Measurement of Electric Currents in Clear, Discolored, and Decayed Wood from Living Trees

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ABSTRACT

Electric currents, that were generated by polarizing metal electrodes and measured in microamperes, increased progressively from clear to discolored and to decayed wood of red maple and red oak. These currents varied inversely with resistance to a pulsed electric current. There were, however, no statistical differences between the resistance or current measurements of sapwood and discolored heartwood of red oak. The pattern of electric currents could be used to detect discolored and decayed wood from living trees.

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Discolored and decayed wood in living trees has been detected by measurements of electrical resistance (5,8), impedance (7), and capacitance (6). All these electrical techniques required a signal generated by a power source and the measurements were taken with stainless steel electrodes of similar quality. Levengood (2,3) described a method to measure "bioelectric currents" in living trees, and concluded that the amount of bioelectric current could be related to tree vigor. He used polarizing electrodes of different metals in these experiments and an external power source was not needed. The object of our investigation was to determine whether electric currents generated by various combinations of polarizing metal electrodes could detect discolored and decayed wood in living trees.

The electrical measurements were made on sections of clear, discolored, and decayed wood of nine red maple (*Acer rubrum* L.) and on sections of clear sapwood and clear, discolored, and decayed heartwood of five red oak (*Quercus rubra* L.) trees that were growing in the Cadwell Experimental Forest in Pelham, Massachusetts. The trees, which ranged from 11 to 36 cm diam at 1.4 m aboveground, were cut during winter 1974 and bolts were transported to a laboratory in Amherst, Massachusetts, where 5-cm-thick disks were cut from the bolts. Each electrical measurement was made by placing electrodes 2 cm apart and 1 cm deep in well-defined areas of clear, discolored, or decayed wood on the transverse surface of the disks.

Electric current measurements were made with metal rod electrodes approximately 2 mm in diam and 5 cm in length of stainless steel, copper, zinc, silver, and aluminum. All metals were of greater than 99% purity except stainless steel which was composed of approximately 66% iron, 20% chromium, and 11% nickel. Zinc-coated or "galvanized" electrodes were also used in some measurements instead of pure zinc. Electric currents were measured on a 0-50 and a 0-10 μA galvanometer. Various metal electrode combinations were inserted into the wood as described previously, and then connected via alligator clips to the wires from a galvanometer. Measurements were recorded approximately 15 s after the electrodes were connected to the galvanometer or after the needle on the meter had stabilized. Voltage measurements between these electrodes were then taken on an oscilloscope. Electrical resistance was measured with stainless steel probes on an apparatus developed by Skutt et al (5), that delivered a constant pulse of 0.5 μA for 0.5 ms with a 10 ms interval between pulses. These measurements were used for a standard comparison for the electric current measurements.

Solutions of increasing concn of potassium chloride (5×10^{-6} to 0.1 N) in distilled water were prepared. Electric current and electric resistance measurements were taken by placing electrodes 2.0 cm apart and to a 1.0-cm depth into each solution.

Electric currents increased as wood was measured in progressive stages of discoloration and decay in both species (Table 1). There were, however, no statistical differences between the resistance or current measurements of sapwood and discolored heartwood of red oak. Differentiation of these tissues in red oak was not possible with the electrical measurements used in these experiments. Electric currents in wood were related directly to applied voltage, and were inversely proportional to the degree of electrical resistance, but voltage for each electrode combination tested did not change regardless of the tissue-type measured.

Zinc:copper (Zn:Cu) and zinc:silver (Zn-Ag) electrode combinations resulted in the greatest electric currents in all woody tissues that were tested. In decayed red maple wood, measurements with Zn:Cu averaged 22 μA, while Zn:Ag and Zn:stainless steel averaged 26 and 6 μA, respectively. Other combinations of the metals used resulted in current measurements which averaged less than 2.0 μA. Because of its greater availability, the Zn:Cu electrode combination was used in most electric current measurements. A zinc-coated or "galvanized" electrode in combination with copper resulted in measurements that were consistently less than pure Zn:Cu in all tissues, but differences were not significant except in decayed tissues.

The voltage measurements obtained with Zn:Cu electrodes averaged 0.78V in all red maple and red oak tissues. The stainless steel:Zn, stainless steel:Cu, and stainless steel:Ag electrodes resulted in average voltages of 0.45, 0.10, and 0.6 V respectively. The amount of voltage was related directly to the amount of electric current generated from various electrode combinations.

Electric currents were produced in increasing amounts by Zn:Cu electrodes that were placed into potassium chloride solutions of progressively higher concn (Fig. 1). Electrical resistance decreased progressively in these same solutions as concn increased. These solutions represented the approximate range of potassium concns found in clear, discolored, and decayed wood of red maple (8).

Discolored and decayed wood from living trees could be detected with electric currents generated by polarizing metal electrodes. Concentration of mobile ions in potassium chloride solutions was shown to be correlated directly with the amount of current generated from these

TABLE 1. Comparison of electric current and electrical resistance in clear, discolored, and decayed wood of red maple and red oak

Tree species	Tissue condition or type	Mean[a] of electrical measurement	
		Electric[b] current (µA)	Resistance[c] (KΩ)
Red Maple	Clear	5±1	132±11
	Discolored	16±2	25±6
	Decayed	31±6	7±1
Red oak	Sapwood	11±2	64±7
	Clear Heartwood	6±1	140±12
	Discolored Heartwood	10±1	64±8
	Decayed Heartwood	17±7	17±7

[a]Means based on at least 20 measurements. The confidence limits, $P = 0.05$ are reported for each treatment mean.
[b]Zinc:copper electrodes were used for electric current measurements.
[c]Electrical resistance was measured with stainless steel moisture probes.

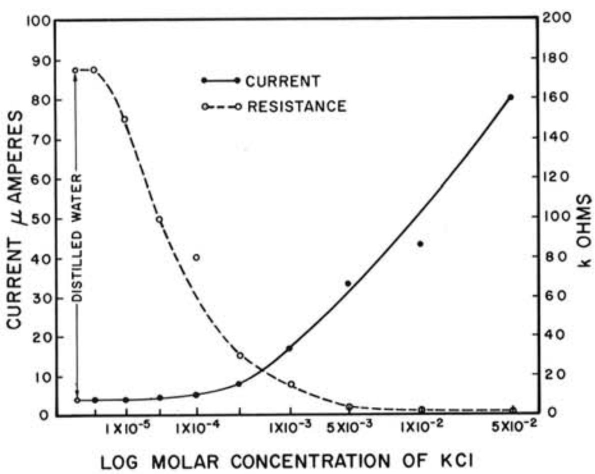

Fig. 1. Comparison of electric current and electrical resistance in increasing concn of potassium chloride solutions. Zn:Cu electrodes used to produce the electric current.

solutions. Increased concns of mobile ions were shown to be correlated to decreases in electrical resistance in discolored and decayed wood (8). It appears that concns of mobile ions are also an important factor in the amount of electric current produced in wood.

The system of polarizing metal electrodes can be thought of as a type of simple galvanic cell. The voltage differences between electrodes are related to the differences in electrical activities between the metals that were used (1). The voltage of any one electrode metal combination does not change in wood but the current flow of the cell is dependent upon concns of mobile ions as electron carriers. The wood is the source of these ions and any changes in ion concn in wood will affect current flow. This type of galvanic cell is not limited to wood in living trees and has been reported by Packman (4) in wood products which are exposed to seawater and fastened with nails of different electrical properties.

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