How 45 Years of Water Treatment Expertise at Teck is Supporting Continued Mining at Red Dog

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Intent for Today

Teck has over 45 years of experience in water treatment.

Today we are presenting on how that experience has benefited our Red Dog Operation in northwest Alaska Teck's Experience in Water Treatment

High Density Sludge (HDS) Process

Water Treatment at Red Dog Operations

HDS Water Treatment Plants

Reverse Osmosis Water Treatment Plant

Lessons Learned

Teck Operates Numerous Water Treatment Plants

WATER TREATMENT TECHNOLOGY	SITE NAME	TARGET CONSTITUENTS
High Density Sludge (HDS)	Sullivan Mine	Zn, Fe, Cd, Cu
High Density Sludge (HDS)	Louvicourt Mine	SO ₄ , Cu, Fe, Zn
Low Density Sludge (LDS)	Pine Point Mine	Zn, Pb, Cu
Slaked Lime System	Duck Pond Mine	Cu, Zn
Biological Passive Treatment	Pend Oreille Mine (POM)	Zn, Pb
Saturated Rock Fill (SRF)	Elkview Operations (EVO)	Se, NO₃
Saturated Rock Fill (SRF)	Fording River Operations – North (FRO-N)	Se, NO₃
Biological Active Water Treatment Facility (AWTF)	Line Creek Operations (LCO)	Se, NO₃
Biological Active Water Treatment Facility (AWTF)	Fording River Operations – South (FRO-S)	Se, NO₃
Antiscalant Addition Skid	Various Sites	CaCO ₃
High Density Sludge (HDS)	Trail Operations	As, Cd, Cu, Pb, Hg, Tl, Zn
High Density Sludge (HDS) & Aerobic MBBR	Trail Operations	Cu, Cd, Zn, Mn, Fe, NH ₃ /NH ₄ ⁺
Slaked Lime System	Red Dog Operations (RDO)	TDS, Zn, Pb, Fe
High Density Sludge (HDS)	Red Dog Operations (RDO)	TDS, Zn, Pb, Fe, Cd
High Density Sludge (HDS)	Red Dog Operations (RDO)	TDS, Zn, Pb, Fe
Reverse Osmosis (RO) Water Treatment Plant	Red Dog Operations (RDO)	TDS
Reverse Osmosis (RO) Desalination Plant	Quebrada Blanca (QB) Operations	TDS



1970's



Teck's Experience with Water Treatment Started at Sullivan Mine

- Former silver, lead, zinc mine located in Kimberly, BC
 - Operated from 1909 to 2001
- Water treatment commenced in 1979
 - High Density Sludge (HDS) process for acid mine drainage (AMD) treatment
 - Seasonal operation
 - Typically treats ~1.6 to 3.3 Mm³/year
 - Average rate of 13,000 L/min



Overview – High Density Sludge (HDS) Process Sullivan Drainage HDS Treatment Process



1990's



Overview – Red Dog Operations

- Open pit zinc and lead mine located in northwest Alaska
- Commenced operation in 1989 in a partnership with NANA Regional Corp.
- Tailings Storage Facility (TSF) collects mill tailings, precipitation, waste dump runoff, groundwater, treated Acid Rock Drainage (ARD) and camp site wastewater
- Main Pit Water Reservoir (MPWR) collects seepage and runoff from in-pit waste stockpiles, and occasionally ARD from Main Waste Stockpile (MWS)
- Discharges treated water to Red Dog Creek
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Tailings Storage Facility (TSF) Water Quality TSF Reclaim Water Chemistry (WTP Influent Quality) & Discharge Limits

PARAMETER	UNITS	RECLAIM WATER ¹ PERMIT LII	
SO4 ²⁻	mg/L	4,200	-
Ca, total	mg/L	530	_
Cd, total	µg/L	7,000	1.4
Cu, total	µg/L	162	21
Fe, total	mg/L	17	-
Mg, total	mg/L	220	_
Mn, total	mg/L	51	-
Pb, total	µg/L	1,967	8.1
Zn, total	mg/L	680	0.221
рН	s.u.	4.8	6.5 – 10.5
TDS	_	5,700 mg/L	21,986 mt / year

- Reclaim water present in the TSF is the sole water source for discharge to the environment (Red Dog Creek)
- Reclaim water present in the TSF is supersaturated with gypsum (CaSO₄·2H₂O)
- Discharge seasons limited to ~5 months/year

¹ 2020 to 2022 average concentration

² Average monthly permit limit at discharge monitoring location (excluding TDS limit)

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RDO High Density Sludge Water Treatment Plants (WTP) WTP#1, WTP#2 and WTP#3

SYSTEM	AVG. TREATMENT CAPACITY (M ³ /DAY)	WATER SOURCE	OPERATING PERIOD
WTP#1	27,250	Reclaim or ARD	Year-Round
WTP#2	54,500	Reclaim	Summer
WTP#3	8,175	ARD	Summer



Reclaim water (TSF)

- Treated in WTP#1 and WTP#2 during the summer for discharge
- HDS effluent polished via Sand Filters before discharge
- Acid Rock Drainage (MWS)
 - Treated in WTP#1 during winter
 - Treated in WTP#3 during summer
- WTP#1 clarifier is covered allows for year-round operation
- WTP#3 operates with no clarifier

Reclaim Water HDS Treatment for Discharge



- Teck Technical Services supported HDS treatment optimization
 - Sulfide addition for cadmium (Cd) removal as sulfides
 - Seed addition for gypsum desaturation
 - Sludge recirculation optimization for metals and sulfate removal Teck

Enhancing HDS Treatment Performance at RDO Seeding with Fresh Gypsum





- Numerous pilot test campaigns at Teck Technical Services' and RDO's facilities to enhance TDS removal efficiency
- Slurried gypsum added in WTP#2 to assist in desaturating reclaim water of gypsum
- In 2022, dry gypsum plant installed to supplement existing slurried gypsum delivery system
 - ~2.5 g/L gypsum seed dosage achieved

Red Dog WTP#3 Flowsheet Acid Rock Drainage (ARD) Treatment



- WTP#3 operates as a basic lime treatment system no flocculation or clarification
 - Sludge and water effluent is discharged to the TSF

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Treats ARD with the option to co-treat pit water during the summer

2020's



Changing Climate Conditions have Resulted in Changes in Water Treatment Demands

- Increasing TDS concentrations upstream and downstream of site due to permafrost degradation have affected RDO's ability to discharge water
- Short term measures included:
 - Restricting discharge
 - Storing more water on site
- Long-term measure: enhance TDS removal

RDO Reverse Osmosis Water Treatment Plant (RO-WTP) RO-WTP Installation in 2020



- Reverse osmosis (RO) technology was selected to support RDO's TSF water treatment objectives
 - Ability to produce low TDS (< 50 mg/L) treated water
- Teck Technical Services supported the piloting, design & implementation of the RO-WTP
 - Continued technical support to optimize RO-WTP operation

RDO Integrated Water Treatment Flowsheet High Density Sludge (HDS) and Reverse Osmosis (RO) Water Treatment Plants (WTP)



- RO-WTP accepts HDS clarifier overflow (WTP#1 or #2)
 - Feeding untreated reclaim water is not possible due to high metals concentrations (severe scaling)
 - RO-WTP includes Microfiltration (MF) and Reverse Osmosis (RO) skids
 - MF is used to remove suspended and colloidal particles
 - RO is used to remove TDS
 - RO permeate is blended with HDS effluent in Sand Filter building
 - RO brine is currently returned to the TSF

Overview – RO-WTP Microfiltration (MF) & Reverse Osmosis (RO) Systems





RDO Reverse Osmosis (RO) Operations

Feed		64% recovery	Permeate	Pe	ermeate	Brine	
Analyte	Conc. (mg/L)			Analyte	Conc. (mg/L)	Analyte	Conc. (mg/L)
TDS	3,830	Feed		TDS	< 40	TDS	10,800
Са	690			Ca	0.5	Ca	1,180
SO ₄	2,400			SO ₄	2.8	SO ₄	8,090

- Significant improvements were instituted to maximize RO-WTP uptime and production
 - Real-time measurement & control
 - Multi-pronged scaling/biofouling mitigation strategies
- Increasing RO recoveries will minimize RO brine volume produced – TDS load in brine will remain unchanged
- How can the brine be effectively managed?
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Assuming 3,750 mg/L TDS and 1,600 gpm RO feed



Lessons Learned

- Strong and wide in-house knowledge base has been critical in the development and optimization of water management solutions
 - Technical Services backgrounds: engineering, geochemistry, molecular biology, biology, chemistry, etc.
 - Sharing knowledge across operations is invaluable
- No universal 'silver bullet' exists to address water challenges faced across the industry
 - Holistic treatment approach is site/water chemistry specific
 - Process measurement and control is key
 - Pre-treatment, pre-treatment, pre-treatment!
- Appropriate brine management strategy is vital to mitigate long-term environmental impacts of disposal/storage
 - Opportunity for brine reuse or recovery of value-added products?
- Enhancing water management capabilities via both source control and treatment system upgrades is vital to sustained production, environmental compliance and community safety

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