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# LIME RETENTION IN ANTHRACITE COAL-BREAKER REFUSE

*Abstract.*—Hydrated lime was applied to extremely acid anthracite coal-breaker refuse at rates of 2.5 and 5.0 tons per acre. The lime raised the pH to neutral range, and this range was still in evidence 7 years after treatment. The pH readings decreased with the depth of the refuse profile, and below 9 inches they approximated those of the control plots. The 2.5-tons-of-lime-per-acre treatment was almost as effective as the 5.0-ton treatment. Application of lime in establishing vegetation on coal-breaker refuse is recommended and encouraged.

Anthracite coal-breaker refuse is a pyrite-bearing material. It is extremely acid—too acid for plant survival. It is a continuing source of acid mine drainage, adversely affecting streams and rivers of the region. One way to minimize this acidity is to apply sufficient lime or lime materials.

Lime and lime materials are accepted soil amendments in agriculture, as well as in intensively managed forests; and their benefits have been well documented in the literature.

Lime has many functions in soil, but its primary function is to adjust the base saturation of soil colloids on the exchange complex by replacing the hydrogen ions with calcium ions. Thus it reduces acidity and may alleviate possible toxic levels of iron, manganese, aluminum, and other ions that are known to be phytotoxic at excessive levels.

In 1965 we applied lime to coal-breaker refuse in the Anthracite Region of Pennsylvania to establish crownvetch (*Coronilla varia* L.), Japanese larch (*Larix leptolepis* [Sieb. and Zucc.] Gord.), and red pine (*Pinus resinosa* Ait.). We found that lime was essential for establishing them.

But with the application of lime, two important questions arose: Will the lime effect be of short or long duration? To what depth in the refuse profile will this effect extend?

This is a report on the levels of reaction of (1) the 0- to 3-inch surface layer for 7 consecutive years after liming; and (2) the 15-inch profile 5½ years after lime application on graded refuse and 6½ years after application on ungraded refuse.

## The Study

In the spring of 1965 we applied hydrated lime (125 percent $CaCO_3$ equivalent) on two anthracite coal-breaker refuse piles—at Tamaqua in the Southern Coal Field and at Shamokin in the Western-Middle Coal Field. At both locations the lime was applied to the surface, although some incorporation may have occurred during subsequent planting.

The coal-breaker refuse in Tamaqua was about 60 years old, graded to near level, and compacted; and it had a pH value of 3.9. Six plots, each measuring 20 by 30 feet, were limed at a rate of 2.5 tons per acre; a like number of plots were limed at 5.0 tons per acre. The liming rates were estimated on lime-requirement data, designed to raise the pH to about 6.0 and 7.0 respectively. The plots were planted to crownvetch.

The coal-breaker refuse pile in Shamokin was about 70 years old, ungraded, with about 45° slope and a southern aspect; it had a pH value of 3.3. Four plots, each measuring 60 by 60 feet, were limed at 5.0 tons per acre and were planted to Japanese larch and red pine seedlings. In 1969 the plots were interplanted with hybrid poplar (*Populus hybrid*) clone NE–388. At both locations the necessary control plots were established. The experimental design, site characteristics, treatment, and early performance of crownvetch and trees have already been reported (*Czapowskyj, et al. 1968; Czapowskyj, in press*).

Refuse samples from the 0- and 3-inch surface layer were taken in the spring or fall from 1965 to 1972. The pH values were determined, and means were computed from the limed and control plots.

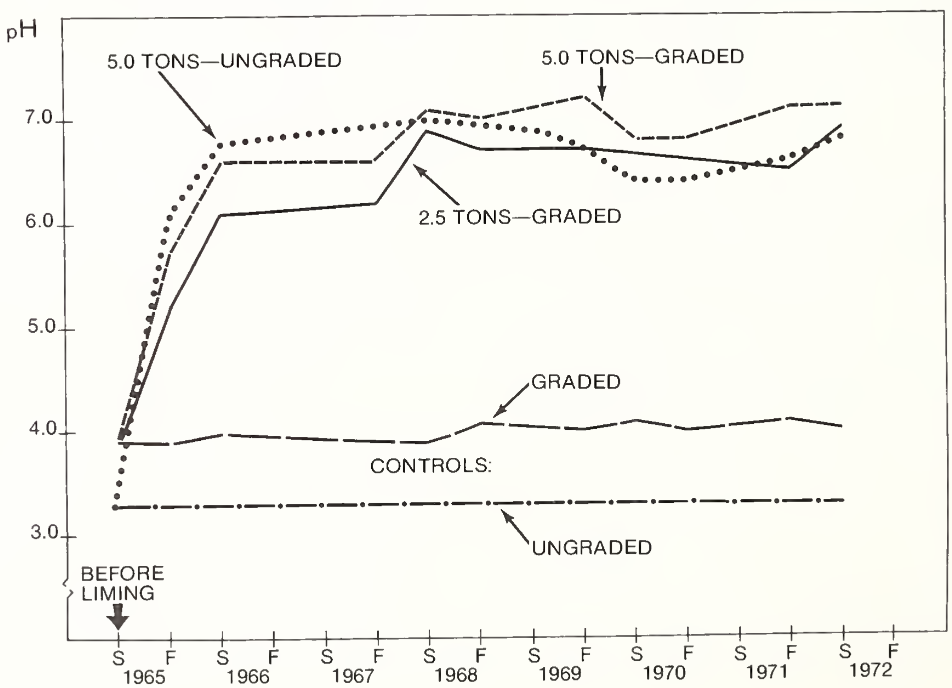
In the fall of 1970 we collected a series of samples at 3-inch intervals to the 15-inch depth from the refuse pile in Tamaqua and in the fall of 1971 from the Shamokin refuse pile. Limed and control plots were sampled. 144 samples were collected from the plots in Tamaqua and 120 from the plots in Shamokin.

All pH values were determined, using a Beckman Zeromatic pH meter in an aqueous solution of 1 to 1 spoil-water ratio and allowing a 30-minute equilibrium period. Mean pH values and ranges were computed and tabulated.

## Results and Discussion

*pH of the surface layer.*—Before liming, the experimental plots were highly acid (fig. 1). As expected, lime gradually raised the pH of the surface layer of both the graded and un-

Figure 1.—Average pH values of graded and ungraded anthracite coal-breaker refuse related to liming rate and years after application. S = spring; F = fall.



graded coal-breaker refuse plots. Three years after liming, the neutral range was reached, and it remained in this range for the following 2 years. During the sixth year, the mean pH values decreased slightly and then increased slightly in the fall of 1971 and in the spring of 1972.

The mean pH values of the ungraded refuse at Shamokin, which was limed with 5.0 tons per acre, were slightly higher than the pH values of comparable graded refuse at Tamaqua for the first 3 years. Then pH values of the ungraded refuse decreased slightly during the following years. A slight increase was noted in the spring of 1972 (fig. 1).

*pH of the profile.*—The pH measurements of the refuse profile to 15 inches in the control plots at Tamaqua were 3.9 to 4.0 at all depths.

The effects of lime were evident for 5½ years. Refuse samples from the 0 to 1.0-inch upper surface layer were still near neutral. At 3.0 inches the refuse was slightly to medium acid, but the lowest pH value was within the range of pH values in the control plots. The pH values were somewhat higher for the 5.0-ton lime rate than for the 2.5-ton rate in the upper 3 inches. At 6.0 inches the mean pH values of plots limed at either rate were only slightly higher than those of the control plots, but the pH value of 6.7 in the 2.5-ton-per-acre treatment showed that some of the lime had reached this depth. At the depth of 9 to 15 inches the refuse was extremely acid, and no effect of lime was evident (table 1).

The ungraded refuse plots at Shamokin were more acid than the graded plots at Tamaqua. Here the pH values ranged from 3.0 to 3.5 near the surface and 2.8 to 3.1 at 9 inches in depth. The refuse was near neutral near the surface 6½ years after treatment with 5.0 tons of lime per acre. Below 3 inches in depth, the effect of lime decreased sharply. At 9 inches there was some evidence of lime, but at 12 inches the pH values were almost identical to those of the control plots. The range in pH values at 6 to 9 inches suggested that some lime had migrated downward. This may have been due to the slope steepness and the loose material in the plots or to some incorporation of lime into the refuse during liming, tree planting, and mulching activities.

Table 1.—Average pH values (and ranges) of anthracite coal-breaker refuse

[Average of 8 replications]

| Depth (inches) | Lime in tons per acre: 0 | 2.5 | 5.0 |
|---|---|---|---|
| GRADED REFUSE—TAMAQUA[1] | | | |
| 0.5 | 3.9 (3.5–4.2) | 7.4 (6.6–8.0) | 7.8 (7.6–8.0) |
| 3.0 | 3.9 (3.5–4.2) | 5.9 (4.0–7.8) | 6.5 (4.3–7.6) |
| 6.0 | 4.0 (3.7–4.1) | 4.7 (3.8–6.7) | 4.4 (3.4–5.4) |
| 9.0 | 4.0 (3.6–4.4) | 4.2 (3.4–5.0) | 4.1 (3.9–4.6) |
| 12.0 | 3.9 (3.8–4.2) | 4.1 (3.6–4.6) | 4.2 (3.5–4.9) |
| 15.0 | 3.9 (3.1–4.5) | 3.9 (2.4–4.6) | 4.0 (3.5–4.5) |
| UNGRADED REFUSE—SHAMOKIN[2] | | | |
| 0.5 | 3.3 (3.0–3.5) | — | 6.9 (6.5–7.2) |
| 3.0 | 3.3 (3.0–3.5) | — | 5.7 (4.6–7.2) |
| 6.0 | 3.2 (3.0–3.3) | — | 4.2 (3.1–6.3) |
| 9.0 | 3.0 (2.8–3.1) | — | 3.5 (3.3–3.7) |
| 12.0 | 3.4 (3.4–3.5) | — | 3.5 (3.3–3.7) |
| 15.0 | 3.4 (3.4–3.5) | — | 3.4 (3.1–3.5) |

[1] 5½ years after lime application.
[2] 6½ years after lime application.

*Response of vegetation.*—The effects of lime were also visible in vegetation growth (fig. 2). The planted crownvetch on limed plots in Tamaqua spread vigorously and after six growing seasons attained slightly over 85 percent ground cover on both liming treatments. There was no ground cover on the unlimed plots.

Red pine and Japanese larch on ungraded limed plots in Shamokin attained heights of 3.0 and 5.5 feet respectively. Survival was slightly over 31 percent. High mortality occurred during the first growing season, due mainly to rock slides and erosion from the steep slope. Hybrid poplar NE-388 had 80 percent survival and grew 3.9 feet after three growing seasons. No tree survived on the unlimed plots.

Figure 2.—The "lime line" is clearly visible on this graded coal-breaker refuse. The area on the left was limed; it produced a good cover of crownvetch. The area on the right was not limed; here no crownvetch survived.

## Findings and Conclusions

From this study the following findings and conclusions were made:

- Hydrated lime was highly effective in neutralizing the surface layer of anthracite coal-breaker refuse.
- Lime brought the surface layer (0 to 3 inches) to near neutral pH within a year, and the surface layer was still neutral 7 years after liming.
- Lime effect, in terms of neutral pH ranges and establishment of vegetation, was still in evidence 7 years after treatment.
- The effects of lime were detectable to a depth of 9 to 12 inches only.
- The lower liming rate—2.5 tons per acre—was as beneficial as the higher rate—5.0 tons per acre. Evidently 2.5 tons was enough to neutralize the refuse and establish vegetation on the coal-breaker piles studied.
- Average pH values gradually decreased with depth, and at 9 inches in the graded refuse and at 12 inches in the ungraded refuse, pH values on the treated plots approached the values on the control plots.
- Since comparatively low rates of lime neutralized the refuse for at least 7 years, liming appears to be a practical method for establishing vegetation on anthracite coal-breaker refuse. Its use is recommended.

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