Short-Term Effects of Low pH on the Microfauna of an Activated Sludge Wastewater Treatment System

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Optimum pH for biological (e.g., activated sludge) wastewater treatment is stated to lie between pH 6.5 and 8.0; however, the pH of processed effluent from thermomechanical pulp mills is closer to 4.5 and 5.5. Consequently, pH adjustment of effluent is required with associated costs. The ability of the microfaunal community (protozoa and metazoa) of activated sludge to survive at pH levels below 6.5 was evaluated with samples collected from Corner Brook Pulp and Paper Ltd. (Newfoundland, Canada). Effect of pH was examined at “high pH” (4.5, 5.5 and 6.5 control) and “low pH” (2.5, 3.5 and 6.5 control) under “summer” temperatures of 30°C and “winter” temperatures of 15°C, with impacts assessed after 1 h and 24 h exposure. Effect of pH was found to be temperature-dependent: pH levels down to 4.5 appeared to have little impact on microfaunal abundances at 30°C, but a number of microfauna were negatively affected at 15°C. Low pH levels of 2.5 and 3.5 were detrimental to the population densities of most microfauna. Adverse pH effects were more marked with increased exposure in some cases. An acid-neutralizing ability may be inherent in the activated sludge, as treatment pH increased over 24 h.

Key words: microfauna, activated sludge, pH, acidity, community

Introduction

Activated sludge systems are wastewater treatment systems that provide the necessary conditions (pH, temperature, nutrients and dissolved oxygen) to enhance the ability of bacteria and microfauna to break down industrial (e.g., pulp and paper mill) or domestic effluents (Smook 1992). The efficient functioning of the activated sludge system depends largely on the interaction between bacteria and the community of various microfauna (protozoans and metazoa) in the system. This microfaunal community is dominated by ciliates, flagellates, rotifers, nematodes and gastrotrichs (Sydenham 1971; Task Force on Wastewater Biology 1990). Such organisms may enhance the bacterially mediated waste treatment process of activated sludge systems by removing senescent bacteria cells through predation and by exposing new absorption surfaces on the sludge to bacterial decomposers (Curds 1973; Klopping et al. 1990).
The optimum range of pH for most biological treatment processes of wastewaters is usually between pH 6.5 and 8.0 (Benefield and Randall 1988). Acidic pH levels can lead to significant growth of filamentous algae and fungi in wastewater treatment plants, which in turn can adversely affect the water quality of the final discharge (Droste 1997). For pulp and paper mills, there can also be high costs associated with maintaining near neutral/alkaline pH levels of 6.5 to 8.0 in the activated sludge system. Following thermomechanical pulping (TMP) in a pulp mill, the processed effluent that enters the wastewater treatment system typically has a low pH of approximately 4.5 to 5.5 (Richardson et al. 1991). TMP mills that rely on softwoods (e.g., spruce and fir) for paper production commonly have acidic effluent in this range due to resin and fatty acids in the wood (Lafleur 1990). Corner Brook Pulp and Paper Ltd., a TMP mill located in Corner Brook, Newfoundland, uses annually an estimated 250,000 to 300,000 L of caustic soda (sodium hydroxide NaOH) to increase the pH in the mill’s processed effluent to between 6.5 and 8.0 (M. Lacey, CBPPL, pers. comm.). Few studies have investigated the short-term response of microfauna in activated sludge to low pH levels. If such organisms could survive at pH levels below 6.5, and if there were no adverse effects on the bacteria, then less NaOH would be needed to increase effluent pH, thereby lessening costs to the mill.

Most previous studies have examined the effects of acidity upon populations of individual species of microfauna cultured in growth media, or have investigated the distribution of organisms in freshwater environments. These studies yield little insight into the possible species interactions of the microfaunal community in the activated sludge environment. Wastewater protozoans such as free and stalked ciliates function best when pH levels are between 6 and 8 (Pennak 1989; Task Force on Wastewater Biology 1990). However, Bick and Drews (1973) found that cultured populations of *Aspidisca* and *Vorticella* exhibited pH tolerances down to pH 4.5 and 5.0, respectively, while *Paramecium* populations declined only at pH below 4.0. *Paramecium caudatum* showed reduced swimming velocity and increased avoidance reactions when exposed to pH 3.6 (Doughty 1986). Flagellate protozoan populations surviving in acid mine drainage streams can withstand extremely low pH levels of less than 3.0 (Noland and Gajdics 1967). Small flagellates are also tolerant of low oxygen and acidity that is associated with high levels of organic matter in productive water bodies (Patterson 1996). Under acidic conditions, the permeability of the protozoan cell may increase, thereby raising energetic costs associated with osmoregulation. Consequently, a larger mass of food (bacteria) may be required to maintain protozoan growth at low pH in wastewater treatment systems. Protozoans that encyst can withstand sudden changes in pH then reappear days later adapted to the new conditions (Lackey 1938).

Among the metazoans, rotifer swimming speed has been observed to decline at pH levels below 5.6, while oxygen consumption rate increased as pH dropped from 7.5 to 6.5 (Epp and Winston 1978; Nogrady et al.
1993). Berzins and Pejler (1987) also found that rotifer populations in lakes, streams and bogs were generally low at pH values less than 5.5. However, some species such as Lecane acus, Habrotrocha collaris, Rotatoria rotatoria and Cephalodella intuta were able to tolerate acidic conditions as low as pH 3.5. In contrast, Locke (1992) concluded that rotifers were essentially absent from acidified Ontario lakes with pH of less than 4.5. Rotifer species classified as acid tolerant (tolerant of pH < 7.0) are found in the genera Cephalodella, Lepadella, Lecane, Monostyla, Trichocera and Dicranophorus (Pennak 1989).

Some nematodes can also survive in acidic environments (pH <4.5) with wide pH tolerance (Croll 1970; Merritt 1973). Several species, including Rhabditis terrestris, Caenorhabditid briggsae, Turbatrix acetic and Pangrellus redivus, showed high growth rates when cultured between pH 3.5 and 9.0 (Nicholas 1975). In contrast, the pH tolerances of gastrotrichs have been little studied. Gastrotrichs only appear in wastewater treatment systems when conditions are stable, that is, when there is little fluctuation in pH, temperature and dissolved oxygen (Klopping et al. 1995).

The primary aims of the present study were to evaluate the potential short-term effects of acidification on the microfaunal community of the activated sludge system of Corner Brook Pulp and Paper Ltd. and to determine if microfaunal populations could survive if pH levels were less than 6.5. The pH of processed effluent in TMP mills may range from 4.5 to 5.5 (prior to NaOH addition; Richardson et al. 1991) and most previous studies indicate that pH levels of less than 2.5 are potentially fatal to most of the microfauna found in activated sludge systems. We therefore sought to evaluate the response of the microfauna to pH 6.5, 5.5, 4.5, 3.5 and 2.5, through observations of population densities of several microfaunal taxa at these pH levels. We were interested specifically in the short-term (<24 h) acute toxic effects of low pH on microfaunal population densities, and thus we did not directly examine longer-term microfaunal growth or reproduction rates.

**Materials and Methods**

Biological (activated sludge) waste treatment at Corner Brook Pulp and Paper Ltd. consists of air-activated secondary treatment. Ambient air is blown through a series of diffuser pipes located at the bottom of the aeration basin and bubbles up through the biological mass, keeping these biological solids in suspension and providing oxygen. The volume of air added is controlled by on-line dissolved oxygen (DO) meters, with the target to maintain greater than 1.0 mg/L DO at all times. The system removes approximately 95 to 99% BOD, with BOD discharges averaging 5.2 mg/L ± a standard deviation of 2.1 (1999 data, M. Lacey, CBPPL, pers. comm.). The system has been 100% non-acutely lethal since startup. TSS removal is well above 95% but can vary with sludge quality (biomass settling ability). Mean TSS in discharged effluent for 1999 was 11.6 ± 5.1 mg/L. Mean annual DO and temperature in the aeration basin were 1.30 ± 0.6 mg/L and 29.7 ± 5.2°C, respectively (1999 data; M. Lacey, CBPPL, pers. comm.). The pH of
the wastewater ranged from 6.1 to 9.6 (mean 7.6 \pm 0.4) in the processed effluent pumped into the primary clarifier of the aeration basin, and from 5.9 to 6.9 (mean 6.5 \pm 0.2) in the effluent discharged from the aeration basin.

Samples of activated sludge were collected from the aeration basin at Corner Brook Pulp and Paper in the spring of 1999, with a pilot study to examine microfaunal species in the sludge conducted in the fall of 1997. Each sample contained 1 L of mixed liquor suspended solids (MLSS) taken randomly from the surface of the outflow of the aeration tank using a 1-L cylindrical steel container. Recorded pH, DO and temperature of the MLSS in the aeration tanks averaged 6.6, 1.2 mg/L and 30°C, respectively, at the time of the 1999 sampling. Each sample was immediately poured into a plastic 1-L bottle and transported within 30 minutes to the Environmental Science Laboratory at Sir Wilfred Grenfell College. For each experiment, all experimental procedures were initiated on the same day as sample collection.

In the laboratory, the settling height of the suspended solids in the MLSS was determined to estimate the sludge density and the occurrence of bulking in the activated sludge treatment system. Sludge samples were shaken vigorously for 10 seconds to stir up the suspended solids in the liquor, then a 10-mL sample was put into a 10 mL graduated cylinder to measure the volume of suspended solids that settled out after 30 min. For 1999, the mean SVI (Settled Volume Index) at the mill was recorded as 97 \pm 43, with mean MLSS density (dry) of 4137 \pm 604 mg/L (M. Lacey, CBPPL, pers. comm.).

The pH experiments were carried out in two separate trials, with one trial investigating the effects of “high pH” levels of 4.5 and 5.5 compared to an ambient control pH of 6.5, and another trial investigating the effects of “low pH” levels of 2.5 and 3.5 compared to a control pH of 6.5. The pH experiments had to be separated into these two trials due to time constraints involved in counting of living organisms in the samples. Each trial involved a separate MLSS sample. Each MLSS sample was vigorously shaken for 5 seconds to stir up the suspended solids, then 70-mL subsamples were poured into nine 100-mL beakers. These subsamples were exposed to three treatments (three replicates per treatment), these being control (pH 6.5), pH 5.5 and pH 4.5 for the “high pH” test, and control (pH 6.5), pH 3.5 and pH 2.5 for the “low pH” trial. To reduce the pH of a 70-mL subsample of MLSS from 6.5 to 5.5, three drops of 1 M HCl were required. Five drops of 1 M HCl reduced a 70-mL subsample to pH 4.5, 8 drops to pH 3.5 and 16 drops to pH 2.5. Each of the subsamples was stirred using the pH electrode to promote dispersion as drops of HCl were added. The controls were made up to equal volume with drops of filtered sludge water (filtered through a GF/C filter). Hydrochloric acid was chosen to reduce pH since it can be a common acidic chemical in paper mill effluent, and is not considered a nutrient for bacteria or microfauna.

Once the subsamples had been acidified in each trial, six aliquots of 10 mL each were extracted from each subsample and placed into plastic 25-mL petri dishes. Petri dishes were used since the relatively large ratio of
surface area to volume of sample in a dish should minimize oxygen limitation due to bacterial degradation of organic matter (Patterson 1996). The experiments were run first under “summer” conditions with the petri dishes incubated at 30°C. This temperature corresponds well to May/June temperatures experienced in the activated sludge wastewater system (24 to 26°C; Smith and Campbell 2000) and with a maximum 1999 temperature of 38.2°C in the processed effluent (M. Lacey, CBPPL, pers. comm.). A second set of experiments were run under “winter” conditions with the petri dishes placed into a 15°C incubator. This temperature corresponds to February temperatures experienced in the activated sludge wastewater system (around 19 to 20°C; Kelly 1998) and with a minimum 1999 temperature of 15.7°C in the processed effluent (M. Lacey, CBPPL, pers. comm.). For each level of pH in the trial, the microfauna community was examined from three petri dishes on day 0 (1 h after the subsample was acidified), while the remaining three petri dishes were examined on day 1 (24 h after acidification). Microfauna were examined after 1 h to estimate acute toxicity, and after 24 h to estimate any short-term delayed response that low pH might have on the sludge community. The turnover rate, or maximum sludge age, at the mill was approximately 11 days (standard deviation of 7.5 days; M. Lacey, CBPPL, pers. comm.). An initial pilot study had indicated that microfauna in untreated MLSS could survive for up to 48 h in the petri dishes without noticeable population declines, indicating that adequate oxygen and nutrient concentrations existed during this period.

Organisms from the petri dishes were enumerated using a Sedgewick-Rafter (S-R) cell and microscope at 100X magnification. The pilot study in 1997 had indicated that the MLSS was very dense, preventing enumeration of organisms, and therefore samples were diluted 1:2 by volume with distilled water prior to enumeration. A combined raw count was made along three strips of the S-R cell, for one total count per petri dish, with counts from the three petri dishes averaged for each respective pH-temperature-time combination. The averaged count was then converted to organisms per mL of the original MLSS replicate subsample. Only living microfauna were enumerated, i.e., those showing movement within a 10-second period. Organisms were identified to genus level in most cases using Pennak (1989) and Patterson (1996). For each sample of MLSS, pH measurements were taken at 1 h and 24 h at the selected incubation temperature, using an Accumet pH meter 910. All glassware was cleaned in an acid bath (3% HCl) for 24 h to minimize the possibility of contamination in the experiment. Before reuse, the glassware was rinsed three times with chlorinated tap water and then three times with distilled water.

Statistical analysis of results was carried out using two-way ANOVAs with factors of pH and time on Minitab (Minitab 11.21, 1996), with “summer” and “winter” conditions analyzed separately since different MLSS samples were used for the two temperatures. Degrees of freedom for pH were (2,17), for time (1,17) and for the interaction of pH X time (2,17), i.e., 3 pH treatments X 2 time treatments X 3 MLSS replicates. Count data, such as from S-R cells, often follow a Poisson distribution.
(Elliott 1977). Inspection of the data indicated that transformation prior to parametric ANOVA was not required. Transformation to correct for Poisson is not necessary unless the largest variances are found in the largest samples and the largest sample is more than five times the size of the smallest (Budescu and Appelbaum 1981). For all graphs, confidence limits of the estimated means of triplicate pH treatments at each temperature and time were determined from raw counts assuming a Poisson distribution where the data consist of randomly occurring objects of events. Standard deviations were calculated as the square root of the combined raw count, then multiplied by 2 (approximate t value) to obtain the 95% confidence limits (Elliott 1977).

Results

Microfauna showed varying responses to the different levels of acidification and temperature. A number of protozoa were identified and enumerated: free-swimming ciliates Aspidisca, Paramecium and Trachelophyllum, along with the stalked ciliate Opercularia. Other ciliates (Euplotes, Colpidium, Epistylus and Vorticella), the flagellate euglenoid Peranema and the testate amoeba Arcella had been observed as well in previous examinations of the activated sludge but populations were too low to allow for statistical analysis. A number of metazoa were also enumerated: the gastrotrich Chaetonotus, one taxon of Nematoda, and the rotifers Cephalodella, Monostyla and Habrotrocha. Oligochaetes were also observed occasionally but too rarely to include in statistical analysis. The volume of the settled sludge varied from 1.5 to 3.8 mL (corresponding SVI from 36 to 92) with total number of microfauna in the untreated samples ranging from 1675 to 3113 organisms/mL. The pH of the untreated MLSS (pH control) ranged from 6.5 to 6.6.

Results from the two-way ANOVA (Table 1) indicated that populations of most enumerated microfauna at 30°C showed a decline when subjected to the “low pH” treatment (control versus pH 3.5 and 2.5). These declines were statistically significant (p <0.05 for pH factor) for all free ciliates (Fig. 1), Nematoda (Fig 2) and rotifers (Fig 3). Aspidisca and Trachelophyllum were absent from the dishes at pH 3.5 and 2.5 (Fig. 1). Opercularia (p value 0.443) and Chaetonotus (p value 0.157) showed no significant response to low pH. However, populations of Opercularia were quite low in the “low pH” control (LCO, see Fig. 2) as well, making it difficult to ascertain any pH effect. Interpretation of the Chaetonotus response was also difficult, as the gastrotrich was absent at pH 3.5 at both day 0 and day 1, yet was relatively abundant at pH 2.5 on day 1 (Fig. 2).

Duration of exposure to “low pH” at 30°C was only statistically significant in the case of Trachelophyllum and Nematoda. Trachelophyllum populations were more abundant at control pH at day 1 than day 0, yet were absent at pH 3.5 and 2.5 for both days (Fig. 1). However, control densities were low as well, making interpretation difficult (significant effect of pH X time). Monostyla populations (Fig. 3) were also generally higher at day 1 than day 0, with a significant pH X time effect. Nematoda densi-
ties decreased with declining pH at day 1, but actually increased a bit with increasing acidity at day 0.

The “high pH” treatment (control versus pH 5.5 and 4.5) at 30°C had less impact on the microfauna, with pH alone not a significant factor for

<table>
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<th>Organism</th>
<th>Factor</th>
<th>“Low pH” trial 30°C</th>
<th>“Low pH” trial 15°C</th>
<th>“High pH” trial 30°C</th>
<th>“High pH” trial 15°C</th>
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<td>0.140</td>
<td>0.994</td>
<td>0.206</td>
<td>0.564</td>
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*a “Low pH” trial refers to control (pH 6.5) versus pH 2.5 and 3.5. “High pH” trial refers to control (pH 6.5) versus pH 4.5 and 5.5. Statistical significance (p value) is recorded in bold numbers, all others ns. Note that no Trachelophyllum were found in MLSS sample at 15°C.
Fig. 1. Mean population densities of free ciliates *Aspidisca*, *Paramecium* and *Trachelophyllum* in MLSS at 30°C (“summer” conditions), exposed either to “low pH” (pH 2.5, 3.5 and LCO = low control pH 6.5) or “high pH” (pH 4.5, 5.5 and HCO = high control pH 6.5), sampled at day 0 and day 1. Error bars represent 95% confidence limits about the mean based on a Poisson distribution with three replicates per mean.
Fig. 2. Mean population densities of stalked ciliate *Opercularia* and metazoans *Chaetonotus* and Nematoda in MLSS at 30°C ("summer" conditions), exposed either to "low pH" or "high pH", sampled at day 0 and day 1. Error bars represent 95% confidence limits about the mean based on a Poisson distribution with three replicates per mean.
Fig. 3. Mean population densities of rotifers *Cephalodella*, *Monostyla* and *Habrotrocha* in MLSS at 30°C (“summer” conditions), exposed either to “low pH” or “high pH”, sampled at day 0 and day 1. Error bars represent 95% confidence limits about the mean based on a Poisson distribution with three replicates per mean.
any of the populations (Table 1). Duration of exposure was significant in the case of *Paramecium* (Fig. 1) and *Opercularia* (Fig. 2). Both populations were much lower by day 1 than by day 0. In general, under “summer” conditions, populations did not show declines at pH 4.5 when compared to either pH 5.5 or 6.5.

Similar trends in response to pH were observed for the populations incubated under “winter” conditions at 15°C as compared with “summer” conditions. Populations of most microfauna showed a significant decline when exposed to “low pH” and 15°C (Table 1), with *Aspidisca*, *Paramecium*, *Opercularia* and *Chaetonotus* (Fig. 4 and 6) absent at pH 3.5 and 2.5. Only Nematoda (Fig. 5; $p = 0.108$ for pH factor) was not significantly affected by low pH. Note that no *Trachelophyllum* were observed in the collected MLSS that was later exposed to 15°C. Duration of exposure to “high pH” at 15°C had a significant effect on *Aspidisca* and *Monostyla*; populations of both species were generally lower at day 1 than at day 0. Only *Aspidica* (Fig. 4), *Chaetonotus* (Fig. 5) and *Monostyla* (Fig. 6) showed a significant decline when exposed to “high pH” and 15°C.

Results from Table 2 suggest that the activated sludge may have some ability to neutralize acidity, because over 24 hours the pH of all treated MLSS samples showed a slight increase. The amount of $H^+$ ions that could be neutralized by 70 mL of MLSS varied from 1.44 mmoles at the lowest pH of 2.5 to 0.002 mmoles at the highest pH treatment of pH 5.5.

### Discussion

The results of our small-scale experiments suggest that microfaunal organisms in an activated sludge wastewater treatment system may be able to survive at low pH levels of 4.5 to 5.5, that is, below the stated optimum of pH 6.5 to 8.0 (Benefield and Randall 1988, Pennak 1989). Similarly, in an acidified lake with a pH range of 3.6 to 6.4, Tremaine and Mills (1991) found protozoan abundance to be highest at pH 5.0 to 5.3. However, the temperature of the sludge environment in wastewater treatment is also an important factor to consider. While, in general, pH levels down to 4.5 appeared to have little impact on populations of microfauna under “summer” condi-

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**Table 2.** Potential acid-neutralizing ability of 70-ml activated sludge samples exposed to four pH levels (initial pH) for 24 h at either 15°C or 30°C. H+ ion concentrations expressed as the means of two replicates ± one standard deviation.

<table>
<thead>
<tr>
<th>Initial pH</th>
<th>Range in pH after 24 h</th>
<th>mmoles $H^+$ neutralized per 70 ml MLSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>5.7 – 6.1</td>
<td>0.002 ± 0.001</td>
</tr>
<tr>
<td>4.5</td>
<td>4.9 – 5.9</td>
<td>0.024 ± 0.008</td>
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<tr>
<td>3.5</td>
<td>4.0 – 5.1</td>
<td>0.263 ± 0.064</td>
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<tr>
<td>2.5</td>
<td>2.7 – 2.8</td>
<td>1.440 ± 0.198</td>
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tions of 30°C, population densities of *Aspidisca*, *Chaetonotus* and *Monostyla* were all lowered by such pH under “winter” conditions of 15°C. Presumably, bacterial abundance and microfaunal growth rates were higher at the higher temperature and consequently any adverse impacts of low pH on population density were minimized at the higher temperature treatment. There is some evidence to suggest that the survival of microfauna at pH 4.5 and 5.5 in the MLSS may be partially due to an acid neutralizing capacity inherent in the activated sludge. Over a 24 h period, MLSS samples at pH 4.5 and 5.5 both showed increases in pH, up to 5.9 and 6.1. Given the complex organic nature of the activated sludge, a wide range of buffering reactions might be involved. Tremaine and Mills (1991) suggested that anaerobic microbial reduction of iron and sulfate might buffer pH in lake sediments, sufficient to maintain a neutrophilic protozoan community.

As expected, pH levels of 2.5 and 3.5 had a negative effect on the population densities of the majority of the microfauna in the activated

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**Fig. 4.** Mean population densities of free ciliates *Aspidisca* and *Paramecium* in MLSS at 15°C (“winter” conditions), exposed either to “low pH” or “high pH”, sampled at day 0 and day 1. Error bars represent 95% confidence limits about the mean based on a Poisson distribution with three replicates per mean.
Fig. 5. Mean population densities of stalked ciliate *Opercularia* and metazoans *Chaetonotus* and Nematoda in MLSS at 15°C (“winter” conditions), exposed either to “low pH” or “high pH”, sampled at day 0 and day 1. Error bars represent 95% confidence limits about the mean based on a Poisson distribution with three replicates per mean.
Fig. 6. Mean population densities of rotifers *Cephalodella*, *Monostyla* and *Habrotrocha* in MLSS at 15°C (“winter” conditions), exposed either to “low pH” or “high pH”, sampled at day 0 and day 1. Error bars represent 95% confidence limits about the mean based on a Poisson distribution with three replicates per mean.
sludge. The resultant depauperate microfaunal community would most likely lead to suboptimal wastewater treatment (by not being able to remove senescent bacteria, etc.) under such acidic conditions.

Some of the species in the activated sludge may be more ecologically tolerant of acidic conditions due to strong selection pressures of the activated sludge environment. Among the protozoa that we enumerated, *Opercularia* appeared to be the organism whose population density was the least significantly affected by declining pH. However, since numbers of *Opercularia* were generally low, it is difficult to draw a strong conclusion about the protozoan’s overall pH tolerance. *Aspidisca* appeared to be the most sensitive protozoa to pH in our experiments. This is in contrast to the results of Bick and Drews (1973) who were able to culture *Aspidisca costata* and *A. lyncus* successfully down to pH 4.5 and 4.7, respectively.

Among the metazoa in our experiments, both *Habrotrocha* and *Cephalodella* were not significantly affected by “high pH” treatment at either temperature, in contrast with the other rotifer *Monostyla*. Nematode population densities were only significantly affected by acidity at the “low pH” treatment at 30°C. Species of rotifers *Habrotrocha* and *Cephalodella* are known to tolerate acidic conditions as low as pH 3.0 (Berzins and Pejler 1987), while some nematodes can show high growth rates at low pH as well (Merritt 1973; Nicholas 1975). Of course, varying responses of the different microfauna to the pH treatments may not simply reflect tolerance to acidic conditions. A measure of pH can be taken as a gross measurement of many chemical factors in an aquatic system, any of which, singly or collectively, may affect population growth (Pennak 1989).

There was some indication that certain microfaunal organisms may be more affected by a 24-h exposure to acidic pH than by a 1-h exposure. ANOVA results yielded seven instances of significant time effects, or a significant effect of day 1 versus day 0. At “high pH”, both *Paramecium* and *Opercularia* populations were significantly lower by day 1 than by day 0 at 30°C (although this was also true of the HCO control), while *Aspidisca* and *Monostyla* populations were significantly lower by day 1 than by day 0 at 15°C. At “low pH” and 30°C, populations of nematodes were lower by day 1 than by day 0, while populations of *Trachelophyllum* were eliminated on both days. At “low pH” and 15°C, populations of *Chaetonotus* were significantly less abundant at day 1 than day 0 (except in the control treatment), while *Aspidisca* populations were eliminated at pH 2.5 and 3.5 by both days.

There is therefore some evidence to suggest that the microfaunal community of the activated sludge of Corner Brook Pulp and Paper’s wastewater treatment system is not adversely affected by pH 4.5 and 5.5. Such aquatic microfauna in sludge environments may survive at lower pH conditions than will similar organisms in non-sludge environments. This could result from the potential acid neutralizing ability of the sludge itself. However, this lack of a pH impact on the microfauna is clearly temperature-dependent. Consequently, for optimal wastewater processing to take place, pH levels could only be left below 6.5 when temperatures were high (that is, during summer). As well, pH levels of 2.5 and 3.5 are clearly detrimental to the microfaunal community, resulting in lowered abundances.
and species losses. Adverse pH effects in general seem more marked the longer the sludge is left at low pH (see Bick and Drews 1973). The results of this study also indicate that population densities of different microfaunal organisms exhibit different short-term responses to low pH. However, in order to clearly demonstrate a toxic long-term (>24 h) effect on the microfaunal community, future studies need to more directly examine acid effects on microfaunal growth and reproduction in the constantly flushing sludge environment. If low pH significantly increases the doubling time of a given organism such that it exceeds the turnover time (flushing or wastage rate) or maximum age of the sludge, then populations of that organism will eventually be washed out of the activated sludge over a few mean cell retention times. Such “wash-out” will result in decreased species diversity. For these reasons, it would perhaps not be economically advisable for Corner Brook Pulp and Paper Ltd. to try and run the wastewater treatment process at pH slightly less than 6.5 for prolonged periods of time. Any savings derived from using less NaOH (or any other alkaline substance, such as cement kiln dust; Smith and Campbell 2000) to adjust pH might be negated by a loss of microfaunal species diversity, with possible resultant suboptimal wastewater treatment. Such loss in species diversity would be more likely to occur during winter due to possible lower temperatures of intake water (a local pond) coming in to the mill’s wastewater system.

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