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REJUVENATION PROCESSES APPLIED TO "POISONED" ANION EXCHANGERS
IN URANIUM PROCESSING - A REVIEW

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by

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ABSTRACT

The removal of "poisons" from anion exchangers in uranium
processing of Canadian radioactive ores is commonly called rejuvenation
or regeneration. The economics of the ion exchange recovery of uranium
is adversely effected by a decrease in the capacity and efficiency of the
anion exchangers, due to being "poisoned" by silica, elemental sulphur,
molybdenum and tetrathionates. These "poisons" have a high affinity for
the anion exchanger, are preferentially adsorbed to the uranyl complex,
and do not desorb with the reagents used normally in the uranyl
desorption phase. The frequency of rejuvenation and the reagents
required for rejuvenation are determined by the severity of the "poisoning"
accumulated by the exchanger in contact with the uranium leach liquor.

Caustic soda (NaOH), at $\simeq 18 ¢/lb$ is commonly used to remove uranium
anion exchangers of tetrathionate ($S_4O_6^=$) "poisons". A potential saving
in operating cost would be of consequence if other reagents, e.g., sodium
carbonate (Na_2CO_3) at $\simeq 3.6 ¢/lb$ or calcium hydroxide ($Ca(OH)_2$) at $\simeq 1.9 ¢/lb$
were effective in removing $S_4O_6^=$ from a "poisoned" exchanger. A rejuvenation
process for a test program was adopted after a perusal of the literature.

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INTRODUCTION

The rejuvenation or regeneration of anion-exchange resins, in Canadian uranium processing mills, is commonly applied to remove resin "poisons" from the exchangers. "Poisons", such as tetrathionates, silica, elemental sulphur, molybdenum, etc., affect the economics of the uranium separation process by decreasing the efficiency and the capacity of the exchanger for uranium. These "poisons", which are adsorbed preferentially to the uranyl complex, appear to possess a high affinity for the anion exchanger.

The rejuvenation process, in most uranium mills, is performed in a separate plant. The full capacity of the ion-exchange circuit thus remains available for uranium recovery. The separate plant precludes a cost and amortization for extra tanks and reagents for the rejuvenation process. Labour costs plus any downtime, due to resin transfer to the separate plant, would also affect the economics of the uranium recovery process. Caustic soda (NaOH), most commonly used to remove "poison", has become a more noticeable operating expenditure at $\approx$18¢/lb. The literature has consequently been reviewed to outline the reagents used for the various "poisons" and the frequency of rejuvenation in the different mills. Less expensive reagents such as Na_2CO_3 at $\approx$2.8¢/lb or CaO at $\approx$1.6¢/lb may be suitable substitutes for caustic in the rejuvenation process. The milder reagents may also reduce the "osmotic" shock or resin rupture undergone in making rapid changes from one resin form to another with the strong reagents such as NaOH and H_2SO_4.

This report is presented as background to a test program to determine the suitability of less expensive Na_2CO_3 and CaO reagents as alternatives to the costly and strong NaOH reagent for rejuvenating anion exchangers. Learning to cope with "poisoning" anions, produced during uranium extraction of radioactive ores, is an aid for an uninterrupted supply of uranium nuclear fuel for potential national energy requirements.

REJUVENATION PROCESSES

Generally, a caustic solution (NaOH) is used to, 1) dissolve and elute silica or adsorbed silicates, and 2) decompose tetrathionates ($S_4O_6=$). Whether the silica exists in solution as a silicate anion or a colloidal silicic acid is unknown. Poor adsorption and channelling in the columns is the result of lump formation of the resin beads cemented by the silica. The caustic decomposition of the tetrathionates ($S_4O_6=$) occurs in two phases[1] as:

$$4S_4O_6{}^{2-} + 6OH^- \rightarrow 5S_2O_3{}^{2-} + 2S_3O_6{}^{2-} + 3H_2O \qquad (1)$$

$$2S_3O_6{}^{2-} + 6OH^- \rightarrow S_2O_3{}^{2-} + 4SO_3{}^{2-} + 3H_2O \qquad (2)$$
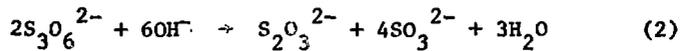
The second reaction is much slower than the first. A neutral solution of NaCl is frequently used to desorb the trithionate $(S_3O_6)^{2-}$ and thiosulphate $(S_2O_3)^{2-}$ from the exchanger. Another investigator (1) believes these poly-thionates are sulphides, as H_2SO_4 addition to the resin, instead of NaCl, causes the evolution of H_2S.

Rejuvenation in South Africa 1946-56

The process stages in a rejuvenation plant are (1):

1. **Column Inspection** - the upper layers of the quartz or sand bed of an empty ion-exchange column are removed for washing and resizing. This is to prevent finer particles from sinking and being lost via the lower distributor. The continual observance of the quartz bed is recommended to prevent caking of the bed and the formation and growth of organic material that decreases solution flow through the quartz or gravel bed (Fig. 1).

2. **Resin Transfer** - The resin to be rejuvenated is transferred

BACKWASH OUT ← PREGNANT IN

FLUSH WATER IN → SEMI-PREGNANT IN

FIRST ELUATE

SECOND ELUATE

RESIN

SEMI-PREGNANT TO
NEXT COLUMN

BARREN

HIGH VALUE
BARREN

GRAVEL
BED

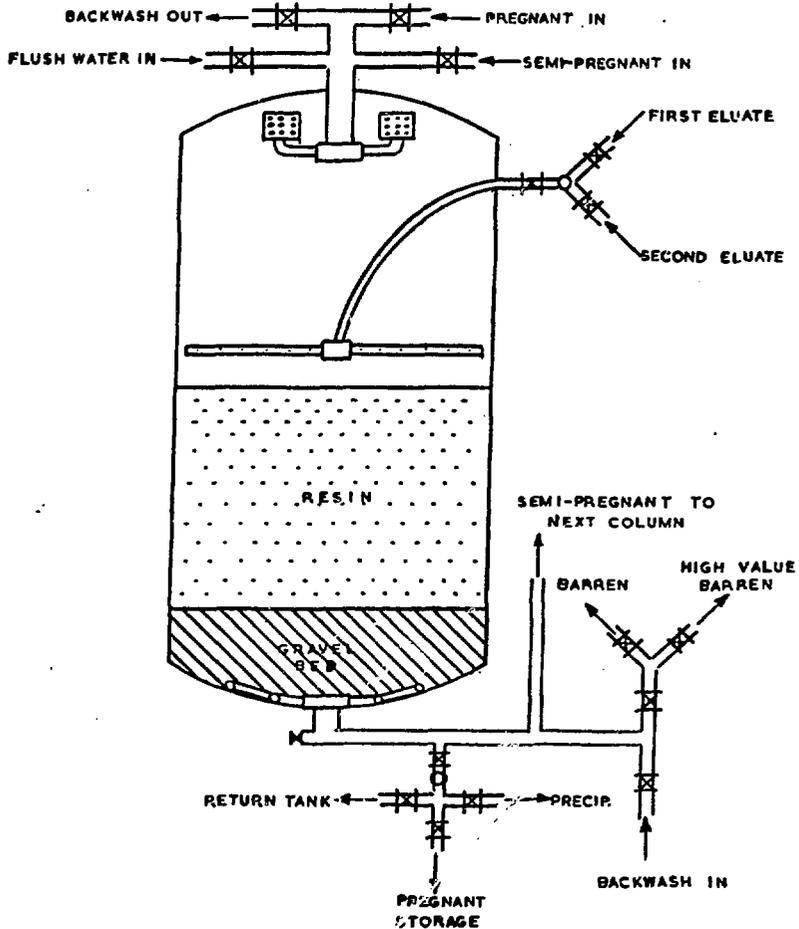RETURN TANK ← PRECIP.

BACKWASH IN

PREGNANT
STORAGE

FIGURE 1. ION EXCHANGE COLUMN SHOWING RELATIONSHIP
BETWEEN RESIN, QUARTZ OR GRAVEL BEDS AND
BACKWASH PIPES

hydraulically with backwash water to produce a fluid resin/water
mixture that leaves the column through a backwash pipe to a clean column.

    3. Neutralization of Resin - A preliminary 5% NaOH treatment of
the resin in the clean column ensures resin neutralization. The volume
of caustic/resin volume is not mentioned. An elution method of passing
1/2 to 1% of NaOH through the resin bed is time consuming.

    4. The Caustic Rejuvenation (1) - This stage differs widely at the
various mills. Four thousand to thirteen thousand gallons of 3 to 6% NaOH, at 10 to
130 gpm, are passed through the resin bed. Complete decomposition of the
tetrathionates is the result of a sufficiently long contact period. Static
contact with 10% NaOH over an unspecified long period of time is desirable.
This is followed by displacement with 2-bed volumes of fresh caustic. Low flow-
rates are recommended as the resin specific gravity is lowest when in the
-OH form.

    5. Neutral Salt Treatment - The salts used, 5% NaCl, 5%
Na_2SO_4 or 5% NH_4NO_3 vary from one South African uranium mill to another.
NH_4NO_3 is used mainly in mills where the resin is desorbed with nitrate and
is beneficial to the removal of tetrathionate poisoning. Neutral salts, it is
assumed, desorb the resin of sulphides and polythionates such as thiosulphate,
and trithionate. Some mills indicate that chloride and nitrate salts are
more effective than sulphate salts. Sodium chloride is generally more
economical than the other salts. The neutral salt treatment also reduces the
chance of osmotic shock before proceeding from the NaOH treatment to service
with acidified leach liquors.

    6. Re-acidification - 3% H_2SO_4 is adequate for acidification after
the salt treatment. Channelling, due to lump formation, should be watched
for and avoided.

7. Backwash – An upflow of water expands the resin bed, without resin loss, to cleanse the resin bed by allowing any slime formation collected during adsorption to escape with the backwash effluent. Backwashing, until the effluent is clear, also classifies the resin bed for the next column operation.

8. Final Inspection – Finally, the resin is sampled and analyzed for cobalt, silica and sulphur in South African mills. A comparison of the ash content, before and after rejuvenation, is more often the method used to determine the suitability of the resin for service.

South African Rejuvenation – 1978

A consultant's report (2) on South African activities confirms, after 21 years, that silica, tetrathionate and cobalt-cyanide complexes still reduce uranium capacities and loading kinetics by accumulation in the resin, unless removed by rejuvenation processes.

Caustic rejuvenation for removal of silica, despite efforts to minimize silica build-up on resin by controlling the pH of acidified backwash water, was necessary at intervals of 4 to 12 months at most South African fixed-bed ion-exchange operations.

Poisoned resin with 3 to 4% SiO_2, after transfer to a rejuvenation tank, was backwashed with water, then contacted first with 1% NaOH solution, then, with 5% NaOH for up to 16 hours. The bed volume of resin was trans-ferred back to a fixed-bed column after being sulphated with dilute H_2SO_4. The rejuvenated resin contained 0.1 to 0.3% silica (SiO_2). No NaOH consump-tion data were presented.

Tetrathionate ($S_4O_6^{2-}$) poisoned resin was similarly rejuvenated with 5 to 10% NaOH despite efforts to control tetrathionate poisoning by

maintaining acid concentrations >5g. H_2SO_4/litre in uranium bearing leach liquor.

It has been found inexpensive and simple to treat about 1/10 of the resin capacity continuously with NaOH to combat silica poisoning at Blyvooruitzicht (2), South Africa, with the arrival of counter-current ion-exchange column (CCIX) plants, which included NaOH rejuvenation tanks. Consequently, the build-up of tetrathionate poisons has not been noticeable. It has been generally stated, for these reasons, the CCIX plants are, less prone to SiO_2 and $S_4O_6^{2-}$ poisoning because of the built-in caustic rejuvenation plant.

Resin Rejuvenation at Elliot Lake

Amberlite strong base resin IRA-400, in fixed-bed air-dome sets of 4-column ion-exchange at Pronto Uranium Mines, Elliot Lake[3], Canada, was rejuvenated every 8×10^6 Imperial gallons or 4 to 5 months. This rejuvenation cleansed the poisoned resin of thorium, titanium and phosphates.

Poisoned resin, after a $NaCl/H_2SO_4$ desorption, was flushed from its column to a separate tank. The empty column was filled with rejuvenated or fresh resin from a rejuvenation column. The poisoned resin in the tank was then flushed to the rejuvenation tank for the treatment, shown in Table I.

TABLE I

Rejuvenation Procedure in Four-Column Fixed-Bed Plant

a) 6.5 bed volumes of 2% NaOH at 40 US gpm to waste.
b) 1.0 bed volumes of 2% NaOH in which the resin soaks for 8 hours.
c) Water flush at 100 US gpm for 1 hour – to waste.
d) Backwash for 1 hour at as high a flowrate as possible without losing resin – to backwash tank.
e) Drain down column, necessary after backwash in an air-dome column.
f) 1.6 bed volumes of 25% H_2SO_4 at 40 US gpm – to waste.
g) 1.0 bed volumes of 25% H_2SO_4 in which the resin soaks for 8 hours.
h) Water flush at 100 US gpm for 1 hour – to waste.
i) Backwash for $1\frac{1}{2}$ hours at as high a flow as possible.
j) Drain down.
k) Regenerated resin now sits until required for use in the plant.

This rejuvenation treatment reduced the resin ash content from about 10% to 0.5%.

IRA-400 resin is rejuvenated in situ at intervals of 11×10^6 Imperial gallons or 8 months, in fixed-bed water-dome sets of 3-column (3) ion-exchange at another Elliot Lake operation. Poisoned resin is cleansed of phosphate, thorium and titanium ions, after a nitrate desorption and water wash by following the procedure in Table 2.

TABLE 2

Resin Rejuvenation Procedure in Three-Column Fixed-Bed Plant

a) 3/4 bed volumes of 2% NaOH at 10 Imperial gpm – to waste.
b) $2\frac{1}{2}$ bed volumes of 5% NaOH at 10 Imperial gpm – to waste.
c) 2 bed volumes of 2% NaOH at 10 Imperial gpm – to waste.
d) Water flush 30 minutes at 100 Imperial gpm – to waste.
e) Backwash 1 hour at 80 Imperial gpm – to waste.
f) 4 bed volumes of 25% H_2SO_4 at 10 Imperial gpm – to leach.
g) Water flush 1 hour at 100 Imperial gpm – to waste.
h) Backwash 2 hours with top manhole open so the highest possible rate can be obtained with no loss of resin.

This rejuvenation treatment reduced the resin ash content from 12 to 0.7%. The authors (3) had only experienced one rejuvenation on the moving-bed column, at Elliot Lake, after the resin ash content had reached 12.6% in the moving-bed ion-exchange plant. The reviewed paper (3) was underway before the final ash content had been analyzed. The reagents used were similar to the 3-column nitrate desorption plants in Table 2.

Clegg & Foley on Rejuvenation (4)

Other authors (4) describe the caustic-soda rejuvenation of anion-exchange resins as a process for removing the poisons, such as molybdenum, tetrathionates, silica and sulphur. Most plants use the caustic rejuvenation process when the operating capacity has decreased to a level where the uranium leach liquor cannot be processed. This interval may range from a month or so to every year or two. All operating uranium mills use this caustic rejuvenation process for silica removal at some time.

The column of resin to be rejuvenated is well backwashed, in the pretreatment of the resin (4), after a thorough desorption of the uranium. This is to rid the resin of any slimes or solids that are apt to form lumps on the addition of the caustic. The resin is moved by upflow to an external rejuvenation column or tank, and is replaced in the production circuit by an already rejuvenated or fresh column of resin to minimize the down time of the uranium recovery circuit.

The resin to be rejuvenated (4), which is in either the chloride, nitrate, sulfate or bisulfate form, is neutralized to pH 7.0 by contacting the bed with about 0.5 lb NaOH/cu. ft. resin as a 0.5 to 1.0% NaOH solution.

The next phase of the rejuvenation process is to increase the NaOH concentration to a range of 3 to 6% to remove the silica precipitated inside

the resin bed as a soluble Na-silicate at a low flowrate. This higher

concentration consumes 12 to 20 lbs NaOH/cu. ft. resin (4). Three bed

volumes of a 5% caustic recycle solution, in a split-rejuvenation process,

is followed by 3 bed volumes of fresh 5% caustic. The effluent of the

fresh 5% caustic is stored and recycled to a subsequent split rejuvenation.

A 10% NaOH rejuvenation may be necessary to treat the less readily dis-

placed poisons, such as molybdenum (Mo), tetrathionates ($S_4O_6^{2-}$), etc.

The next phase is to convert or neutralize (4) the resin by

passing a brine solution or a 3 to 5% H_2SO_4 solution downflow until the

effluent is <pH 7.0. Finally, the resin is water backwashed thoroughly to

classify and rid the resin bed of lumps and foreign material; then the

resin volume is ready for service on next adsorption.

Merritt on Resin Rejuvenation (5)

Ion-exchange resins, contaminated by poisons or surface coatings,

may usually be rejuvenated by one or a combination of common chemical

reagents. A resin surface, for example, coated or fouled with $CaCO_3$ (5) may

be removed by static contact with pH 1.0 HCl solution for up to 4 days,

or an 8 hour contact with a pH 1.0 HNO_3 solution.

Resins fouled with iron, molybdenum, organic matter, silica,

thorium, titanium and zirconium contaminants have been rejuvenated with

12 N H_2SO_4 (5). Five to ten bed volumes of 0.5% of NaOH or NH_4OH + 0.1 M Cl

or NO_3 also removes molybdenum (Mo). Converting the resin from the -OH

form to the -Cl form before contact with strong acids effectively reduces

"resin shock." A solution of 0.5% NaOH or NH_4OH added to bleed solutions

has also been found effective for Mo-removal from resins.

Resins, containing silica and titanium poisons, have been rejuvenated

with a H_2SO_4/ammonium bifluoride mixture (5). It is best; in the silica

removal with NaOH, to neutralize an acidified resin with a neutral brine or

0.5% NaOH before introducing the stronger 5% NaOH to dissolve the silica

in the resin bed. A caustic desorption diffuses soluble Na-silicate out

of the resin bed. Silica removal consumes 12 to 20 lbs NaOH/cu. ft. resin.

The resin is converted to a salt form before placing the treated resin

back in service in contact with acidic leach liquors. Otherwise, hydroxy

precipitates of iron, silica, uranium, etc., may form.

A NaOH rejuvenation slowly transforms the mechanical sulfur

poison to a polysulphide (5) which is desorbed with a chloride.

The tetrathionate (5) ($S_4O_6^{2-}$) poison on the anion exchanger is

desorbed with a 5 to 10% NaOH solution according to equation (1). A brine

or dilute acid desorption then displaces the thiosulfate ($S_2O_3^{2-}$) and

trithionate ($S_3O_6^{2-}$) left on the resin by the caustic rejuvenation.

Tetrathionate removal by means of Na_2S or sulfite solution is suggested (5)

as an alternative.

Rejuvenation with Cyanide Waste at Stilfontien, South Africa (6)

Stilfontein Gold Mining Co., Transvaal, South Africa (6) found

that uranium mill resin, Amberlite IRA-400, fouled with the silica and

tetrathionate poisons, could be rejuvenated with alkaline cyanidation

wastes a: pH 11.0 simultaneous with the recovery of cyanide. Table 3

shows a comparison of the rejuvenation of silica and tetrathionate with

5% NaOH and with cyanidation waste.

TABLE 3

A Comparison of the Rejuvenation of Stilfontein Uranium Mill IRA-400
Resin With 5% NaOH and With Cyanidation Waste (pH 11.0) (6)

Rejuvenation Reagent	% Removal	
	Silica	Tetrathionates
pH 11.0 Cyanidation Waste	75.9	81.3
5% NaOH	96.3	30.0

The estimated economic advantage of using cyanidation waste as a rejuvenation reagent, instead of NaOH at the Stilfontein uranium mill, was £5000/annum in 1958 currency.

Resin Rejuvenation at Kerr-McGee (7)

Still another investigator (7) reports that cobalticyanide, molybdenum, silica and tetrathionate have been the most prominent poisons in the uranium recovery industry. Phosphate, titanium, organic material and zirconium poisons are less prominent.

The loading charactistics of fresh Amberlite IRA-400 is compared, in Figure 2, with resin that was poisoned after ≃100 cycles with a uranium leach liquor. The "poisoned resin" shows a 1% uranium breakthrough after 10 bed volumes of feed liquor, whereas the fresh resin produced 55 bed volumes of barren effluent before the 1% uranium breakthrough.

The desorption characteristics of the same fresh and poisoned resins after a saturation loading is shown in Figure 3. More desorption feed solution is needed to desorb the poisoned resin to the same low uranium concentration, compared with the fresh resin desorption, even though the poisoned resin has a lower saturation loading than the fresh resin.
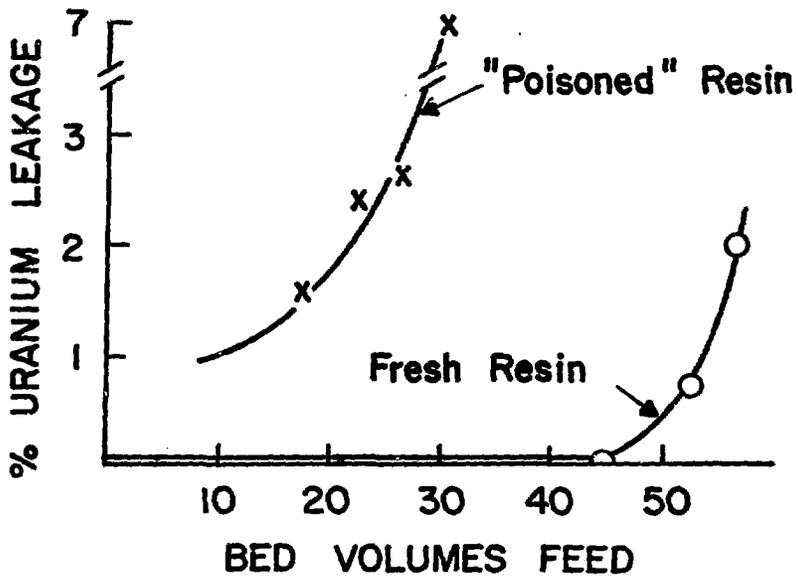
FIGURE 2. A COMPARISON OF LOADING CHARACTERISTICS
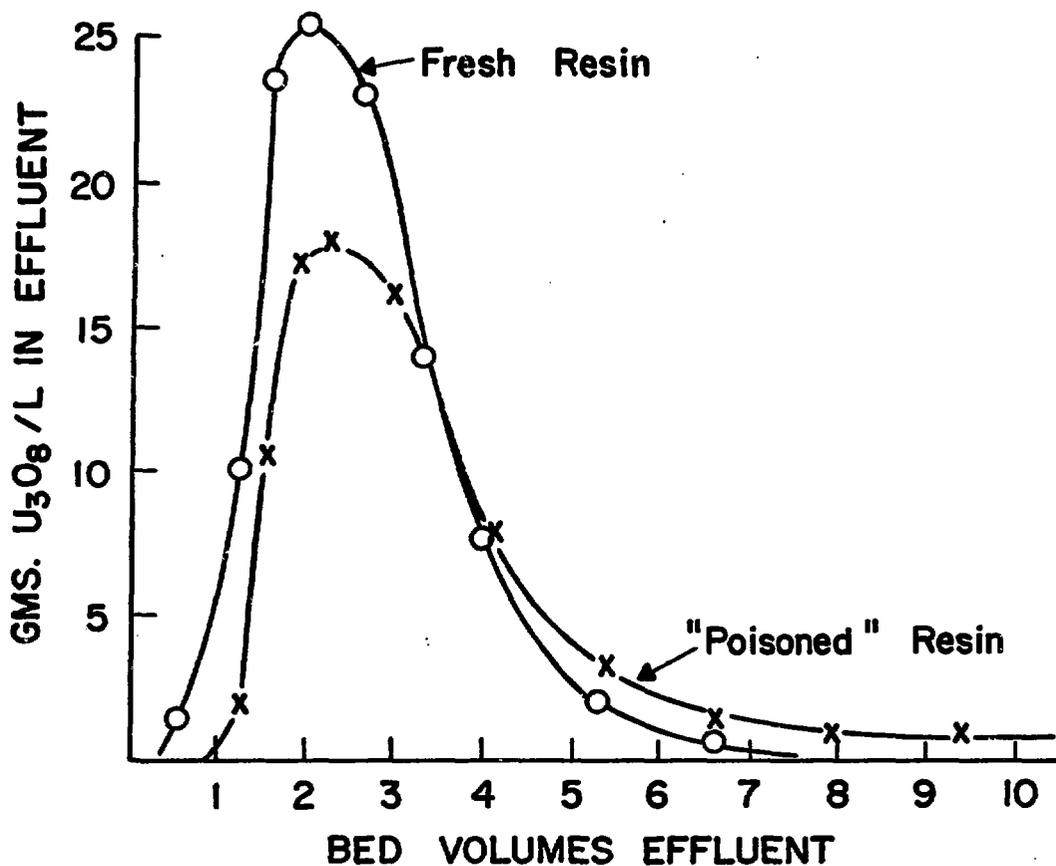OF FRESH AND "POISONED" AMBERLITE IRA-400[7]

FIGURE 3. A COMPARISON OF DESORPTION CHARACTERISTICS OF FRESH AND "POISONED" AMBERLITE IRA-400[7]

A 60% H_2SO_4 non-selective pug leach of uranium ore at the Navajo Uranium Division mill, Shiprock, New Mexico (7), dissolved the uranium plus undesirable minerals which produced the resin "poisoners", with up to 4.9% molybdenum, zirconium, titanium, hafnium, silicon, iron, phosphate and organic humates.

A resin ash content of 7% was achieved in 40 cycles. This increased to between 14 and 20% in 130 resin cycles. Operating resin capacities for uranium decreased noticeably with excess uranium leakage in barren effluents. Uranium breakthrough capacities decreased to 30% of fresh resin breakthrough capacity. The long tails on desorption curves, like Figure 3, became totally unsatisfactory. The Shiprock mill settled on the condensed inverse process, shown in Table 4, after much laboratory testing with the various rejuvenation processes shown. Fouled resins rejuvenated by the condensed inverse method over a 44-hour period at 4 month intervals over a period of 2 years showed no sign of deterioration.

The author (7) emphasizes that it is advantageous to convert the resin form from hydroxide to the chloride or sulfate form by contact with the appropriate salt before contact with strong acid or uranium sulphate leach liquors. This avoids osmotic shock to resin and the possibility of precipitation of uranium, iron, silica, etc., in the resin bed.

Rejuvenation of Poisoned Resin at Agnew Lake

Agnew Lake Mines Ltd, Espanola, Ontario, in the spring of 1978, was plagued with intolerable operating loading of uranium in the Himsley columns, due to tetrathionate ($S_4O_6^=$) poisoning formed by oxidation of pyrite during bacterial heap leaching of low-grade uranium ore piles.

TABLE 4

Resin Regeneration Processes

| Process	Reagent Sequence	Bed Volumes	Contact Time Hr.	% Ash Initial	Final	% Removal	Capacity gm U_3O_8/liter Resin Break-through	Saturation	Effluent Assay U_3O_8 ppm
EDTA	10% EDTA, 1 N NaCl, 1 N NaOH	27	33	7	0.33	95.3	55	69	...
	10% NaCl	4	2	9.1	0.6	93.4	51	61	<10
	10% NaOH	10	8						
	6% NaCl	3	...						
H_2SO_4 NaOH	48% H_2SO_4	15	12	7	0.55	92.1	55	67	<10
	10% NaOH	10	8						
	10% NaCl	4-5	3						
Complete inverse process	0.8 N NH_4NO_3-0.25 N H_2SO_4	9	7.5	14.6	0.11	99.2	54-57	63-66	<10
	10% Na_2CO_3	7	8						
	10% NaOH	8	8						
	10% NaCL	6	4						
	42% H_2SO_4	4.5	20						
Condensed inverse process	10% NaOH-10% NaCl	6	15	18.7	0.71	96.2	57	...	...
	10% NaCl	6	6						
	20% H_2SO_4	7	24						
Fresh resin capacity		...	...	...	...	...	60	72	<10

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A Himsley exchange column containing 240 cu. ft. of poisoned Duolite A-101 resin, after a 12% H_2SO_4 desorption of uranium, was water washed, desorbed first with 2% NaOH, then the column of resin was air-agitated with 8% NaOH for $\simeq 8$ hours (8). The strong NaOH was removed by water washing the resin column. The cleansed resin was then desorbed with 10% NaCl to convert the resin from the OH to the Cl form before uranium adsorption. This treatment would also minimize osmotic shock.

Eight hundred kilograms of sulphur, formerly tetrathionates ($S_4O_6^=$), was removed from the resin.

Removal of Tetrathionates at Mines Branch

Laboratory tests were performed to rejuvenate Amberlite IRA-400 resin that had been poisoned deliberately with uranium leach liquor "spiked" to 2 g $S_4O_6^=$/litre with $Na_2S_4O_6$ (9).

A 0.9 N NH_4NO_3 + 0.5 N HNO_3 desorbing solution appeared to strip the tetrathionate thoroughly from the resin, with evidence of strong gas evolution. The tetrathionates were probably oxidized to the sulphate with the formation of NO_2 gas, as:

$$S_4O_6^= + 14NO_3^- + 8H^+ \longrightarrow 4SO_4^{2-} + 14NO_2\uparrow + 4H_2O \qquad (3)$$
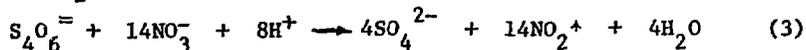
The NO_2 gas formed voids in the resin bed which were difficult to remove.

A 1 N NaCl + 0.5 NHO_3 desorbent was not as efficient as the above nitrate desorbent, but seemed very satisfactory. Copious free sulphur precipitated in both of the above desorbents, and in the NO_3 form of the resin columns on standing, as:

$$S_4O_6^= + 2NO_3^- \rightarrow 2SO_4^{2-} + 2S^0\downarrow + 2NO_2\uparrow \qquad (4)$$
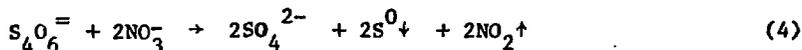
Chlorate desorbents would be ineffective in controlling the $S_4O_6^=$ build-up as the $S_4O_6^=$ is only partially removed.

DISCUSSION AND CONCLUSIONS

The evolution of NO_2 gas from an oxidation reaction on a resin exchanger is a potential hazard to ion exchange operators when contacting organic resins with strong oxidants such as nitric acid, chlorine, hydrogen peroxide, potassium permanganate, perchlorate, etc. (10). Anion-exchange resins are potentially hazardous when stored, dried or disposed of in the nitrate or perchlorate forms.

Resins can be contacted with dilute solutions of most oxidants under controlled laboratory conditions. However, hazardous conditions arise when contacting resins with more concentrated solutions of oxidants in large-scale commercial operations; violent exothermic reactions can occur in columns where heat is not readily dissipated, resulting in rapid formation of extreme pressures and explosions.

The degree of resin "poisoning" appears to be a function of:

1. the minerals in the radioactive ore to be treated, e.g., sulphides and silica which are subsequently solubilized in the leaching process

2. the selectivity or non-selectivity of leaching conditions, reagents, temperature, etc., and

3. the chemical change undergone by mineral constituents in solids preparation and leaching, e.g., sulphide oxidation, silica hydrolysis, and $Fe^{2+} \rightarrow Fe^{3+}$.

"Poisons" are produced which have a greater affinity for resin adsorption than the uranyl sulphate complex anion. These "poisons", once they are sorbed, will not desorb readily with the desorbing reagents normally used for uranium desorption. The severity of poisoning, resulting from resin contact with the final leach liquor, determines the reagents employed in the rejuvenation process and the frequency of rejuvenation.

The literature reviewed indicates that caustic soda (NaOH) is the reagent most commonly used to rid uranium exchangers of tetrathionate "poisons". The similarity in the rejuvenation processes end there. The rejuvenation procedure and the frequency of rejuvenation varies in the different mills. Consequently, a rejuvenation process was adopted that would encompass all the reviewed rejuvenation processes for the tetrathionate "poison". The adopted process is outlined as follows:

1. Water wash of resin bed to displace desorbing solution.
2. Downflow neutralization of resin bed with 2% NaOH to pH 7.0.
3. Replace 2% NaOH with 3 bed volumes of 10% NaOH and agitate with air for 7 to 8 hours.
4. Replace spent NaOH with 3 bed volumes of fresh 10% NaOH and air agitate as in (3).
5. Repeat 4. (In an industrial application, the spent NaOH from steps (4) and (5) could be recycled to a subsequent rejuvenation).
6. Drain spent caustic and desorb $S_2O_3^{2-}$ and $S_3O_6^{2-}$ (equation 1) from resin bed with 10% until effluent pH = <7.
7. Water backwash to classify and check for lumps of resin.
8. Resin bed ready for service.

The relatively mild and inexpensive alkaline cyanidation waste, at Stilfontein (6), was almost 3 times more effective than NaOH in removing tetrathionate "poison" from an anion exchanger. Gold cyanidation mills, unfortunately, are geographically far removed from uranium ore processing mills in Canada. However, the reagents Na_2CO_3 and $Ca(OH)_2$, which are sufficiently alkaline and inexpensive relative to NaOH, were chosen as rejuvenation reagents in testwork to cleanse an anion exchanger deliberately "poisoned" with tetrathionate ($S_4O_6^{=}$). A potential saving in operating cost would result if these reagents are as beneficial as NaOH in removing the tetrathionate "poison".

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