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Vacuum-pressure prewetting—A simple and rapid method to water saturate wood for experimental purposes

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Abstract

A simple and rapid method to prepare water-saturated wood by vacuum-pressure prewetting is presented. Submerged wood pieces can be prepared easily for any experimental purposes without long periods of prewetting and without additional tools for holding the wood under water. The particular wood piece must be submerged in a water filled suction flask that is connected to a diaphragm vacuum pump. Due to the evacuation of the air from the flask the wood rapidly soaks up water until it is saturated. In the experiments, branches displayed a logarithmic water saturation curve soaking up the highest amount of water during the first 10 s of air evacuation. Most branches were water saturated during this time. The method works best for wood pieces with a low or medium density supporting a rapid soaking of water, whereas very dense wood needs much more time to become water saturated. The main problem of the method is the loss of bark material from natural branches and the splitting of larger woods due to the rapid swelling caused by the water uptake. However, this method could be used for any experimental purposes needing standardized submerged wood, like investigations of epixylic biofilm development, colonization of wood by aquatic invertebrates, decomposition of submerged wood, or invertebrate food choice experiments.

Wood enters streams mainly by litterfall from trees but also laterally by being washed into the stream during inundation of floodplains (Benfield 1997). However, the lateral input of wood litter from the floodplain to the stream can be higher sometimes than the amount of litterfall (Cuffney 1988). Thus, branches can enter streams with different moisture contents depending on the state of wood decay (Boddy 1983). The water content of fallen wood is influenced by rainfall before abscission and by the humidity of the soil on which the particular branch lay. Branches entering the streams by litterfall or lateral input from the forest floor are often preconditioned (Swift et al. 1976) and moistened (Boddy 1983).

To date, experimental studies on natural wood breakdown in streams mostly used terrestrial woody debris cut from trees or wood surrogates like ice-cream sticks, tongue depressors, or tooth pickers (see list in Spänhoff and Meyer 2004), which were dry or pre-dried and held underwater by fixing devices or weights. Artificial submersion of dry wood might fail to simulate water absorption of floating wood and the process of wood decomposition in aquatic ecosystems. Breakdown of fallen wood being washed from the floodplain into the stream might be simulated more naturally by using prewetted rather than dry wood.

Furthermore, prewetted wood can be used to investigate epixylic biofilm development and invertebrate colonization of submerged wood. Colonization of woody debris by drifting and/or actively moving aquatic invertebrates is likely facilitated after the particular wood piece has been water saturated and sunk to the streambed. Experiments investigating the colonization dynamics of aquatic invertebrates on submerged wood should therefore use water-saturated wood instead of dry wood that is artificially fixed to the stream bottom.

This paper presents a simple and very rapid method to prewet wood that can be used subsequently for all types of experimental investigations on the ecological role of wood in aquatic systems.

Materials and procedures

Wood material—Branches from beech (*Fagus sylvatica*), poplar (*Populus tremula*), and pine (*Pinus sylvestris*) were water saturated by vacuum-pressure prewetting. Poplar branches (1.5–2.5 m) were cut from trees and stored for more than 1 yr in a room with low air humidity. The branches displayed no indications of decomposition prior to the experiment start. These poplar branches were cut into smaller pieces (15–20 cm length, 3–5 cm diameter) a few days before prewetting. Beech and pine branches also were cut from a single tree, and some

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branches were collected from the forest floor around the same tree to compare unconditioned "fresh" wood to "old" wood in an advanced state of decomposition. These branches were cut into smaller pieces immediately after collection and stored for 4 months in a dry room.

Two different sizes of fresh and old beech branches were used (small = 15 cm in length and 2–3 cm in diameter and large = 15 cm length, 5–6 cm diameter), whereas pine branches were of various sizes (10–30 cm) and diameters (2–5 cm). Subsamples of all wood types were dried at 105°C to constant weight to obtain moisture content that was used to calculate dry mass of all branches used for prewetting. Pine branches collected from the forest soil and cut from the tree were separated into three groups of differing density measured by the water replacement method (Spänhoff et al. 2001). Density was calculated by the ratio of calculated dry mass to volume (Spänhoff et al. 2001).

Prewetting procedure—A 5 L suction (bottleneck) flask was connected to a diaphragm vacuum pump (volume flow rate 1.7 m^3/h, Type MZ 2C, Fa. Vacuubrand) creating an underpressure of 0.9 bar inside the flask for prewetting of the branches. The flask was filled with tap water up to the bottleneck (6.6 cm inner diameter) and three to five branches were put into the flask in such way that the branches were submerged and held under water. Air evacuation was performed after sealing the suction flask with a rubber stopper for 10–60 s. The flask was ventilated after each air evacuation procedure and the branches weighed to the nearest 0.1 g. Then the branches were put again in the flask and the procedure of air evacuation was repeated until the branches remained on the flask bottom or the wet mass did not increase any more (point of water saturation). Water content of the branches (% of total wet weight) was calculated after each weighing assuming a constant dry mass of wood that was calculated at the start of the experiment. After ending of the experimental prewetting, all branches were dried at 105°C to constant weight to check the branches for loss of dry mass caused by leaching.

Assessment

All branches reached the point of water saturation by vacuum-pressure prewetting within a few minutes. Smaller beech branches reached higher final water contents than larger ones and preconditioned wood soaked up more water than fresh wood. Spänhoff et al. (2001) found in a field study that submerged wood with a lower density stored more water than wood of the same tree species with a higher density. Larger preconditioned beech branches were water saturated by prewetting within 45 s, whereas small branches needed only 20 s (Fig. 1A). Small fresh beech branches were water saturated after a mean air evacuation period of ca. 90 s. Larger and fresh beech branches soaked up no more water after 240 s but still floated on the water surface (Fig. 1B).

Preconditioned pine branches of different density also displayed different patterns of water saturation (Fig. 2).

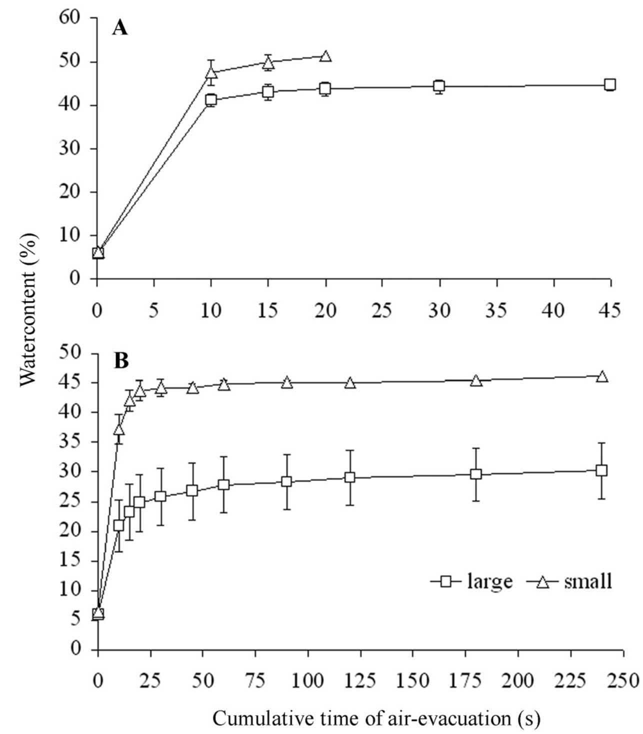

Fig. 1. Water saturation by vacuum-pressure prewetting of (A) preconditioned and (B) fresh beech branches of different size (mean ± SD, n = 5–7).

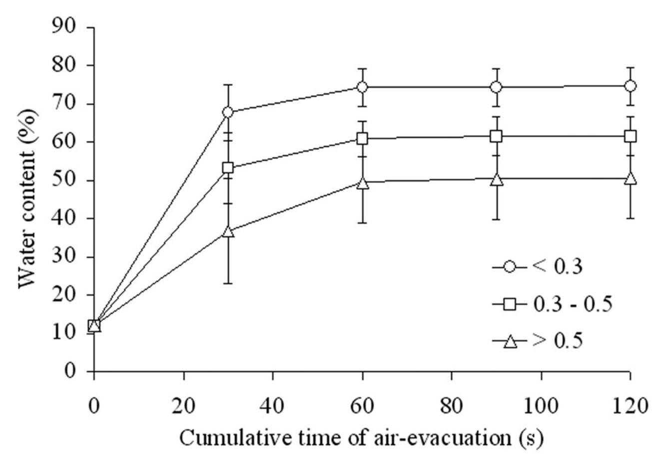

Fig. 2. Water saturation by vacuum-pressure prewetting of preconditioned pine branches of different density (mean ± SD, n = 5–7).

Final water content was inversely related to the density of the branches. However, all pine branches were water saturated after 120 s and sunk to the flask bottom independent from their density. Those branches with a density <0.3 already were water saturated after the first air evacuation period of 30 s. Fresh pine branches reached the point of water saturation after 300 s, but still floated on the water surface (Fig. 3).

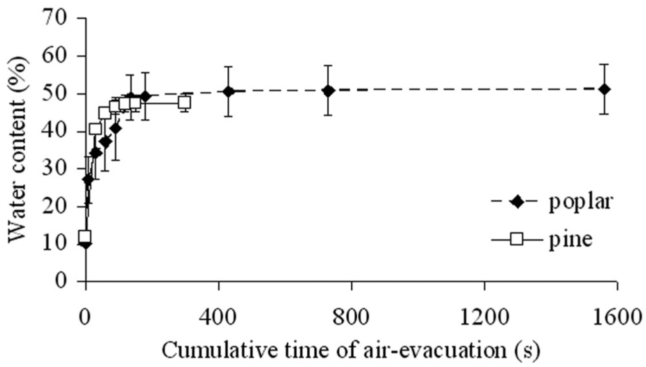

Fig. 3. Water saturation by vacuum-pressure prewetting of fresh poplar and pine branches (mean ± SD, *n* = 5).

Poplar branches were cut into smaller pieces directly before the experiment start. As a consequence they still contained high moisture content (10.2%) although they had been air dried for almost 1 yr. During the vacuum-pressure prewetting, the water soluble cell contents of the wood were leached out and the branches lost 3.3 ± 0.5% (mean ± SD) of their calculated initial dry mass. Compared to the fresh beech and pine branches, the poplar branches reached the point of water saturation after 135 s and thereafter soaked up only very little additional water. Nevertheless, the branches still floated on the water surface after 1600 s of air-evacuation and remained at a relatively constant wet weight (Fig. 3).

Discussion

The vacuum-pressure prewetting method proved useful to rapidly prewet wood until water saturation for experimental purposes. Preconditioned wood of all tested tree species became rapidly water saturated, sank to the bottom of the flask, and remained submerged without any further burdening. No mass loss of initially calculated dry mass by leaching could be observed, making the branches still suitable for any kind of investigations on wood mass loss by invertebrate feeding or microbial decomposition both in field and laboratory experiments.

Nevertheless, some restrictions were observed. Fresh wood rapidly reached the point of water saturation but still floated on the water surface. Although the air evacuation was extended to 1600 s, the fresh branches soaked up no more water and did not sink to the bottom. Additionally, fresh wood started to erupt when reaching a certain point of water saturation due to the swelling of the wood.

However, due to the preconditioning of most wood before entering streams in nature (Swift et al. 1976), it seems to be more important that the present method works well for preconditioned wood. Nevertheless, it remains unknown whether it is closer to natural conditions to use prewetted or dry wood for investigation of processes related to submerged wood in aquatic ecosystems. Wood entering streams by litterfall is likely dry and will float on the water surface until it becomes water saturated and sinks to the stream bottom. It is likely at this time that most of the colonization and decomposition processes of submerged wood take place. Wood entering streams by lateral input is likely wet, depending on the moisture content of the soil, so experimentally prewetted wood simulates the subsequent processing of such wood in aquatic ecosystems. Future studies could use the presented method to compare breakdown rates, colonization patterns by aquatic invertebrates, and epixylic biofilm development of prewetted wood against dry wood. This could contribute to a better understanding of the natural processing of wood in aquatic ecosystems.

Comments and recommendations

The presented method enables rapid prewetting of wood pieces to different moisture contents depending on the time and intensity of vacuum application. Boddy (1983) demonstrated that branches on forest floors had different moisture contents depending on rainfall and soil humidity. Thus, the use of prewetted wood might better simulate the natural processing of wood in aquatic systems than dry or pre-dried wood commonly used in experimental studies until now.

Additionally, wood can be prepared by the vacuum-pressure prewetting method in various ways by manipulating the water for prewetting. For instance, wood could be prewetted with water from streams with different nutrient concentrations and numbers of suspended bacteria and fungal conidia. This incubated wood could provide useful aspects to investigate the effect of nutrients and microbes on wood decomposition in aquatic ecosystems. Fungal growth assessed by ergosterol concentrations is stimulated in dry pine wood that is artifically submerged in streams (Spänhoff and Gessner 2004). As moisture content of wood is an important factor for fungal growth (Rayner and Boddy 1988) the amount of water stored in the wood at the start of the experiment can affect the experimental outcome.

Finally, the method can be used to prepare standardized submerged wood for feeding or food choice experiments of aquatic invertebrates. Few laboratory experiments used woody debris for studies on food preference or habitat choice of aquatic invertebrates until now (Schulte et al. 2002, Storry et al. 2006), likely due to the difficult handling of floating wood. Prewetted wood might be more appropiate to simulate natural conditions than dry wood that is artificially submerged for such food or habitat choice experiments as dry wood move with the water current and can therefore negatively influence invertebrate colonization.

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