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CANADA

DEPARTMENT OF ENERGY MINES AND RESOURCES

MINES BRANCH

OTTAWA

MINES BRANCH INVESTIGATION REPORT

IR 70-12

February ~~25~~, 1970

A STATISTICAL ANALYSIS OF URANIUM LEACHING DATA FROM RIO ALGOM MINES LIMITED, ELLIOT LAKE, ONTARIO

by

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SUMMARY

A detailed statistical analysis was conducted of data from fifty-three individual uranium, acid leaching tests done by the staff of Rio Algom Mines Limited. The effects of initial acid addition in the range 20 to 90 lb H_2SO_4/ton and leaching temperature in the range of 70 to 90°C on uranium extraction, acid consumption, and ferric/ferrous ratio of the leach solution were tested. Due mainly to the experimental error in this work being greater than many observed variations where test conditions were varied, the results of the statistical analysis are of limited value in that they were only useful in indicating general trends. The most important trends, indicated by the relevant correlation coefficients, are that uranium extraction and acid consumption increase with increased acid addition and temperature.

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INTRODUCTION

In September 1969, the research staff of Rio Algom Mines Limited, Elliot Lake, Ontario, requested that the Mines Branch conduct a statistical analysis on the results of a designed leaching experiment carried out by the company's R & D staff. The data from this experiment were received from the company on 30 October, 1969.

The leaching experiment was designed around three independent variables: acid at eight levels between 20-90 lb/ton, temperature at seven levels between 70-90 C°, and time at two levels between 24-48 hours. The dependent variables measured during each individual test were; U_3O_8 extraction (%), free acid (g/l), acid consumption (lb/ton), and ferric/ferrous ratio. The data are reproduced in Table 1 which contains measurements obtained from fifty-three individual tests. Eleven of these tests were replicated to obtain an estimate of experimental error.

PROCEDURE

The correlations between the dependent and independent variables were tested by calculating the relevant correlation coefficients. Also, first- and second-order linear regression equations relating the dependent and independent variables were calculated [1]. The regression analysis calculations produced approximately fifty empirical models for statistical assessment. Assessment was further aided by scanning about 500 computer-produced plots which graphically compared the data obtained during the test work with the results predicted by the models.

A verbal explanation of the detailed findings, along with the computer listings with suitable notations of the results, was presented to the company's research staff at a meeting held at Elliot Lake, Ontario, January 6, 1970. In attendance were E. Barnes, K. Keshvani and R. Simpson, representing Rio Algom, and the author representing the Extraction Metallurgy Division. Since the detailed results, which were not very conclusive, have been communicated to the company, only a summary of the results is given in this report.

Table 1

U308 ACID LEACH TEST DATA FROM RIO ALGOM≠S QUIRKE MINE ELLIOT LAKE ONTARIO

RUN NO.	ACID	TEMP	24HR U308 EXT	24HR H+	48HR U308 EXT	48HR RATIO FERIC TO FEROUS	48HR H+	48HR ACID USED	REPLICATED RUNS
	(LB/T)	(C)	(%)	(G/L)	(%)		(G/L)	(LB/T)	123456789**
1	20.0	70.0	41.3	0.01	68.0	0.014	0.01	20.0	
2	30.0	70.0	65.1	2.40	75.8	0.057	3.50	26.7	
3	40.0	70.0	56.4	9.00	64.1	0.260	7.00	33.1	
4	50.0	70.0	64.8	17.10	76.9	0.260	13.70	37.5	
5	20.0	75.0	40.6	0.01	61.7	0.026	0.01	20.0	
6	30.0	75.0	68.8	2.60	81.9	0.098	3.00	27.2	
7	40.0	75.0	56.7	8.50	71.8	0.232	6.60	34.0	1
8	40.0	75.0	70.9	8.50	77.0	0.257	6.90	33.6	1
9	50.0	75.0	69.1	15.90	81.6	0.265	12.40	38.5	
10	20.0	80.0	75.7	1.00	79.9	0.061	0.70	19.3	2
11	30.0	80.0	78.4	4.90	90.1	0.096	3.90	26.4	3
12	40.0	80.0	80.5	10.20	85.4	0.196	8.60	32.1	4
13	50.0	80.0	86.2	16.80	95.9	0.265	14.20	37.0	5
14	50.0	80.0	84.4	16.40	91.8	0.279	13.70	37.3	5
15	20.0	85.0	41.8	0.01	62.1	0.127	0.30	19.7	6
16	20.0	85.0	57.2	0.01	73.3	0.123	0.80	19.3	6
17	30.0	85.0	74.4	3.30	84.2	0.217	2.80	27.2	7
18	40.0	85.0	48.2	7.30	65.7	0.202	5.30	35.2	8
19	50.0	85.0	61.0	13.10	82.7	0.073	10.30	39.5	9
20	20.0	90.0	77.9	0.90	83.1	0.085	1.50	18.7	
21	30.0	90.0	84.6	4.20	92.5	0.315	4.20	26.1	+
22	30.0	90.0	84.8	4.40	93.9	0.158	4.10	26.1	+
23	40.0	90.0	76.1	8.70	94.7	0.127	9.20	31.6	
24	50.0	90.0	90.2	14.10	97.8	0.191	14.00	37.3	
25	20.0	80.0	-----	------	73.7	0.067	0.70	20.0	2
26	20.0	80.0	-----	------	75.0	------	------	20.0	2
27	30.0	80.0	-----	------	81.8	0.071	3.70	26.6	3
28	40.0	80.0	-----	------	77.0	0.170	8.10	32.6	4
29	50.0	80.0	-----	------	86.0	0.269	15.10	36.2	5
30	20.0	85.0	56.7	0.10	74.9	0.122	1.00	19.0	6
31	20.0	85.0	41.5	0.01	68.3	0.102	0.70	19.3	6
32	30.0	85.0	72.0	3.00	83.5	------	3.30	26.9	7
33	40.0	85.0	55.5	7.40	72.6	------	7.30	35.2	8
34	50.0	85.0	66.8	13.00	87.0	------	11.40	39.5	9
35	20.0	82.5	31.2	0.01	58.5	0.013	0.01	20.0	
36	30.0	82.5	69.4	3.20	79.5	0.197	2.70	26.6	
37	40.0	82.5	70.1	6.70	82.1	0.159	7.50	33.1	
38	50.0	82.5	74.5	14.50	83.0	0.265	9.80	41.0	
39	60.0	82.5	71.1	20.90	88.3	0.231	16.80	44.9	
40	20.0	87.5	79.1	1.20	88.2	0.132	1.30	18.8	
41	30.0	87.5	85.8	4.40	92.3	0.155	4.10	26.1	
42	40.0	87.5	80.1	8.70	92.4	0.110	9.00	31.6	
43	50.0	87.5	86.6	14.50	95.9	0.161	12.60	37.8	
44	-----	-----	-----	------	----	------	------	-----	
45	60.0	87.5	92.0	20.80	97.6	0.250	17.30	43.9	
46	60.0	70.0	76.5	------	84.8	------	------	-----	
47	70.0	70.0	84.3	------	89.2	------	------	-----	
48	80.0	70.0	88.0	------	93.0	------	------	-----	
49	90.0	70.0	93.3	------	95.2	------	------	-----	
50	60.0	80.0	88.6	------	93.3	0.259	17.40	44.2	
51	70.0	80.0	91.6	------	96.2	0.274	24.80	47.9	
52	80.0	80.0	93.1	------	96.9	0.228	31.40	52.1	
53	90.0	80.0	95.5	------	97.0	0.195	39.00	55.3	*
54	90.0	80.0	-----	------	96.9	------	------	-----	*

RESULTS

Most of the correlation coefficients calculated were statistically significant and ranged from 0.3 to 0.8 for the relationships investigated. Generally the lower values were obtained for the correlation between retention time and extraction and temperature and extraction, while the higher values were obtained for such correlations as final acid concentration or acid consumption versus initial acid addition.

Neither the first- or second-order equations, developed from the data, provided satisfactory fits to the data. They could not therefore be used to predict the effects of experimental conditions not actually tested. In effect the regression equations did not provide any additional information over that supplied by the correlation coefficients. Since none of these equations were of any statistical value they are not reproduced in this report.

The relatively low correlation coefficients obtained and the failure of the linear regression technique to yield significant relationships between the independent and dependent variables can be attributed to two factors. The first of these is the experimental error associated with the observed values of the prime response, uranium extraction. The variation in uranium extraction with duplicate tests was as much as 15% (Table 1, Tests 15 and 16), after 24 hours of leaching, and as much as 11% (Table 1, Tests 18 and 34) after 48 hours. Consequently in many cases there were greater variations in the extractions obtained in duplicate tests than there were in tests having different variable levels. Consequently it is impossible to say that there is any statistical significance to the observed drop in extraction between 80 and 90°C, although the consistency of the temperature effect throughout the test work suggests that it is a real effect.

The second factor influencing the statistical significance of the results is the consistent drop in extraction with 40 lb H_2SO_4 per ton as compared to that obtained at 30 lb H_2SO_4 per ton when other experimental conditions are similar. This is difficult to understand since it is not what would be expected either from chemical considerations or from the trend observed in all the other tests in Table 1 where an increase in acid addition usually results in an increased extraction. The effect of both of the above factors is that, when a first-order regression equation is calculated from all the results, the values predicted from the

equation, where 40 lb H_2SO_4/ton and 80° to 90°C are used, are considerably different from the observed results but are within the expected experimental error. Consequently the value of the regression equation is in serious doubt.

CONCLUSIONS

Because of the problems introduced by the experimental error and the results obtained with 40 lb H_2SO_4 per ton, the only significant statistics obtainable from the test observations were the correlation coefficients. The conclusions that can be made on the basis of the correlation coefficients are listed below, and they are essentially the same conclusions as can be obtained from a visual inspection of the results.

1. The U_3O_8 extraction shows a significantly positive correlation with initial acid addition in the range of 20 to 90 lb H_2SO_4 per ton and with leaching temperature in the range of 70 to 90°C. There is also, as might be expected, a significant positive correlation of the interaction effect of temperature and acid addition with U_3O_8 extraction.

2. Free-acid concentrations increased with increased amounts of acid added and also increased as a result of the interaction effect between acid and temperature. Time and temperature alone had no significant effect on the free-acid concentration in the solution.

3. Acid consumption increased with increased amounts of acid and as a result of the interaction effect between acid and temperature. The effect of temperature alone on the acid consumption was negligible.

4. Ferric to ferrous ratio increased with increased amounts of acid but temperature had no significant effect on this response.

The work done in analysing statistically the results of this leaching investigation suggests that the results are being influenced by uncontrolled variables and/or some form of bias. To settle the questions that are still unresolved, a further controlled experiment would have to be done in which the individual tests would be run in a random sequence, and would be controlled in such a way as to reduce experimental error to within $\pm$ 5% of the absolute values of the observations, if possible.

REFERENCES

1. Draper and Smith, "Applied Regression Analysis", Wiley, 1967.