THE EFFECTS OF URANIUM MINING ON ENVIRONMENTAL GAMMA RAY EXPOSURES

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1. INTRODUCTION

Uranium mining has been conducted by several companies in south Texas since the mid 1950's after deposits were discovered on the surface. Most of the ore removed since the early 1960's has come from depths of 20 to 50 meters, and is mined by the open-pit method. This process leaves piles of waste rock and the deep pit at abandonment. This waste rock, termed overburden, can contain enough uranium and progeny to produce gamma ray exposure rates greater than the 0.5 rem per year limit required by the Texas Department of Health Resources (TDHR) for non-occupationally exposed persons.

After a south Texas land owner announced his plans to build a home on an overburden pile, it was decided to perform radiation surveys of abandoned mines in the area. This report contains results of 21 such surveys.

2. DESCRIPTION OF MINING AND SURVEY TECHNIQUES

The south Texas uranium deposits occur in isolated pockets as "roll front" deposits. The boundaries between barren sandstone and mineralized rock are sometimes sharp and othertimes indistinct. The concentrations of uranium can range several thousand fold in distances from one meter to several tens of meters in both vertical and horizontal directions. The distinction between ore and rock to be wasted is, therefore, based upon economic rather than physical considerations.

Before a deposit can be mined, it is necessary for the area, grade and thickness of the ore to be determined by obtaining gamma ray logs of holes drilled in and around the area to be mined. Prior to any mining, the topsoil in the area of the pit and overburden piles may be removed and stockpiled. The overburden is then removed and piled near the pit. As the ore is approached, the uranium content of the removed rock is continually checked. When the grade exceeds the lower limit for milling, the ore is brought to the surface and piled upon the ore pad, an area prepared for that purpose. Next, the ore is loaded onto trucks and shipped to the mill. Historically, the mines were abandoned at this point.

The last material taken from the mine prior to ore removal contains uranium concentrations just below the mill cutoff limit. The elevated radiation levels on the top of the overburden pile can exceed 200 microRoentgen per hour (μR/hr). Our regulatory limit of 0.5 rem per year corresponds to 57 μR/hr above background. If the ore is incompletely removed from the ore pad, it, too, will have high radiation levels.

As practiced prior to the adoption of land reclamation rules by the Texas Railroad Commission, mining left the land with the overburden piled at or near its angle of repose and, as the rock was frequently lacking necessary nutrients for plant growth, the piles were barren. The radiation levels often exceeded 0.5 rem per year also, but the land was considered wasted and of no value as residential property. Water which collected in the pits was often unfit for consumption due both to high dissolved solids content and radioactivity (1). The adoption of practices complying with standards governing the levels of radiation and land reclamation by mining companies is restoring the agricultural and residential value of newly mined areas.

The survey procedure developed by the TDHR uses 25 x 25 mm sodium iodide detectors in a commercially available instrument. The meters have been calibrated in μR/hr by the US Environmental Protection Agency (EPA), which loaned us two of the instruments used in the survey, and by the authors for later calibration of the EPA and the TDHR instruments. The measurements were taken at 0.6 meter nominal heights, usually every 50 meters on parallel lines placed 100 meters apart. Due to the rough nature of the terrain, it was often necessary to alter either the direction or spacing of the lines, and occasionally the spacing between measurements. A survey of the Smith Mine is shown in Figure 1 as an example.

Surveyed mines include those most recently mined as well as some of the older mines. The mines omitted from this survey were omitted because of legal disputes, the fact that mining was in progress, or for time constraints.

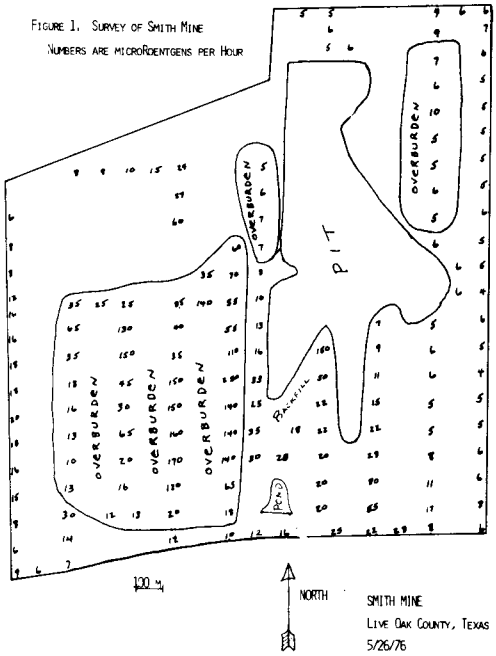


FIGURE 1. SURVEY OF SMITH MINE
NUMBERS ARE MICRORÖENTGENS PER HOUR

TABLE 1. INDIVIDUAL MINE DATA

MINE NAME	Number of Measurements	% > 62 μR/hr	Backfill	Slope Red.	Covering	Normal Bg.	CAUSE
Korzekwa #1 & 2	85	38					BG, P, OB
Galen	121	21	*			*	OB, OP
McLean #1	59	44					OB, OP, P, BG
Kopplin	80	9				*	OB, OP
Weddington	157	13	*			*	OB, P
Felder #1, 2, 3	206	27	*			*	OB, OP
Lauw	132	1.5		*	*		P
Ryan	37	11			*		OB, BG
Gillette Group	223	4.5		*		*	OB
McGrady	172	0.6	*	*	*	*	OB
Wright	77	0		*	*	*	
Pfeil	70	0		*	*	*	
Stoeltje	197	3		*	*	*	OB, OP
Manka	113	3.5			*	*	OB, OP
Pawelek	106	5			*	*	OP, OB
Smith	151	13	*			*	OB
McLean #5	40	18				*	OB, OP
Beiker	83	0			*	*	
Esse	115	3.5	*	*	*	*	OP, OB
Brown	109	0		*	*	*	
Kotzur	58	0		*	*	*	
All Mines	2391	10					
Old Mines	708	24					
New Mines	1683	4					
No Reclamation	901	21					
Partial Reclamation	1490	2					

3. RESULTS AND CONCLUSIONS

High gamma ray exposure rates (in excess of 62 μR/hr) were found on 16 of 21 mined areas surveyed. The causes believed responsible for these high levels are: mineralized overburden (15 of 16); ore pads (8 of 16); mineralized rock in the pit (4 of 16) and background levels over 62 μR/hr (3 of 16).

The mines surveyed are listed in Table 1 in approximate chronological order of the first date of mining. The oldest mine surveyed is the Korzekwa #1 mine dug in 1958 or 1959. The Felder mines were begun in 1969 and are the most recent of the mines considered "old" for this study. The youngest mine is the Kotzur, mined in 1976 and surveyed as reclamation work was being completed. The group considered "new" includes all mines dug to feed a mill opened in 1972, as well as new mines of other companies. The efficiency of the new mill was greater than that of the other two in the area. That, along with the increase in the prices of uranium, resulted in a lower mill cutoff limit and a correspondingly lower radiation level in the wasted rock. Most of the recent mining has also included some land reclamation, including reducing the steepness of the overburden piles, covering them with stockpiled topsoil, and wasting the ore pad into the pit. Topsoil depth on the overburden piles is related to topsoil depths prior to mining, usually zero to three meters. The surveyed areas are listed in Table 1, with the number of measurements, percent of measurements exceeding 62 μR/hr, four columns to indicate if any backfilling of the pit, slope reduction of the overburden, covering of the overburden, and normal background existed. An asterisk (*) means "yes". The column labeled "Cause" contains the reasons for the high readings in order of frequency at that mine. In this column "BG" means the background exceeded 62 μR/hr in at least one spot, "OB" means the overburden exceeded the limit, "OP" means the ore pad exceeded it, and "P" means there was mineralized rock accessible in the pit exceeding the 57 μR/hr limit plus an assumed nominal 5 μR/hr background.

Totals for all mines, those classified as "old", "new", those with no reclamation, and those with partial reclamation are also listed. Partial reclamation means reducing the slopes of the overburden piles and covering them with whatever topsoil existed. Backfilling was not considered to be reclamation.

The data in Table 2 is a summary of the survey data. The frequency of readings falling within each of the indicated ranges (each one-fifth of a decade on a logarithmic scale) for all mines, and for the four classifications of mines, is shown. The histograms in Figure 2 are for the cases of no reclamation and partial reclamation and are from the Table 2 data. An obvious difference exists in the distribution of radiation levels between the two classifications. Radiation levels are considerably higher for the case of no reclamation. Reclamation efforts without regard to the radiation levels (as the reclamation has been done in the past) are very successful in reducing the gamma ray exposure rates on abandoned uranium mines, but are not completely successful in reducing them to below the regulatory maximum. Mines abandoned without reclamation efforts present potential radiation hazards to persons who may occupy homes built there. The hazard stems from the direct gamma ray exposures and from the radon emanating from the mineralized rock. It should be emphasized that our limit on radiation levels of 57 μR/hr above background resulting from uranium ore may not provide sufficient protection from radon to occupants of buildings which may be built upon that land (2).

Similar results are obtained by comparing the "old" to "new" mines, but nearly the same two groups of mines are being compared, as can be seen from close inspection of Table 1.

Current requirements for reclamation by both Texas agencies regulating uranium mining include sloping the overburden piles to reduce erosion; covering the piles to provide shielding and reduce slightly the radon emanation; planting grasses to reduce erosion; removing all traces of ore from the ore pad; and contouring the land to drain rainfall runoff into the pit reducing the dissolved mineral content (and thereby the radioactivity) and allowing silt to cover the pit bottom.

TABLE 2. STATISTICAL SUMMARY OF SURVEY MEASUREMENTS

CRITERION	DOSE RATE (μR/HR)														
	0-5	6-9	10-15	16-25	26-39	40-62	63-99	100-158	159-251	252-398	399-631	632-999	1000-1590	1591-2520	2521-UP
All Mines	4.6	29.8	27.8	15.5	7.5	5.1	3.2	3.3	2.3	0.6	0.1	0.0	0.04	0.04	0.04
Old Mines	0.4	8.9	18.8	21.6	15.8	10.9	7.5	7.2	6.4	1.8	0.4	0.0	0.1	0.0	0.1
New Mines	6.4	38.6	31.6	12.9	4.0	2.7	1.4	1.7	0.5	0.1	0.0	0.0	0.0	0.1	0.0
No Reclamation	2.9	11.4	18.2	21.7	14.4	9.8	6.8	7.1	5.6	1.4	0.3	0.0	0.1	0.0	0.1
Partial Reclamation	5.6	40.9	34.6	11.7	3.3	2.3	1.0	1.1	0.2	0.1	0.0	0.0	0.0	0.1	0.0

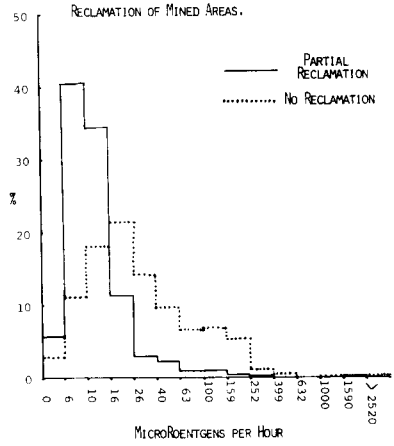
Other reclamation possible includes totally backfilling the pits, usually an expensive alternate unless the material comes from an adjacent pit. Weakly mineralized rock could be stockpiled separately and covered. This would allow future milling without more mining, should it become economical.

4. SUMMARY

Uranium mining has resulted in radiation levels at some abandoned uranium mines exceeding regulatory limits. On approximately one-tenth of the mined area of south Texas, radiation levels exceed 0.5 rem per year. In three instances, levels exceed 5 rem per year. Although no one is believed to be receiving exposures in excess of 0.5 rem per year now, the area being mined is increasing, and so is the State's population. Individuals occupying a dwelling built on an area exceeding our limits could receive excessive lung exposures from radon as well as gamma ray exposures exceeding 0.5 rem per year.

Radiation levels on mines can be reduced through reclamation efforts on the part of the mining company. One of the most effective methods is to cover the overburden piles with dirt or rock not containing significant concentrations of uranium and its progeny and by wasting the ore pad into the pit.

FIGURE 2. FREQUENCY OF OCCURRENCE OF GAMMA RAY EXPOSURE RATES FOR THE CASES OF PARTIAL RECLAMATION AND NO RECLAMATION OF MINED AREAS.



While covering the mineralized overburden with topsoil effectively reduces the gamma ray dose rate, it is insufficient protection against radon 222 emanation unless the cover is several meters thick. This is not always possible using locally available topsoil for cover.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

(1) Wukasch, M.D. and Cook, L.M., 1972. "Environmental Surveillance in South Texas" in The National Radiation Environment II, p. 845 ff, U. S. ERDA CONF - 720805 - p. 2.

(2) Fitzgerald, J.D.; Guimond, R.J.; and Shaw, R.A.; November 1976. "A Preliminary Evaluation of the Control of Indoor Radon Daughter Levels in New Structures" U. S. EPA.