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LEAF LITTER BREAKDOWN IN STREAMS RECEIVING TREATED AND UNTREATED METAL MINE DRAINAGE

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Rates of alder leaf decomposition were used as an ecosystem-level measure of effects of untreated and treated acid mine drainage on two Colorado mountain streams. Untreated mine effluents had low pH and high concentrations of metals, particularly iron. Deposition of ferric hydroxide on leaf surfaces inhibited colonization by decomposers, such as fungi and aquatic insects, and thus little leaf breakdown occurred. Treated effluents had improved water quality (basic pH, low metal concentrations), but suspended flocs released by the treatment process buried leaves and reduced consumer activity. The rate of leaf breakdown was not significantly different from the rate with untreated effluents; thus improvement in water quality alone was insufficient to restore this important pathway of energy flow in headwater streams.

Introduction

Terrestrial plant litter is an important source of energy for consumers in many headwater streams. The dynamics of its decomposition, particularly the leaf fraction, has been a focal point of contemporary research in stream ecology (Anderson and Sedell, 1979).

The breakdown of whole leaves in streams involves rapid leaching of soluble compounds and subsequent fragmentation to fine particulates (Cummins, 1974). Fragmentation results from physical and biological agents, including abrasion caused by turbulence, microbial metabolism, and the feeding activities of benthic invertebrates. The relative contribution of each factor varies with leaf species, geographic region, and composition of biotic communities (Anderson and Sedell, 1979).

Because of its importance in the flow of energy in streams, leaf decomposition provides an ecosystem-level measure of pollution effects. In this study we used rates of leaf breakdown as an indicator of the response of lotic consumers to effluents of treated and untreated acid mine drainage in two Colorado mountain streams. In Colorado, many of the estimated 30,000 abandoned metal mining operations significantly affect local water quality (Wentz, 1974).

In a previous examination of the study streams, Boyne *et al.* (1982) found greatly reduced numbers and biomass of benthic invertebrates downstream from the entrance of untreated mine drainage. However, concentrations of heavy metals were below toxic levels for some species, particularly "shredders" that consume whole leaves. They hypothesized that the absence of shredders resulted from deposition of ferric hydroxide on leaf surfaces, which inhibited microbial colonization and thus lowered food quality (Cummins, 1974). Treatment of effluents to remove iron and eliminate deposition of ferric hydroxide would presumably allow microbial colonization and subsequent feeding by shredders, and thus increase rates of leaf breakdown. The present examination was performed to determine whether an improvement in water quality following treatment is sufficient to restore the pathways of energy flow, as evidenced by rates of leaf breakdown.

Study Areas

The two study streams were Kerber Creek (38°18'N, 106°08'W), a third-order tributary of San Luis Creek near Villa Grove (3000 m a.m.s.l., gradient = 3%), and Coal Creek (38°53'N, 107°01'W), a third-order tributary of the Slate River near Crested Butte (2830 m, gradient = 3%). The two sites at Kerber Creek were located upstream (Site K-1) and downstream (Site K-2) from the entrance of untreated mine drainage that severely degraded water quality (Ingwersen, 1982; Wentz, 1974). Control (Site C-1) and impact (Site C-2) sites on Coal Creek were located above and below the entrance of treated mine effluents. Sites C-1 and K-1 were similar in physical-chemical characteristics: pH = 7.5-7.7; conductivity = 90-100 μS cm^{-1}; mean temperature = 2.0 °C; dissolved oxygen at or near saturation, and concentrations of heavy metals below detection limits (0.01 mg L^{-1}). Characteristics at Site K-2 were pH = 6.1-6.4; conductivity = 460-510 μS cm^{-1}; mean temperature = 3.8 °C; dissolved oxygen at 83%-90% saturation. Mean concentrations of selected metals were 9 mg L^{-1} for total iron, 16 mg L^{-1} for total zinc, and 11 mg L^{-1} for total manganese. Extensive deposits of ferric hydroxide were present on stream substrates. At site C-2, mean values of physical-chemical parameters were pH = 7.2-7.4; conductivity = 430-560 μS cm^{-1}; temperature = 3.8 °C; dissolved oxygen at or near saturation; and concentrations of metals below detection limits. However, effluents carried larger quantities of a flocculent material consisting of a synthetic polymer. The polymer is used to precipitate metals and was apparently released accidentally during operation of the treatment plant. This floc settled on the streambed, forming a layer several centimeters thick.

Materials and Methods

Alder leaves were used as the test species because of their rapid rate of breakdown (Short *et al.*, 1980) and abundance along both study streams. Leaves were collected just before abscission in September 1981 and preleached in the laboratory using filtered stream water. Weight loss from leaching was determined by placing 0.1 g of leaf material in a beaker with stream water and incubating at 2 °C (24 h). After leaching, leaves were air dried, oven dried (60 °C, 48 h), weighed into 5-g packs, and strung on monofilament line (Short *et al.*, 1980). Each leaf pack was then lashed to a brick and placed in the study sites on 10–11 October (approximately 4 months after treatment of effluents into Coal Creek had begun). Five packs were recovered from each site at 2-, 5-, and 8-week intervals. Remaining packs were recovered in April 1982 (28 weeks). During collection, the pack was cut free from its brick and placed in a plastic bag with 5% formalin. In the laboratory each pack was rinsed with tap water to remove sediments, oven dried, weighed to the nearest 0.1 g, and combusted at 550 °C (4 h) to determine ash-free mass.

Shredders associated with the leaf packs were stored in 80% ethanol until identified and enumerated. Total biomass was determined by drying at 60 °C (48 h).

Results and Discussion

Leaf processing in streams follows an exponential decay model: $Y_t = Y_0 e^{-kt}$, where Y_t = leaf mass remaining after t days; Y_0 = initial mass (= 5.0 g DW or 4.6 g AFDW); and k = rate loss coefficient (Petersen and Cummins, 1974). After allowing for losses from leaching (=18.4% ±4.4% of DW, 1 S.D., N = 20), loss rate coefficients were calculated for each study site from the percent remaining data in Fig. 1. All regressions were significant ($P \leq 0.01$). Loss rate coefficients and the time required for 50% loss of leaf material were k = 0.0147, 48 days at site K-1; 0.0032, 217 days at site K-2; 0.0109, 64 days at site C-1; and 0.0037, 187 days at site C-2. Packs recovered in April from sites K-1 and C-1 show that these rate loss coefficients are representative of long-term rates of leaf breakdown. Only veins and petioles remained of packs at site K-1 after 196 days, and the calculated time for 90% processing was 157 days. At site C-1, a mean of 24% of the leaf mass remained from two packs, and this percentage is within calculated 95% confidence limits (5%-27% remaining after 196 days).

Rates of alder leaf breakdown at the two control sites are similar to rates reported for other streams at similar

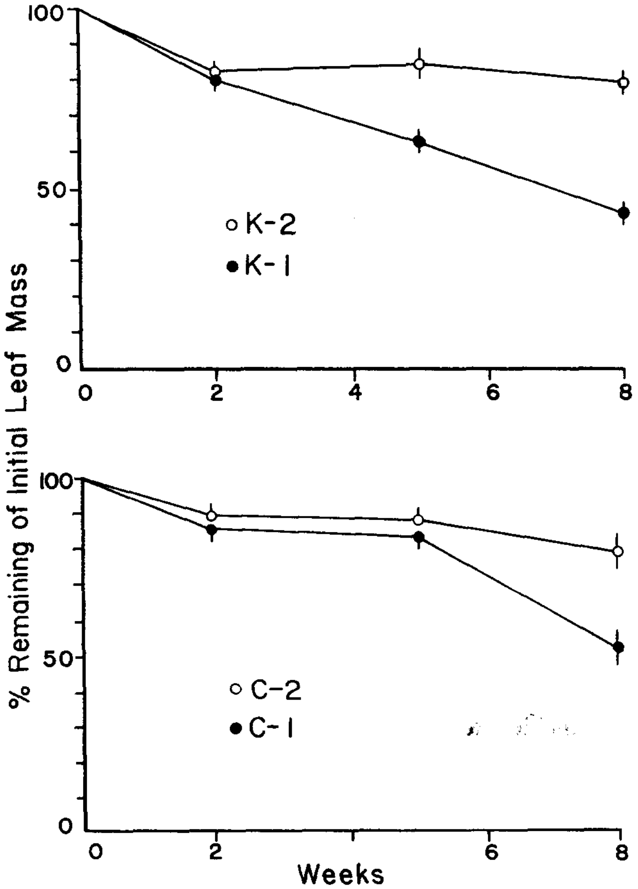

Fig. 1. Loss of leaf mass during fall 1981 in Kerber and Coal Creeks, CO, at control sites (K-1 and C-1), a site receiving untreated mine effluents (K-2), and a site receiving treated effluents (C-2). Vertical bars indicate ± 1 S.E.

temperatures (Sedell *et al.*, 1975; Short and Ward, 1980). Microscopic examination of unpreserved leaf fragments after 8 weeks in-stream showed extensive growths of fungal mycelia and surface bacteria (Fig. 2). Hyphae of Basidiomycetes fungi were common, but further identification was precluded by the absence of reproductive structures. The higher rate loss coefficient at site K-1 compared to C-1 can be attributed to a greater abundance of shredders. Shredder abundance averaged 18 individuals and 14.1 mg DW per leaf pack at K-1, whereas values at C-1 were 3 individuals and 1.8 mg DW per pack. These differences reflected the species present and their life cycles. Shredder activity in Kerber Creek resulted from late-instars of *Pteronarcella badia* (Plecoptera) and *Dicosmoecus* sp. (Trichoptera). In Coal Creek the dominant shredders were winter stoneflies (*Zapada* spp.) present mainly as early instars.

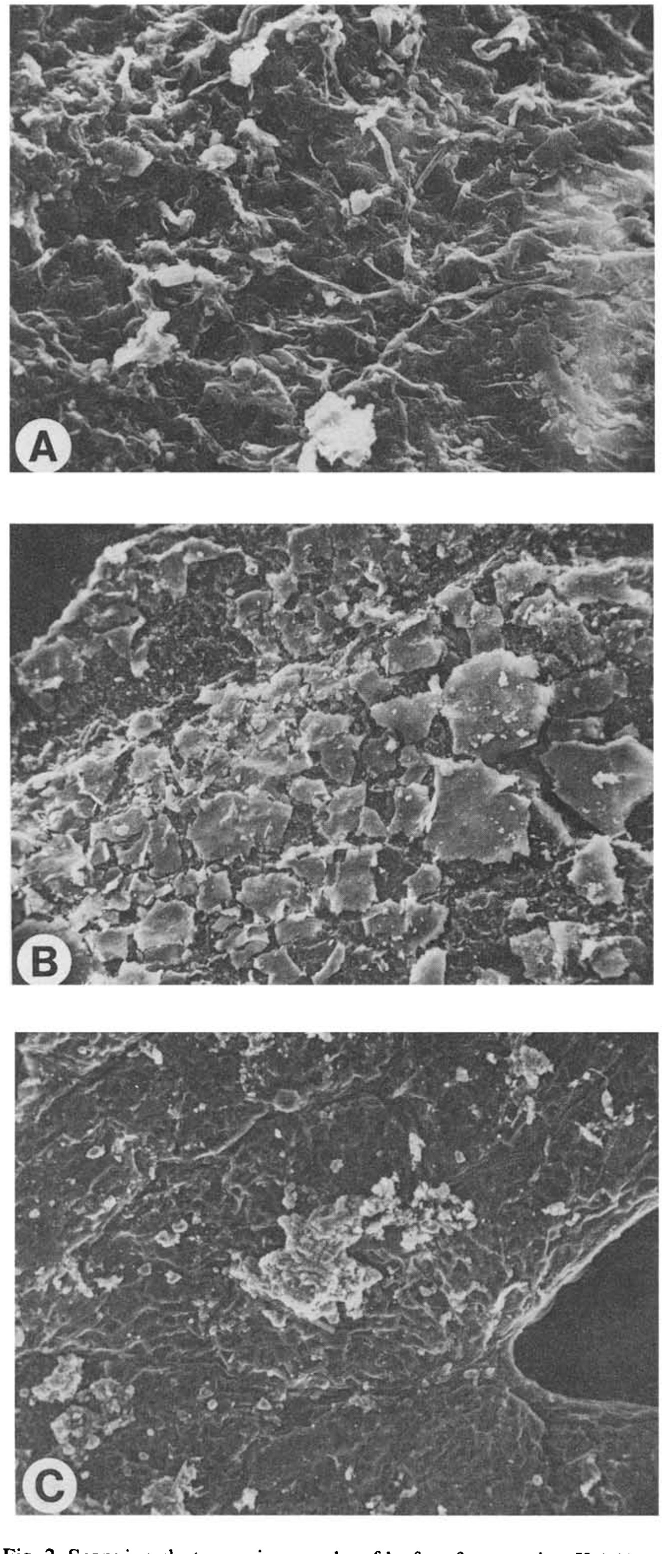

Fig. 2. Scanning electron micrographs of leaf surfaces at sites K-1 (A, 400×), K-2 (B, 80×), and C-2 (C, 100×). Note deposits of ferric hydroxide on leaves in B and polymer floc from treatment on leaves in C.

The loss rate coefficient at site K-2 was significantly lower than the coefficient for site K-1 ($F = 92.9403$, d.f. = 1, 35, $P < 0.01$; analysis of covariance from Sokal and Rohlf, 1969). Extensive coatings of ferric hydroxide on leaves at site K-2 inhibited microbial colonization and feeding by shredders (Fig. 2). The only mechanism of leaf breakdown was mechanical disruption by current. These results concur with previous studies that have shown greatly reduced decomposition rates in aquatic habitats with low pH and high metal concentrations (Forbes and Magnuson, 1980; Giesy, 1978; Guthrie *et al.*, 1978).

The loss rate coefficient at site C-2 was significantly lower than the coefficient at site C-1 ($F = 29.0985$, d.f. = 1, 35, $P < 0.01$) but was equivalent to the coefficient at site K-2 ($F = 0.3149$, d.f. = 1, 34, $P = 0.58$). The low rate at C-2 resulted from several factors: (1) within 2 weeks, all leaf packs were buried by the floc released in the treated effluent, and buried leaves have been shown to lose mass slower than leaves on the surface (Herbst, 1980); (2) little microbial colonization occurred due to adherence of floc to leaf surfaces (Fig. 2); (3) as at site K-2, only a single shredder was collected among all leaf packs. The loss of mass that occurred probably resulted from abrasion by shifting floc.

Conclusions

Operation of a treatment plant, while greatly improving the overall water quality of a stream receiving metal mine effluents, released flocculent materials which were deposited on the stream substrate. This deposition reduced the breakdown of leaf litter to a rate equivalent to that occurring in a stream receiving untreated mine effluents. The mechanism lowering rate loss coefficients was the same in both cases – inhibition of microbial colonization by surface deposits and subsequent lack of feeding by shredder insects. Thus the pathways of energy flow within the treated system were not restored despite improvements in overall water quality.

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References

Anderson, N. H. and Sedell, J. R. (1979) Detritus processing by macroinvertebrates in stream ecosystems, *Ann. Rev. Entomol.* **24**, 351-377.

Boyne, H. S., Ingwersen, J. B., Ward, J. V., Gray, L. J., Harvey, J., and Ponce, S. L. (1982) Environmental assessment of stream pollution by mine drainage as a function of geologic type and reclamation success. Colorado School of Mines, Golden, CO.

Cummins, K. W. (1974) Structure and function of stream ecosystems, *Bioscience* **24**, 631-641.

Forbes, A. M. and Magnuson, J. J. (1980) Decomposition and microbial colonization of leaves in a stream modified by coal ash effluent, *Hydrobiol.* **76**, 263-267.

Giesy, J. P., Jr. (1978) Cadmium inhibition of leaf decomposition in an aquatic microcosm, *Chemosphere* **7**, 467-476.

Guthrie, R. K., Cherry, D. S., and Singleton, F. L. (1978) Responses of heterotrophic bacterial populations to pH changes in coal ash effluent, *Water Res. Bull.* **14**, 803-808.

Herbst, G. N. (1980) Effects of burial on food value and consumption of leaf detritus by aquatic invertebrates in a lowland forest stream, *Oikos* **35**, 411-424.

Ingwersen, J. B. (1982) Downstream recovery of selected Colorado streams subject to acid drainage from abandoned metal mines. M. S. Thesis, Colorado State University, Fort Collins, CO.

Petersen, R. C. and Cummins, K. W. (1974) Leaf processing in a woodland stream, *Freshwater Biol.* **4**, 343-368.

Sedell, J. R., Triska, F. J., and Triska, N. M. (1975) The processing of conifer and hardwood leaves in two coniferous forest streams. I. Weight loss and associated invertebrates, *Verh. Int. Verein. Limnol.* **19**, 1617-1627.

Short, R. A. and Ward, J. V. (1980) Leaf litter processing in a regulated Rocky Mountain stream, *Can. J. Fish. Aquat. Sci.* **37**, 123-127.

Short, R. A., Canton, S. P., and Ward, J. V. (1980) Detritus processing and associated macroinvertebrates in a Colorado mountain stream, *Ecology* **61**, 727-732.

Sokal, R. R. and Rohlf, F. J. (1969) *Biometry*. W. H. Freeman, San Francisco, CA.

Wentz, D. A. (1974) Effect of mine drainage on the quality of streams in Colorado, 1971-72. Water Res. Circ. No. 21, U.S. Geological Survey, Denver, CO.