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DEPARTMENT OF CIVIL ENGINEERING  
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## **Part I**

Determination of Approximate Efficiencies and Capacities  
of Various Adsorbents.

## INTRODUCTION

This study was undertaken in response to a request from the provincial Ministry of Health, to evaluate several methods for removal of uranium from well water in the Okanagan Valley of B.C. The naturally occurring uranium levels in some of these wells is above 100 ppb, and as the drinking water standard for uranium is 20 ppb, it has become necessary to develop an efficient, easily operated system to reduce uranium concentration. This study comprises the first step in this process by selecting the most appropriate adsorbent and estimating its efficiency and capacity.

## SELECTION OF ADSORBENTS

Peat was chosen as an adsorbent for evaluation because of its known adsorbing capacity and because of its ready availability in the Okanagan Valley. Its relatively innocuous nature makes it suitable for general home use by untrained operators. Peat was supplied by Radiation Protection Service from a local distributor (Western Peat Moss Ltd.). Activated carbons were also investigated because of their known adsorptive properties and ease of use. Because no information could be found on the nature of uranium adsorption, a wide range of charcoals were tested (acid washed charcoal, BDH; alkaline charcoal, BDH; coconut charcoal, Fisher, 6-14 mesh; coconut charcoal, Fisher finely ground).

Ion-exchange resins were studied because of their long-term suitability for treating water. Both cation and anion exchange resins were tested because the ionic characteristics of the uranium was not known. The salt form of the resins was chosen over the acid form as being more suitable for home use by untrained operators because of the ease and safety of regenerating exhausted columns with saline solution. The resins tested were obtained from Dow Chemical [DOWEX HCRW2 (cation) and DOWEX SBR (anion)].

The water sample was obtained by Radiation Protection Service from a well in the Okanagan Valley and was stored at 4° during the study period. The initial measured uranium concentration was 113 ppb.

## METHODOLOGY

### Peat and Activated Carbon Batch Tests

For preliminary testing, batch tests were done using 2 grams of activated carbon or oven-dried (104° C overnight) peat in 300 ml well water. Samples were stirred at 50 rpm for 2 hours using a Phipps & Bird six-unit paddle stirrer. Samples were filtered through #4 Whatman filters to remove adsorbant, because initial tests showed that centrifugation alone did not adequately separate the adsorbent from the water sample. Testing determined that the filters did not measurably remove uranium from the sample. Filtrate was sent to Chemex Labs Ltd. (North Vancouver, B.C.) for uranium analysis.

Subsequent batch tests were performed with peat using 600 ml of well water and a range of peat doses from 0.5 g to 5.0 g. The peat was dried as above and samples were stirred and filtered as above except that #2 Whatman filters were used to provide better separation. Observation showed that inadequate or uneven wetting of the peat left some of the peat floating on the surface of the water even after two hours stirring. At low loadings, this caused extreme variation in the results making it impossible to accurately estimate the peat capacity. In an effort to overcome this floating, oven-dried peat was weighed out and stirred in deionized distilled water for several hours to wet the peat. The peat was then removed by filtering and resuspended in the test well water. This reduced the floating problem although it did not eliminate it altogether. A second series of batch tests were run with pre-wetted peat and some duplicate loadings were included. This is the data which was used for calculating capacity. Some metal and chemical analyses were done on the filtrates from these tests as well as uranium analyses.

## Ion-Exchange Resin Tests

Small-scale ion-exchange resin columns were set up in the lab. These consisted simply of 50 ml glass burets with a quartz wool plug inserted above the stopcock. The ID dimension of the column was approximately 1 cm and columns were packed to a height of 25 cm so that approximately 25 ml of resin was contained in the column. Resins were prepared by soaking for 1/2 hours in deionized distilled water (anion exchange resin) or 10% NaCl solution (cation exchange resin) to swell the resin. No fines were developed during the soaking period.

For preliminary tests, approximately 300 ml of well water were applied to each at the rate of 9 ml/min. A subsequent test was run using only the anion exchange resin under the above conditions. This time, well water was pumped onto the column continuously and the eluant was analyzed periodically for uranium, chloride, sulphate and alkalinity.



## Analyses

Uranium analyses were conducted by Chemc. Labs Ltd. (North Vancouver, B.C.). Briefly, this method consists of the fluorimetric analysis of the uranium in a NaF/LiF fused disc prepared from the sample.

Metal analyses were carried out in our own labs using atomic absorption spectrophotometry. The EPA procedure for metals digestion was used and samples were analyzed on a Jarell Ash Model 810 or a Perkin-Elmer Model 703 AAS using techniques in operator manuals for both instruments.

All other analyses used Standard Methods for the Examination of Water and Wastewater, 14th ed. Chloride analysis was done by the mercuric nitrate method; colour was analysed on a Hellige Aqua Tester; hardness (calcium and total) was measured by EDTA titration; and sulphate was analysed by the turbidimetric method using a Bausch & Lomb Spectronic 88 spectrophotometer.

## Results

### I Initial Absorbent Tests

A partial analysis of the untreated well water sample is presented in Table I.

Preliminary batch tests were conducted using peat, various activated carbons and ion-exchange resins as absorbents with the results show in Table II. As only peat and the anion-exchange resin removed uranium significantly, all other absorbents were excluded from further testing. Both peat and the anion-exchange resin reduced uranium levels to well below the acceptable level of 20 ppb so more quantitative testing was done on both absorbents.

### II Peat Tests

The results of the detailed peat testing are presented in Table III. The peat was efficient at uranium removal, with the heavier loadings reducing uranium concentration to less than 1.0 ppb. These data were plotted to yield Langmuir Adsorption Isotherm (Fig. 1) and the Freundlich Adsorption Isotherm (Fig. 2). The former plot was used to calculate capacity. The equation of a straight-line plot is:

$$\frac{C/x}{m} = \frac{1}{aK} + \frac{C}{a}$$

where: C = concentration of adsorbate still in solution at equilibrium.

x = amount of adsorbate held by m grams of adsorbent

a = number of moles of adsorbate required to saturate 1 gram of adsorbent.

K = equilibrium constant for adsorption reaction.

The intercept is defined as  $1/aK$  and the slope as  $1/a$ . The slope was

obtained from the lower, linear portion of the curve and the capacity calculated as approximately 20 mg uranium per kg of peat. At this capacity, assuming an average value of 100 ppb for the uranium in the well water, it would require about 5 grams of peat to treat one litre of water.

The only impurity released in significant quantities from the peat was colour. Table II shows that after peat treatment all impurities analyzed were equal to or less than the concentrations present in the untreated water sample. Zinc in particular was significantly reduced by peat treatment and all metals were below drinking water standards. Colour increased to significant and undesirable levels as peat loading increased although no undesirable odour was detected at any level. For peat treatment to be useful in this application, a secondary purification step to remove colour would be necessary.

### III Anion-Exchange Resin Tests

The data obtained from the anion-exchange resin testing is presented in Table IV. The flow rate varies from a low of 5.8 ml/min to a high of 7.0 ml/min averaging approximately 6.5 ml/min.

At this average flow rate, the detention time of water in the column was approximately <sup>3</sup> minutes. The column removed uranium to less than 5 ppb, well below the desired limit of 20 ppb. This is slightly less efficient than the peat, but this may be due to the low detention time in the column.

Throughout the duration of the experiment, the progress of column saturation was monitored by measuring alkalinity, chloride and sulphate (the turn-around time on uranium analysis was too long to use uranium values for this purpose) as shown in Table IV and

Figure 3. The total capacity of the column calculated from the amount of chloride released, was 30 milliequivalents. Figure 3 also shows that alkalinity had the lowest affinity for the ion-exchange resin, but does not show which of sulphate or uranium had the highest affinity. Therefore, we can only estimate what the total capacity of the column would be for uranium ions. The minimum would be the amount put through in this experiment which was 8.5 litres. This is equivalent to a capacity of 100 mg of uranium per kilogram of resin (i.e., 26 ml column equals approximately 10 grams of resin and 8.5 litres of water initially at 113 ppb uranium was reduced to approximately 5 ppb uranium). This value compares very favourably with that found for the peat trials.

The exact form of the uranium complex is not known, therefore it is not possible to calculate exactly the capacity of the column. However, if we assume a charge of -1 we can obtain an estimate of the maximum capacity (charges of greater than one would reduce the total capacity). The total column capacity is 30 meq, therefore if all of the alkalinity adsorbed to the column were to be replaced by uranium complexes, then an additional 30 meq of uranium complex equal to 30 milli-Moles of uranium ion would be adsorbed. This is equal to 700 g of uranium ion per kilogram of resin (compared to peat at 20 mg uranium ion per kilogram peat). At 100 ppb uranium, our experimental-scale column would saturate at a throughput of  $7 \times 10^4$  litres. The real capacity for uranium adsorption will be somewhere between the two values presented above.

The pH trend during column treatment was upward with time, but evidently stabilizing at a value of about 8.0. The reason for the rise is obviously due to the breakthrough of alkalinity in the bicarbonate form, which then forces a change in the equilibrium condition of the carbonic acid - bicarbonate system. This shift uses up hydrogen ions, thus increasing the effluent pH. No adverse effects are anticipated, unless a very high calcium content is present in the raw water, which may allow some precipitation of  $\text{CaCO}_3$  to occur.

### Conclusions and Recommendations

Both peat and the anion-exchange resin reduced the uranium levels to below the desired limit. The anion-exchange resin is the preferred adsorbent because of its far greater capacity, the clarity (i.e., lack of colour) of the effluent, and its appropriateness for home use (in that the column can be regenerated by backwashing with a saline solution). The estimated maximum capacity for the anion-exchange resin is 0.7 g uranium ion per gram of resin.

Recommendations for the next phase of study, if it is deemed worthwhile, are as follows:

1. determine the exact capacity of the anion-exchange resin for uranium ions,
2. determine the effect of column detention time on efficiency of removal,
3. determine appropriate conditions for regenerating column,
4. estimate column size required for individual home use.

## References

1. EPA Methods for Chemical Analysis of Water and Wastes, March 1979.
2. Standard Methods for the Examination of Water and Wastewater, 14th ed., 1975.

TABLE I

Initial Composition of Untreated Well Water Sample

Analysis		
Uranium	114,107,113,117 ppb	
Lead	<0.005 ppm	
Zinc	1.86 ppm	
Copper	0.06 ppm	
Calcium	57.5 ppm	
Magnesium	22.0 ppm	
Molybdenum	<0.04 ppm	
pH	7.4	
Acidity	19.0 ppm as CaCO <sub>3</sub>	0.4 meq/l
Alkalinity	383 ppm as CaCO <sub>3</sub>	7.7 meq/l
Total Hardness	242 ppm as CaCO <sub>3</sub>	4.8 meq/l
Calcium Hardness	154 ppm as CaCO <sub>3</sub>	3.1 meq/l
Colour	0 APHA	
Chloride	10.5 ppm	0.3 meq/l

TABLE II

Initial Treatments

Treatment	Uranium After Treatment (2 hour contact time with stirring)
2g peat/300 mls water	2.45 ppb
2g H <sup>+</sup> charcoal/300 mls	98
2g OH <sup>-</sup> charcoal/300 mls	92
2g coconut charcoal/300 mls	117, 102 (coarse grind and fine grind)
Cation Exchange Resin	106
Anion Exchange Resin	0.30



TABLE III

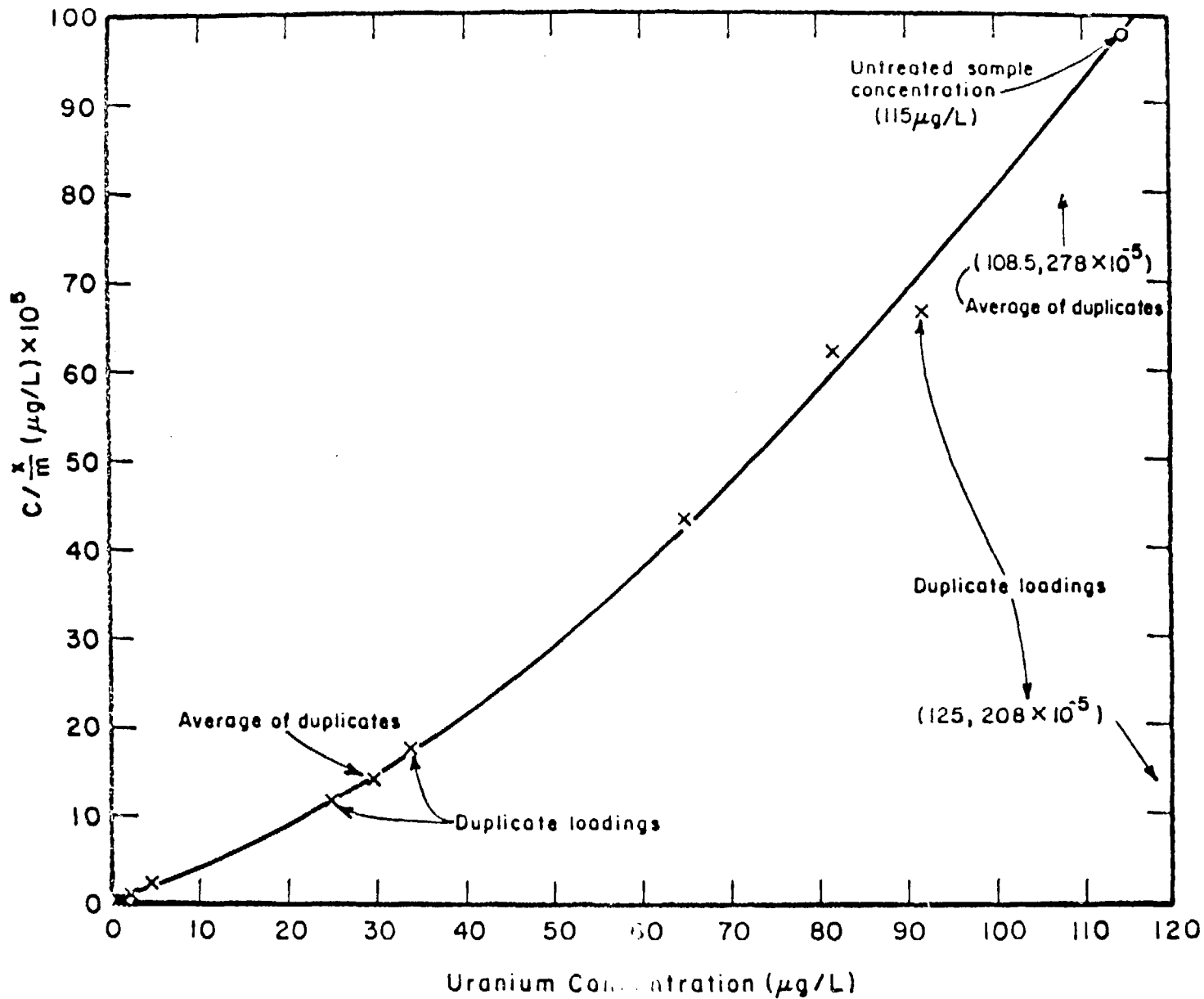
Second Peat Treatment

Peat per 600 mls water	U ppb	Pb ppm	Zn ppm	Cu ppm	Ca ppm	Mg ppm	Colour APHA	Mo ppm
0.5g	133	<0.005	0.21	<0.1	37.5	15.2	8	<0.04
1.0g	125	"	0.13	"	33.8	13.5	8	"
1.0g	92	"	0.12	"	31.3	13.2	15	"
1.5	82	"	0.08	"	24.4	12.2	20	"
2.0	65	"	0.08	"	19.4	10.7	25	"
2.5	34	"	0.09	"	19.4	7.9	30	"
2.5	25	"	0.08	"	11.3	7.4	30	"
3.0	4.5	"	0.03	"	6.3	4.0	35	"
3.5	1.75	"	0.03	"	3.8	2.8	40	"
4.0	0.85	"	0.03	"	3.1	1.8	55	"
4.0	0.95	"	0.02	"	2.5	1.5	50	"
5.0	0.65	"	0.03	"	3.1	0.9	65	"

TABLE IV

Anion Exchange Resin Treatment

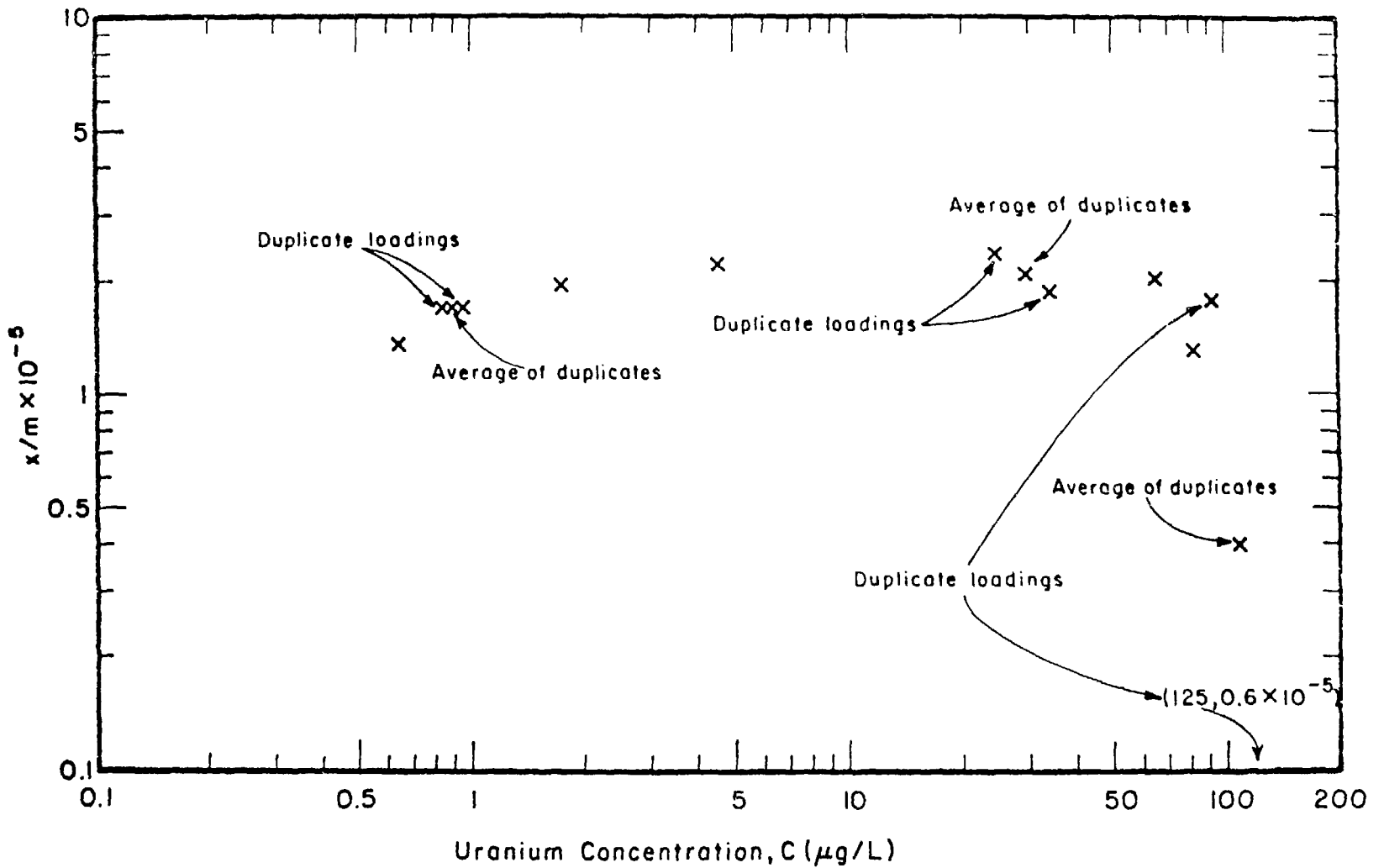
Sample #	Vol (ml)	U ppb	Alk (meq/l)	$\text{SO}_4^-$ (meq/l)	$\text{Cl}^-$ (meq/l)	pH
8012-281	untreated	188.	7.7, 7.7	0.78	0.30, 0.30	6.5
282	1042-1332	4.5	1.5	0	6.4	6.8
283	2192-2467	4.2	3.5	0	5.6	6.8
284	2467-2662	3.9	3.8	0	5.4	6.8
285	2662-2982	4.35	4.04	0	5.1	6.8
286	3342-3522	3.75	4.9	0	4.5	6.8
287	4132-4327	3.45	5.5	0	3.7	7.0
288	5352-5507	3.60	6.6	0	2.6	7.0
289	5902-6067	4.80	7.3	0	2.3	7.9
290	6067-6315	4.20	7.4	0	2.0	8.2
291	6315-6700	4.50	7.8	0	1.9	8.22
292	6700-6907	4.80	7.8	0	1.6	7.95
293	7607-7825	3.90	8.3	0	1.1	8.0
294	8325-8520	4.50	8.6	0	0.8	



LANGMUIR ADSORPTION ISOTHERM

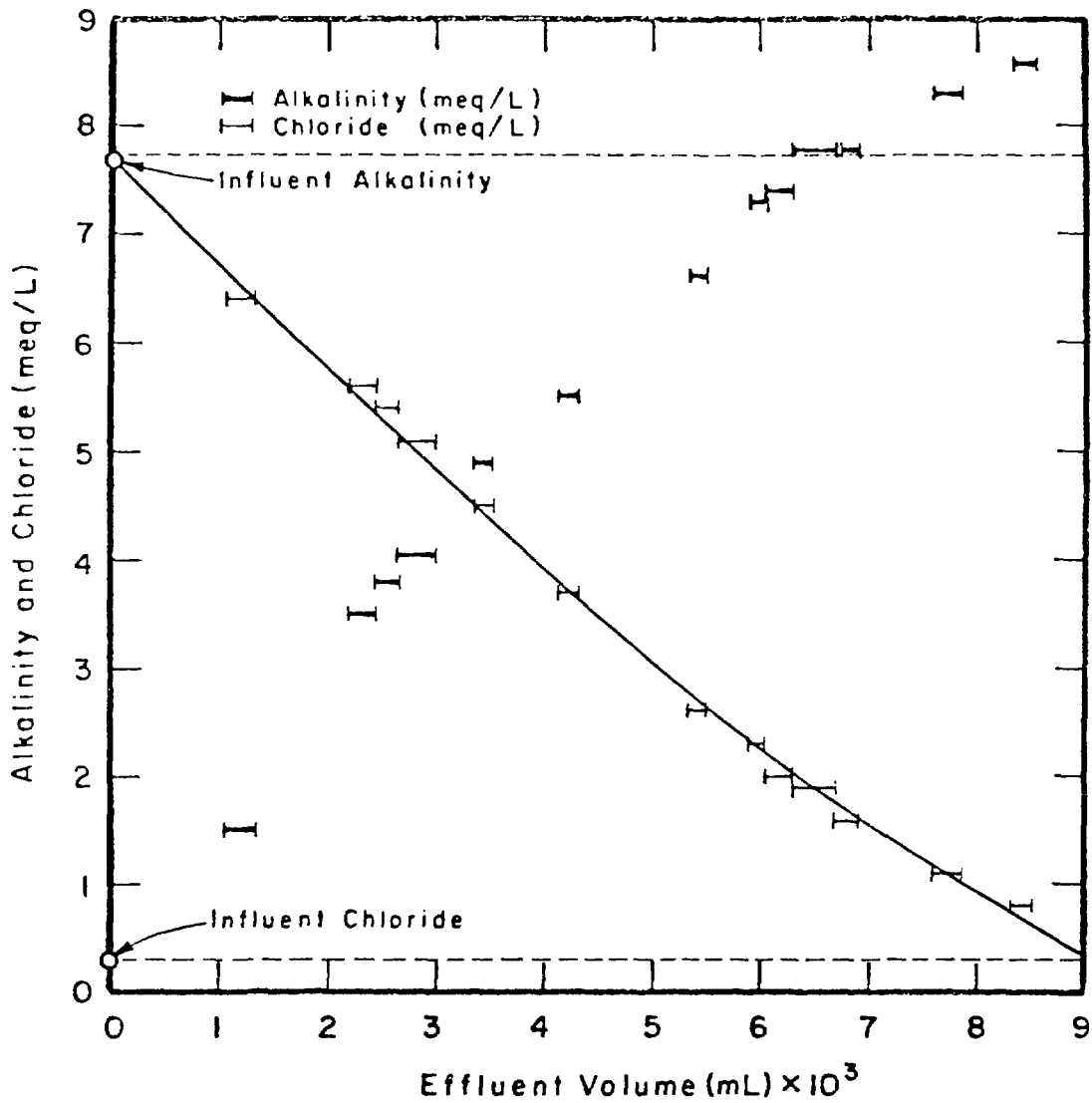
OKANAGAN WELL SAMPLE TREATED WITH PEAT

Figure 1



FREUNDLICH ADSORPTION ISOTHERM  
 OKANAGAN WELL SAMPLE TREATED WITH PEAT

Figure 2



**EFFLUENT CHLORIDE AND ALKALINITY**  
**ANION EXCHANGE RESIN**

Figure 3

## **Part II**

Investigation Of Anion Exchange Resin Properties and Model Design.

## INTRODUCTION

This study was the second phase of a project undertaken in response to a request by the Provincial Ministry of Health, to develop a method to treat well water with a high uranium content. The first phase consisted of an evaluation of several methods for removal of uranium from well waters in the Okanagan Valley of British Columbia. It concluded that anion-exchange resin produced the best removal of uranium, with an approximate maximum capacity of 0.7g uranium ion per gram of resin.

This phase of the study examined the effect of varying detention times, the selectivity of the resin for significant anionic species, and the process of column regeneration. The results obtained were used to design a model treatment system for a typical single family dwelling.

## I. Detention Time

To determine the effect of varying detention time on the efficiency of uranium removal, a small-scale anion-exchange resin column was set up in the laboratory and operated at detention times varying from 1 minute to 20 minutes.

### Methods

The resin column consisted of a glass burette with a quartz wool plug inserted above the stopcock, packed with Dowex SBR, a strongly basic anion exchange resin. The total column volume was 138 ml, composed of 94 grams of dry resin with a void volume of about 56 ml. Well water was fed onto the column by gravity flow and the effluent collected for analysis.

Uranium analysis were conducted by the Ministry of Environment Laboratories (Vancouver, B.C.), using fluorometric analysis of a NaF/LiF fused disc prepared from the sample.

### Results

The effect of varying detention time on efficiency of uranium removal is shown by the data in Table I. Detention times equal to or greater than 3 minutes all produced very efficient uranium removal down to less than 1  $\mu\text{g/L}$  uranium, while a detention time equal to 1 minute removed uranium only to 5.3  $\mu\text{g/L}$ . Therefore, a detention time of approximately 3 minutes was chosen for subsequent column tests as being fast enough to be convenient while still efficiently removing uranium.



## II. Resin Selectivity

To determine the relative selectivity of the resin for significant anionic species, a long-term test was conducted during which the effluent from the exchange column was periodically analyzed for anionic species.

### Methods

A small-scale anion-exchange resin column was set up in the lab. The column was similar to the one described in part I except it used a 25 ml burette and was composed of 10 g. dry resin in a total column volume of 15 ml. The void volume was estimated to be 6.3 ml. The well water was fed onto the column by gravity flow at a flow rate of approximately 2 ml/minutes. Two batches of well water of about 50 litres each were processed through the column and the effluent collected daily for analysis.

Uranium analyses were conducted by the Ministry of Environment as described above. All other analyses were performed in our own laboratory according to Standard Methods for the Estimation of Water and Wastewater, 14th ed. Chloride was analyzed by the mercuric nitrate method and sulphate was analyzed by the turbidimetric method (Bausch & Lomb Spectronic 88).

### Results

The analyses of the effluent from the ion-exchange column are presented in Table 2 and Figures 1 to 3, along with the analysis of the influent, untreated well water. The first 52 litres of influent was designated sample I and the second 56 litres of influent, sample II. The sharp increase in concentration of chloride and sulphates in the effluent at about 55 litres is due to sample II being slightly more concentrated than sample I, not due to any change in adsorption characteristics of the column.

Figure 1 presents the chloride data. Because the resin was in the chloride form, the effluent was initially high in chloride as other anionic species were adsorbed onto the column in place of the chloride. Figure 2 shows that alkalinity increased in the effluent to a level higher than influent (as alkalinity that had initially been adsorbed onto the column was replaced by sulphate and uranium ions) then fell to values equal to influent after about 20 litres had passed through the column. Up to this point, the sulphate in the effluent had been below detection limit (see Figure 3) but quickly rose to levels equivalent to influent as it was replaced by uranium ions. The uranium concentration in the effluent was always less than 1  $\mu\text{g/L}$  (Table 2). This data clearly demonstrates that uranium ions adsorbed preferentially throughout the test run. Even after over 100 litres of sample had passed through the column, effluent uranium was still below 1  $\mu\text{g/L}$ .

From these results, it is clear that the resin tested adsorbed the uranium complex preferentially to sulphate which was in turn adsorbed preferentially to alkalinity.

Knowing that uranium is adsorbed preferentially over the other major anions allows us to calculate an approximate capacity for the resin. In the first phase of the study (Adsorption of Dissolved Uranium From Well Water, Part I) the approximate capacity of the resin was determined experimentally to be 3 meq/g dry resin (which is comparable to the value quoted in the Dow literature of 3.5 meq/g dry resin). As the exact form of the uranium complex is not known, we cannot calculate an exact uranium capacity. However, if we assume a charge of -1, we can calculate a maximum capacity of 3 meq/g dry resin equivalent to 3 m Moles uranium/g dry resin which is approximately 700 mg uranium/g dry resin.

### III. Column Regeneration

The column used in the resin selectivity phase of this study was regenerated to ensure that this resin and eluant are suitable for home use.

#### Methods

The column from part I above was eluted with a solution consisting of 1 M NaCl and 10.15 M  $H_2SO_4$  which was fed by gravity flow at a rate of about 0.5 mls/min (equal to 2 total bed volumes/hour). The eluant was collected in 100 ml aliquots which were analyzed for uranium.

#### Results

The concentration of uranium in the eluant is presented in Table 3 and Figure 4. From Figure 4 it is evident that most of the adsorbed uranium was eluted by the first 300 mls of eluant. Summing the area under the curve in Figure 4 gives a rough estimate of the total uranium removed equal to 5.9 g, which compares within experimental error to 5.5 mg, the amount sorbed by the column during the ion selectivity phase of the study.

### IV. Design of Household Exchanger

There are two criteria of major importance to the design of an ion-exchange unit to serve an individual home water supply:

- 1) minimum liquid retention time in the exchanger, and
- 2) exchange capacity of the resin with respect to uranium, and the resultant calculated frequency of regeneration with the combined NaCl and  $H_2SO_4$  solution.

The small-scale laboratory column test has provided sufficient data to allow some design decisions for a full-scale facility to be made.

Assuming that uranium removal is only required for that portion of the household water supply that services the kitchen sink, the following design flows can be used:

- 1) maximum flow rate  $\approx$  15 litres per minute
- 2) average daily water use  $\approx$  90 litres.

In order to get a two minute minimum detention time of water in the exchange column, an empty column volume of 60 litres is recommended (20 cm dia. by 100 cm. long).

With a column of 60 litre volume, the mass of resin present will be about 40,000 g. The life of that amount of resin (before regeneration is necessary) has been estimated by two methods, to give a minimum and a maximum value.

- 1) Using measured uranium uptake figures from laboratory column study.
  - 5.5 mg. uranium adsorbed on 10g dry resin (with no breakthrough occurring), therefore a minimum anticipated uptake would be 22,000 mg. on 40,000g of resin.
  - using a design uranium concentration of 200  $\mu$ g/L in the well water, and a design water demand of 90 L/day, the resin would last for at least 1200 days, or 3 years, before regeneration is required.
- 2) Using the experimentally determined total anionic-exchange capacity.

- a total adsorptive capacity of 3 meq/g is synonymous with a uranium capacity of about 700 mg/g if it is assumed that there is one gram atom of uranium in each gram equivalent ion adsorbed. This assumption allows a calculation to be made of the maximum anticipated column life at the same flow conditions specified above. That column life is calculated to be more than 3,000 years.

It is obvious from the above that regeneration of the resin is not going to be a frequent task. In all probability the resin will be fouled by other impurities in the water long before it reaches its exchange capacity for uranium. It is probably wise to plan on a column renewal or regeneration frequency of about one year. The decision on renewal vs. regeneration will be an economic one, and can only be made after a full-scale column has been operated under field conditions to determine the required frequency of renewal or regeneration. If regeneration is practised, the data in Figure 1 suggests that some 10 to 15 bed volumes of regenerant will be required to release a substantial portion of the exchanged uranium. For the column size suggested, a regenerant volume of 300 to 450 litres appears to be necessary.

## V. Conclusions and Recommendations

The laboratory-scale column tests have definitely shown that Dowex SB-3 resin has a large capacity for preferentially removing uranium from solution in the well water tested. The general applicability of the resin has not been tested, and in situations where uranium is in solution in a cationic state, this resin will almost assuredly be very ineffective.

Regeneration of this resin needs to be looked at closely before any full-scale system is installed. The data in Figure 4 indicates that a considerably volume of regenerant (about 15 bed volumes) is required to accomplish 50% removal of adsorbed uranium.

It is recommended that a full-scale exchange column now be designed and installed with the help of a qualified manufacturer of ion exchange systems. The following concepts should be considered:

- 1) a column of about 60 litres volume should be used;
- 2) facilities should be built into the installation to allow regenerant solution to be passed through in the reverse direction at a rate of about 2 bed volumes per hour (as per Dow recommendations).

After installation, the column should be operated for a period of at least one year, with monthly sampling done to ensure that uranium breakthrough does not occur sooner. Upon breakthrough, or the expiry of one year, whichever comes sooner, regeneration should be undertaken, with sufficient sampling of the eluant to determine just how much regenerant will be required for regeneration of any other installed columns.

The undertaking of such a field study will allow a decision to be made on the efficacy of resin replacement vs. resin regeneration for such uranium removal columns.

Table 1

Effect of Detention Time on Uranium Removal

Detention time (min)	Measured flow (mls/min)	Effluent Uranium (ppb)
1	52	5.3
2	30	0.6
8	6.5	0.7
14	4.0	0.2
20	2.8	0.3

Untreated water uranium concentration = 41 ppb

Table 2  
Resin Selectivity - Eluant Composition

Cumulative Flow (l)	Uranium (µg/l)	Chloride (meq/l)	Alkalinity (meq/l)	Sulphate (meq/l)	pH (pH units)
untreated					
sample 1	45.6	1.1	8.2	0.78	7.32
1.2	0.4				
2.0	0.3		4.54		7.95
3.5	0.3	3.80	6.68		8.17
4.6	0.2	2.05	8.41		8.44
5.4	0.2	1.57	9.08		8.30
6.7	0.2	1.37	9.41		8.24
8.3	0.2	1.35	9.05	< detection limit	8.23
9.7	0.1	1.38	8.97	"	8.27
12.1	0.3	1.10	8.65	"	8.27
14.6	0.2	1.09	8.50	< detection limit	8.08
17.6	0.3	1.05	8.55	0.20	8.28
19.8	0.2	1.02	8.15	0.80	8.35
22.7	0.1	1.05	8.05	0.87	8.10
28.1	0.1	1.05	8.13	0.91	8.19
31.4	0.1	1.09	8.05	0.83	8.15
34.0	0.1	1.03	8.10	0.87	8.37
36.0	0.2	1.04	8.05	0.83	8.40
38.6	0.2	0.96	8.12	0.83	8.40
41.1	0.1	0.91	8.11	0.92	8.32
43.5	0.1	0.92	8.06	0.88	8.42
45.3	0.2	0.93	8.00	0.88	8.50
47.0	0.1	0.92	8.12	0.94	8.42
51.9	0.2	1.0	8.25	0.90	8.60
Untreated					
Sample 2	56.4	1.80	8.88	1.3	
54.2	0.2	1.60	8.33	0.98	8.35
56.2	0.3	1.58	8.45	1.4	8.45
58.4	0.3	1.69	8.50	1.7	8.45
60.7	0.3	1.73	8.50	1.5	8.49
63.3	0.2	1.78	7.90	1.5	8.60
65.0	0.9	1.74	8.42	1.6	8.51
69.9	0.5	1.75	8.50	1.5	8.46
72.4	0.5	1.76	8.81	1.4	8.39
78.0	0.5	1.76	8.74	1.4	8.48
80.4		1.63	8.67	1.4	8.51
82.4		1.69	8.73	1.5	8.50
84.8		1.66	8.69		8.45
87.1		1.63	8.69		8.46
92.2		1.70	8.68	1.2	8.52
94.7		1.69	8.77		8.45
97.1		1.75	8.57		8.48
100		1.75	8.57	1.3	8.49
106		1.75	8.45		8.38
108	0.5	1.75	8.60	0.94	8.51



Table 3

Column Regeneration

Volume of Eluant (mls)	Uranium in Eluant ( $\mu\text{g/L}$ )
0 - 100	25,400
100 - 200	17,000
200 - 300	12,680
300 - 400	2,400
400 - 500	800
500 - 600	640

FIGURE: 1  
URANIUM REMOVAL STUDY  
Chloride Concentration in Column Effluent

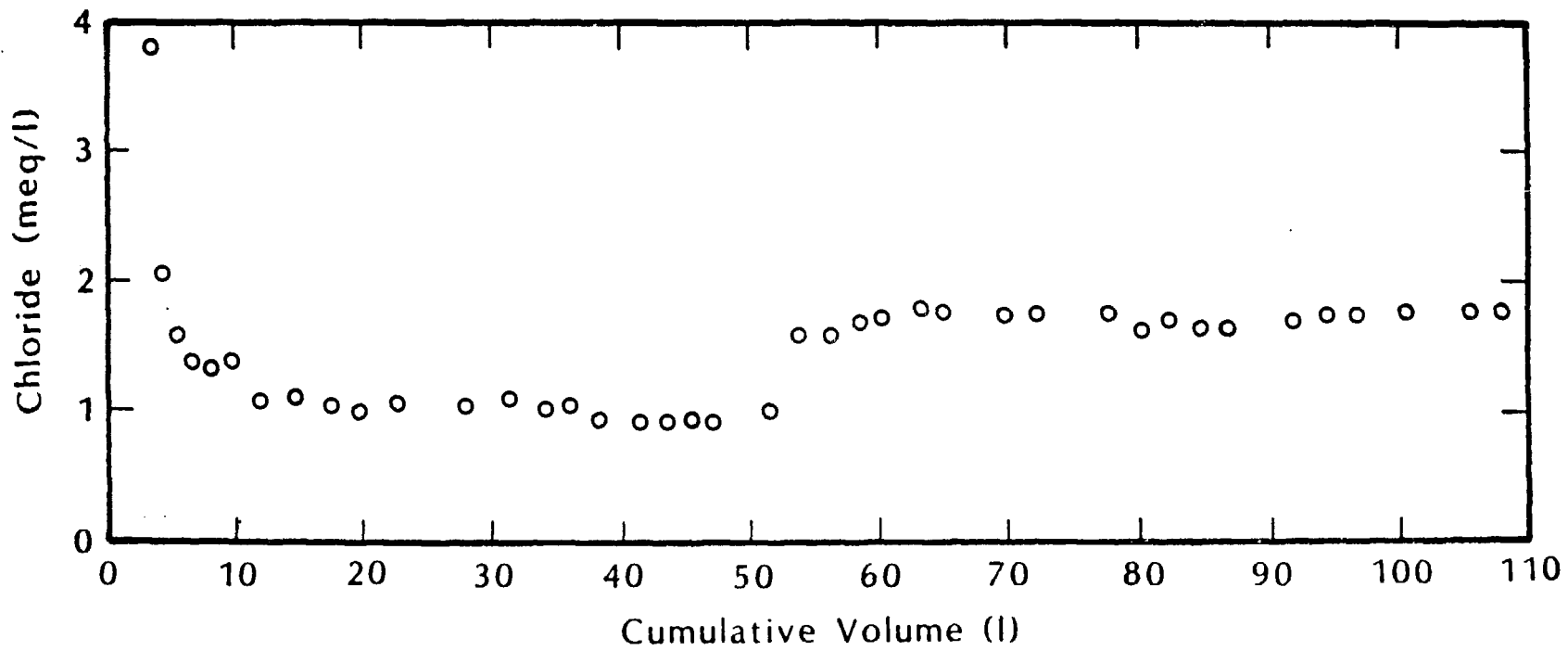


FIGURE: 2  
URANIUM REMOVAL STUDY  
Alkalinity Concentration in Column Effluent

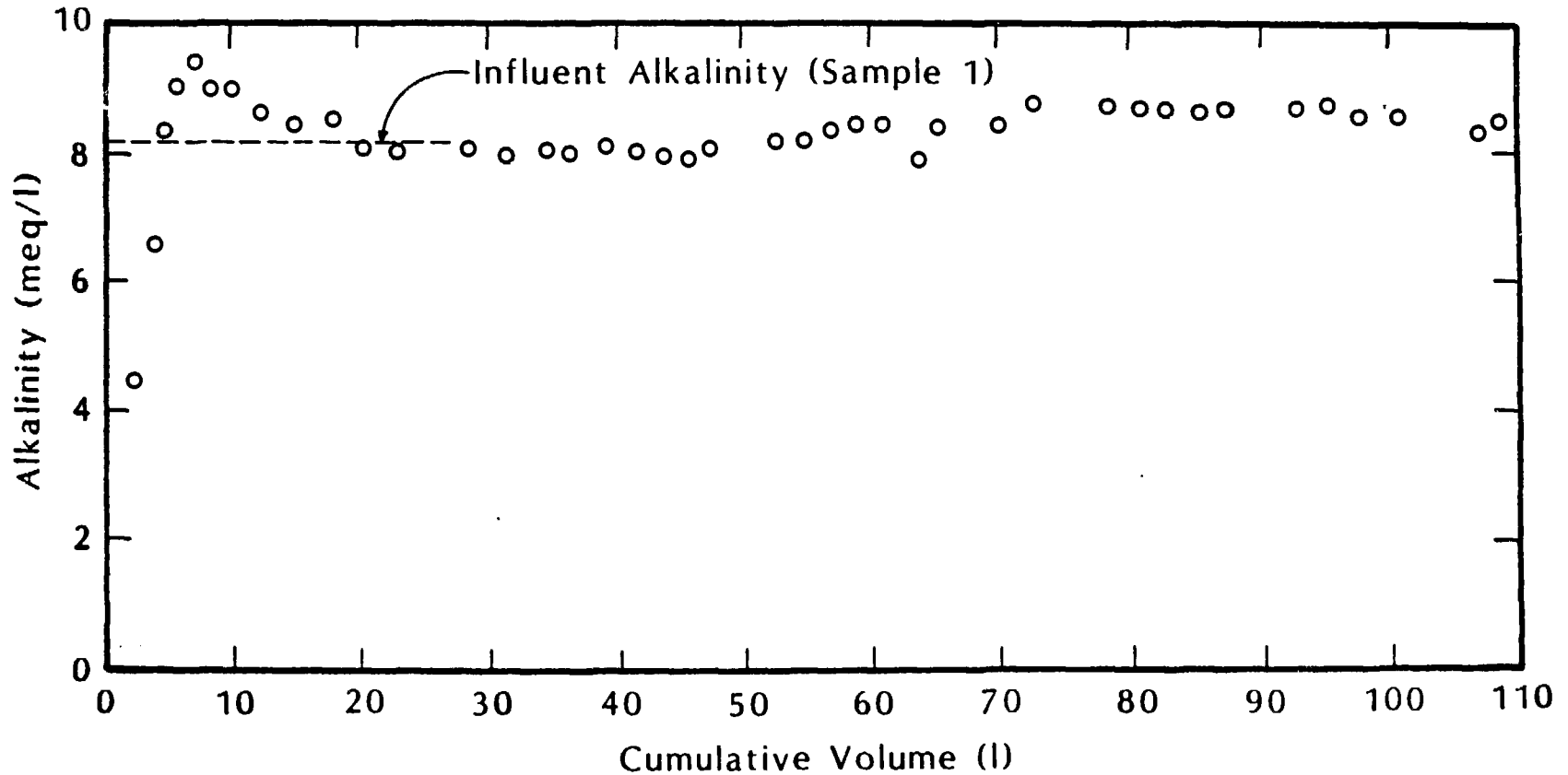


FIGURE: 3  
URANIUM REMOVAL STUDY  
Sulphate Concentration in Column Effluent

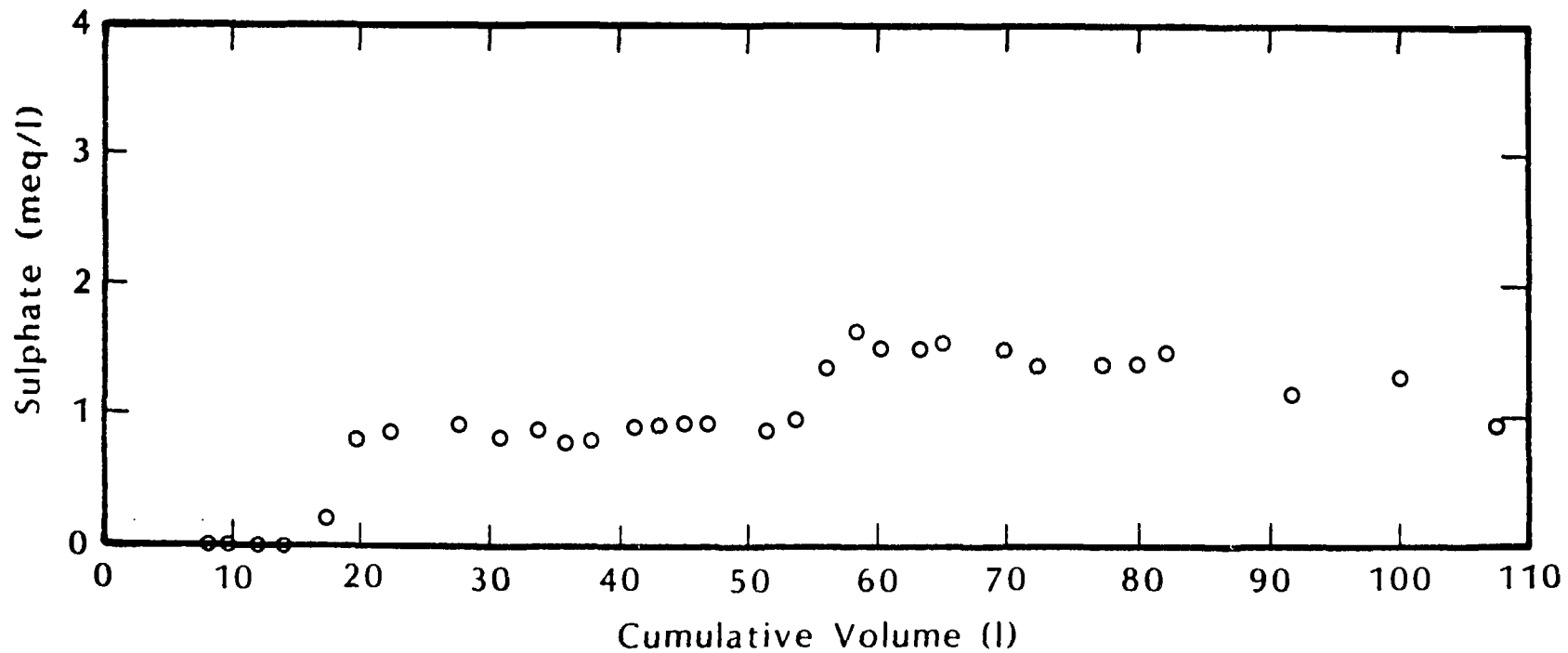


FIGURE: 4  
COLUMN REGENERATION  
Uranium Concentration vs. Eluant Volume

