C;
- Reverse osmosis – disk tube;
- Electrostatic Deionization (ESD);
- Ion Exchange;
- MBR-E.

Water having a high mineral content is generally referred to as ‘hard waater’ and has a tendency to form scale.

PRE treatment is accomplished in two stages, namely, a series of pre-treatment steps, in which suspended matter, oil and grease are reduced, and an advanced stage, in which wastewater contaminants are decreased to certain acceptable discharge limits.

• Chemical precipitation

- Chemical precipitation is the most common technology used in removing dissolved (ionic) metals from solutions, such as process wastewaters containing toxic metals;
- The ionic metals are converted to an insoluble form (particle) by the chemical reaction between the soluble metal compounds and the precipitating reagent;
- A typical chemical precipitation method involves four stages.
    1. Addition of reagents, adjustment of pH to form the precipitate;
    2. Flocculation;
    3. Sedimentation;
    4. Solid–liquid separation.

- **Electrocoagulation**

- For to reduce pollutants, electrocoagulation and advanced oxidation are proposed;
- It was also chosen to reduce the size of the equipment but without affecting the degree of elimination of pollutants;
- Aromatic compounds are known to be more recalcitrant, among which are benzene, toluene, ethyl benzene, xylene isomers (the so-called BTEX), and phenols.

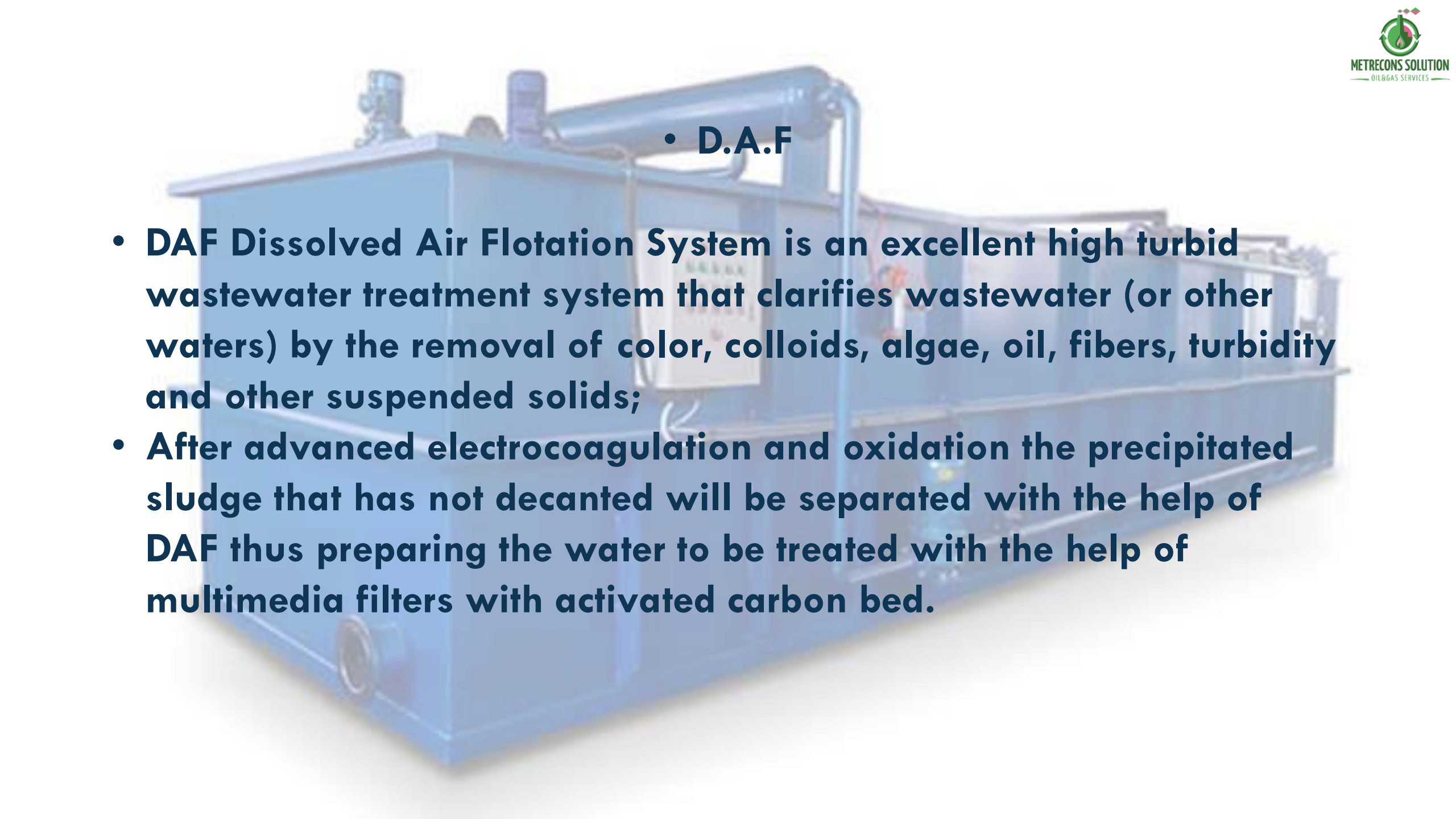
- Advanced oxidation

- Advanced oxidation processes (AOPs), in a broad sense, are a set of chemical treatment procedures designed to remove organic (and sometimes inorganic) materials in water and wastewater by oxidation through reactions with hydroxyl radicals (·OH).
- Generally speaking, chemistry in AOPs could be essentially divided into three parts:

1.Formation of ·OH;

2.Initial attacks on target molecules by ·OH and their breakdown to fragments;

3.Subsequent attacks by ·OH until ultimate mineralization.



- **D.A.F**

- DAF Dissolved Air Flotation System is an excellent high turbid wastewater treatment system that clarifies wastewater (or other waters) by the removal of color, colloids, algae, oil, fibers, turbidity and other suspended solids;
- After advanced electrocoagulation and oxidation the precipitated sludge that has not decanted will be separated with the help of DAF thus preparing the water to be treated with the help of multimedia filters with activated carbon bed.

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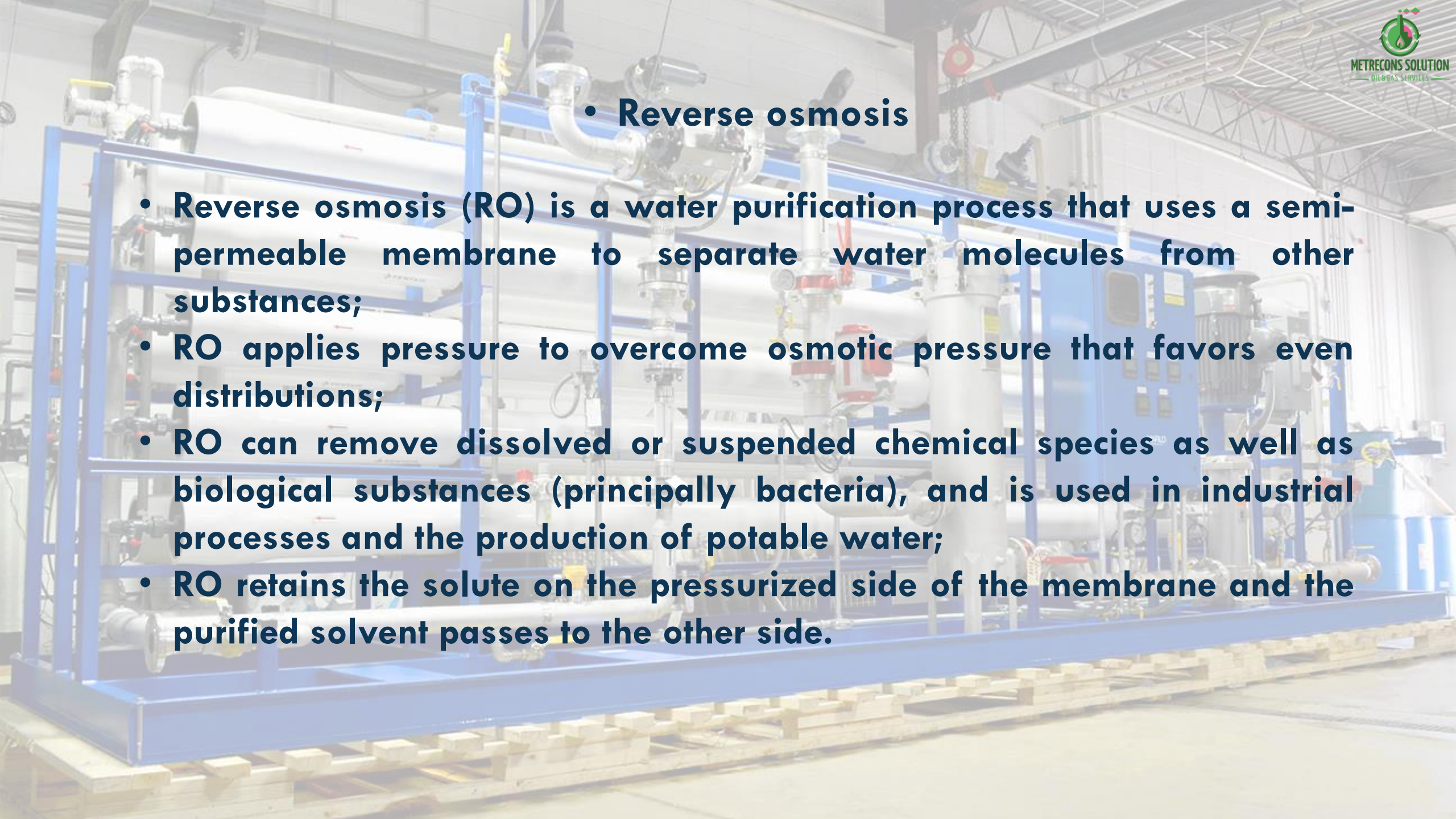
- **G.A.C**

- At these installations all the carbon used is analyzed so that appropriate measures can be taken to handle and remove saturated carbon from the mobile filters. All molecules that have been adsorbed on activated carbon at the customer site are desorbed in reactivation furnaces. These contaminants are then completely destroyed by an incineration and neutralization plant. The entire installation and its emissions are continuously monitored online, which guarantees that only harmless water vapor can be seen coming out of the chimney.

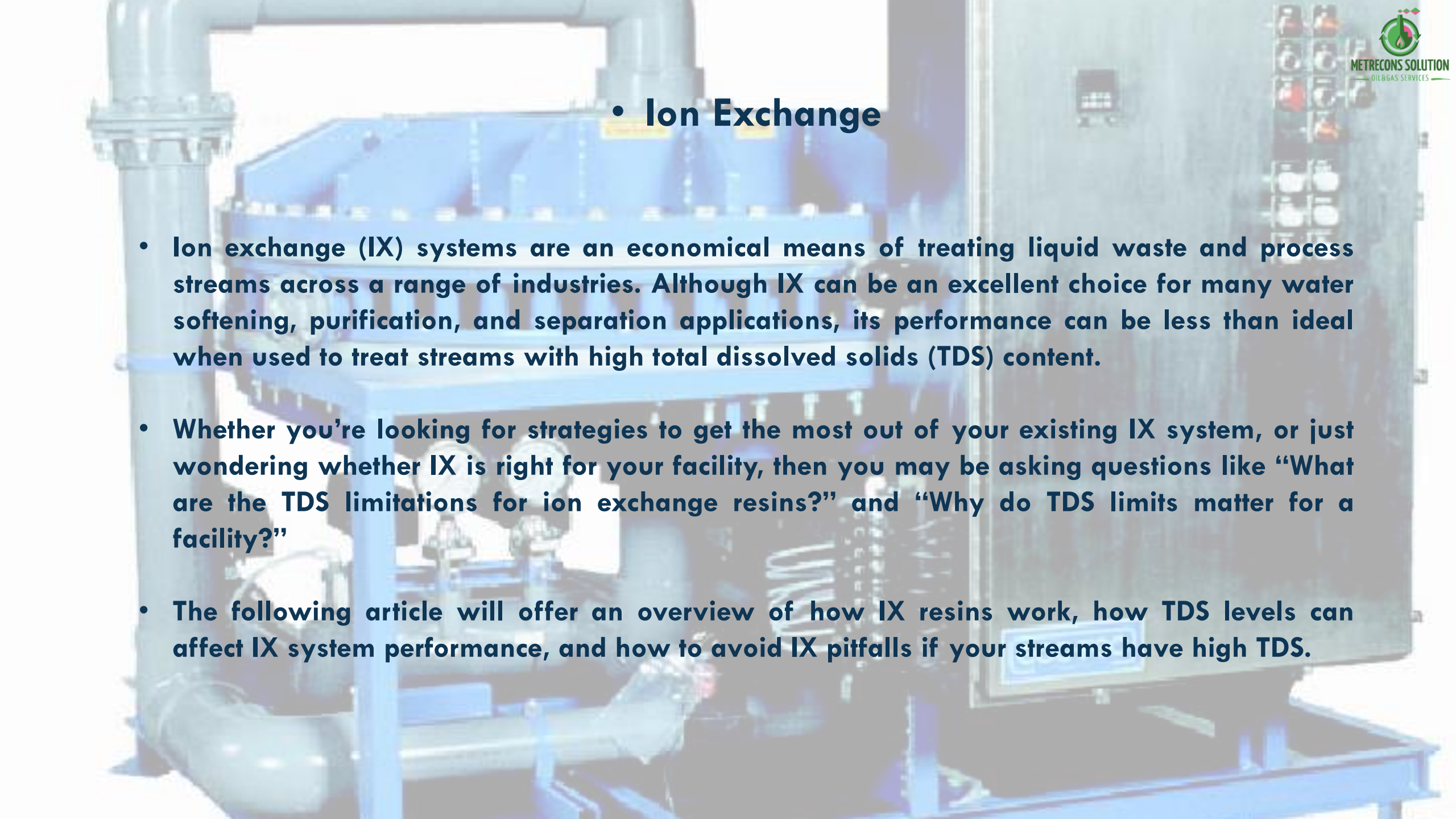


- Reverse osmosis

- Reverse osmosis (RO) is a water purification process that uses a semi-permeable membrane to separate water molecules from other substances;
- RO applies pressure to overcome osmotic pressure that favors even distributions;
- RO can remove dissolved or suspended chemical species as well as biological substances (principally bacteria), and is used in industrial processes and the production of potable water;
- RO retains the solute on the pressurized side of the membrane and the purified solvent passes to the other side.

• Electrostatic Deionization (ESD)

- Electro-static deionization is a proven electrochemical process that effectively lowers the concentration of total dissolved solids (TDS) in water.
- ESD is a cost effective system that utilizes the principles of capacitive deionization based on the company's patented technology.
- Water containing arsenic, nitrate, fluoride, perchlorate, ammonia, sulfate, metals or other ionic compounds can be treated using capacitive deionization.
- ESD is offered in two designs; one removes all charged dissolved solids, while the other preferentially removes monovalent ions such as nitrate and fluoride.
- ESD systems can also be used to concentrate dilute solutions, for example, the recovery of valuable metals or nutrients from waste streams.
- Independent testing of the ESD system has demonstrated its capabilities. The tests targeted 85% removal of specific compounds added separately to tap water. The target was achieved in all cases



• Ion Exchange

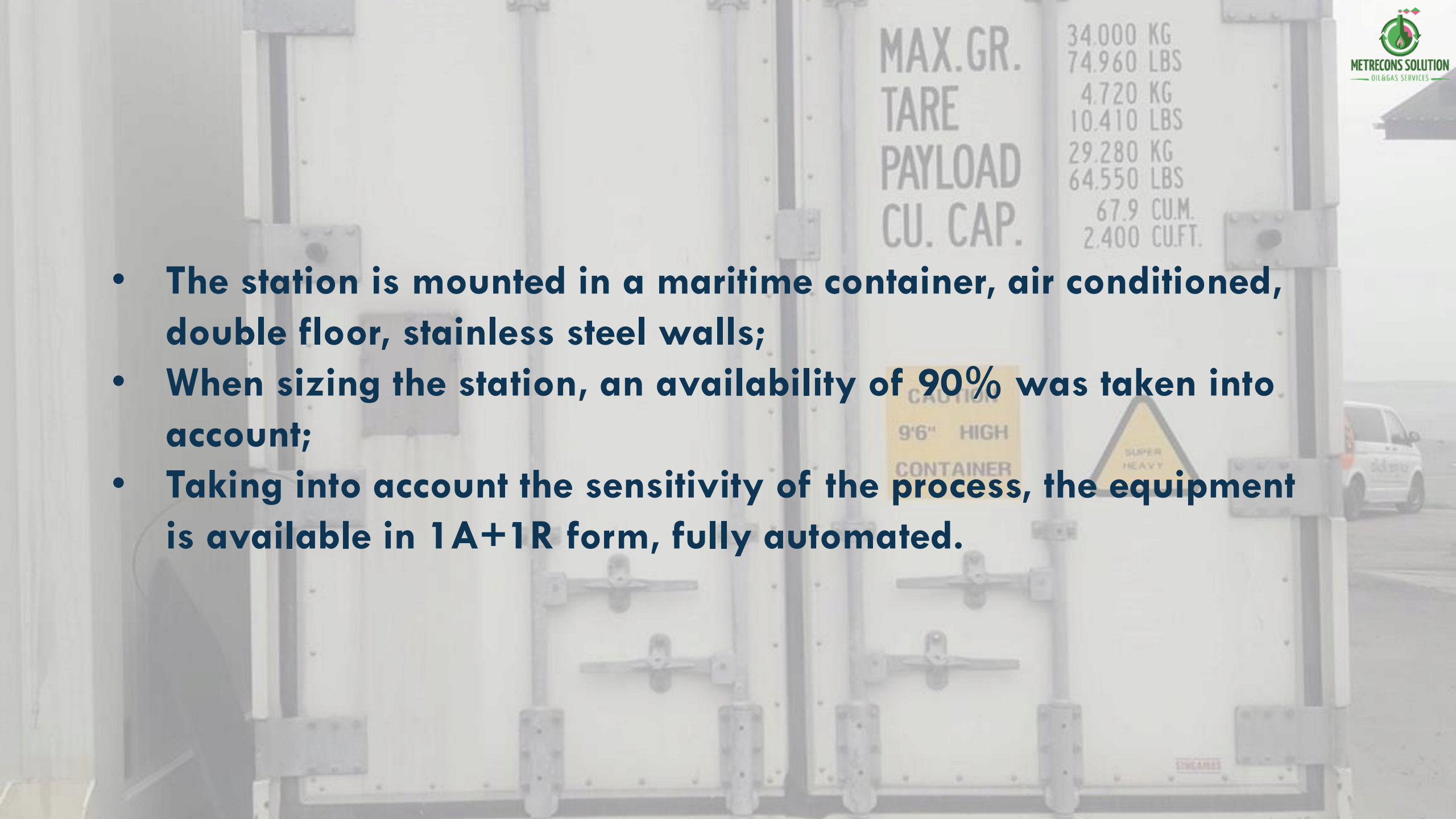
- Ion exchange (IX) systems are an economical means of treating liquid waste and process streams across a range of industries. Although IX can be an excellent choice for many water softening, purification, and separation applications, its performance can be less than ideal when used to treat streams with high total dissolved solids (TDS) content.

- Whether you're looking for strategies to get the most out of your existing IX system, or just wondering whether IX is right for your facility, then you may be asking questions like "What are the TDS limitations for ion exchange resins?" and "Why do TDS limits matter for a facility?"

- The following article will offer an overview of how IX resins work, how TDS levels can affect IX system performance, and how to avoid IX pitfalls if your streams have high TDS.

• MBR-E

- Membrane bioreactor (C-MEM MBR)
- Membrane moving bed biofilm reactor (C-MEM MBBR)
- Landfill leachate
- Grey and rain water treatment
- Pre-treatment before RO
- Elimination of turbidity, algae, bacteria and viruses (Fe, Mn, As with pre-oxidation process)
- Ground and surface water treatment
- Water reuse
- Elimination of Cryptosporidia and Giardia
- Wastewater disinfection
- Package plants for households and for smaller villages
- Mobile water treatment plants
- Emergency supply package
- Gravity driven membrane filtration (C-MEM Zero) without electric power consumption



- The station is mounted in a maritime container, air conditioned, double floor, stainless steel walls;
- When sizing the station, an availability of 90% was taken into account;
- Taking into account the sensitivity of the process, the equipment is available in 1A+1R form, fully automated.

THANK YOU !!!

Technical support: Ph.D. Engineer MAN PETRE

+40 784 288 069

https://www.addmoregreen.com

office@addmoregreen.com

office@metrecons.com