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AN AEROBIC-ANAEROBIC INTERACTIVE SYSTEM FOR SOIL SUSPENSIONS[1]

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Abstract

A system was developed that allows for the simultaneous batch study of aerobic and anaerobic soil suspensions. It is a modification of earlier systems that allowed for the investigation of homogeneous suspensions at desired oxidative-reduction potentials. This system allows for the contents of aerobic and anaerobic reaction vats to be mixed at desired proportions by using a peristaltic pump connecting the two systems. A desktop computer-based data acquisition system is used to control the pumping time and to monitor the redox potential in the respective vats. By using the HP 9825 calculator and the HP-IB bus, one can program the pumping, based on time, *Eh* readings, or other monitorable parameters. Gas samples taken from the air space of each unit permits one to study biological and chemical processes as they are affected by interaction of components from aerobic and anaerobic suspensions.

Additional Index Words: **redox potential, soil gases, microbial processes.**

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The system described herein is a modification of one developed by Patrick et al. (1973) for controlling redox potential (*Eh*) and pH in soil suspensions. This system can be used for batch study of both the liquid and gaseous phase of interactions that involve discrete aerobic, anaerobic, and aerobic-anaerobic conditions. Many processes that have significant agricultural and environmental importance involve aerobic-anaerobic interaction. These processes include nitrification-denitrification (Patrick and Mikkelsen, 1971; Hunt and Lee, 1975; Lance and Whisler, 1972) and the mobilization and subsequent precipitation of iron, manganese, and sulfur in soils and tile drains (Ford, 1974). There has been disagreement as to whether ethylene accumulation occurs under aerobic, anaerobic, or aerobic-anaerobic interactive conditions (Lynch, 1975; Smith and Cook, 1974; Hunt et al., 1980). We are presently using this system to better define the involvement of both aerobic and anaerobic conditions with C_2H_4 accumulation in soils.

Materials and Methods

The system simulating aerobic-anaerobic interaction consists of two independent but mechanically connected vats (Fig. 1). Each vat consists of a Plexiglas[3] cylinder (22 by 15 by 0.7 cm) bonded to a base and a top (20 by 20 by 2 cm), secured by four all-thread bolts (0.64 by 29 cm). A rubber gasket is inserted between the top and the main body of the vat to provide a closed, air-tight vessel. To provide an air-tight seal around the electrodes and glass tubing, eight brass, O-seal, straight-thread connectors and one brass male connector with a rubber septum are mounted into the top of the vat (Cajon UT-1 type).

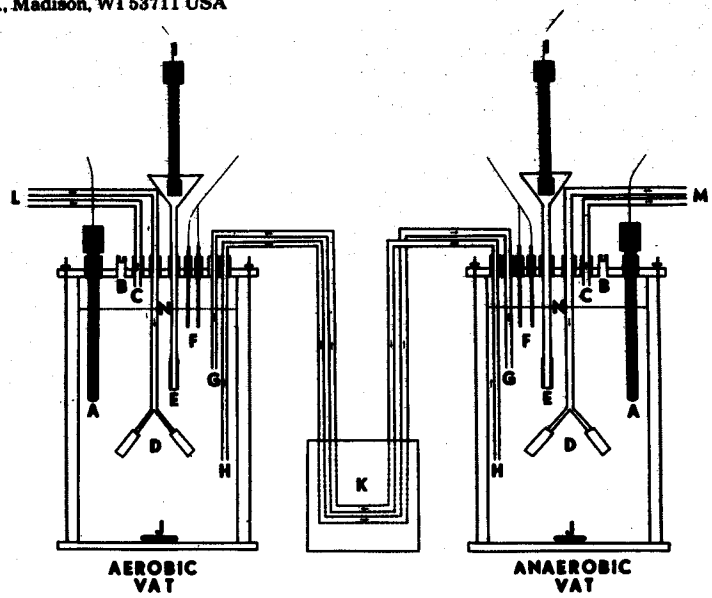

Fig. 1—A schematic of an aerobic-anaerobic interactive simulation system.

Two bright platinum electrodes (F) and a calomel electrode (I) are directly connected to a HP 3455A voltmeter and then to a HP9825A desk-top calculator to monitor *Eh* (Fig. 1). A salt bridge with a semipermeable membrane (E) provides an electrical contact between the calomel electrode and the soil-water suspension. Hydrogen-ion activity is measured with a James solid state pH electrode (A) connected to a pH meter, where the input is converted to an electrical signal. This must be done before pH can be monitored by the voltmeter. As pH is generally stable, we normally monitor it manually.

Gas samples for analysis are withdrawn from the air space of the vat by inserting a hypodermic needle through the rubber septum (B) (Fig. 1). Gas inlets L and M as well as gas outlet C are closed by Teflon-coated stopcocks. Gas is exchanged when a desired gas is bubbled through two air diffusers (D) and a positive pressure is created in the air space, thus, forcing the undesired gases out (C). The gas source (L) for the aerobic vat may be either in commercial tanks or atmospheric air. The gas source for the anaerobic vats is commercial N tanks with an oxygen trap (Oxy-trap, Sargent-Welch) (M). A masterflex peristaltic pump with head model 7017 and tygon tubing (K) transfers portions of the soil-water suspension from one vat to another. To ensure a constant air space and water level (N), the same amount of suspension must be pumped out (H) as is pumped in (G). Consequently, the same peristaltic pump must make two equal, simultaneous transfers. The transferred volume is dependent on the tubing size, pump head size, and the pump speed. Since the pump is entirely controlled by the desktop computer, transfer intervals are held constant. The soil water mixture is kept in suspension by a magnetic stirrer and stirring bar (J).

The desktop computer-based data acquisition system (DAS) consists of a Hewlett Packard 9825A desktop computer interfaced to 20 channels of low level signal data, 10 channels of relays for on-off control, a Hewlett Packard 3455A digital voltmeter, and a Hewlett Packard 39308A timing generator (Fig. 2). The peristaltic pumps were interfaced to the DAS by adding a small circuit for on-off control. The DAS was programmed to monitor the Eh and the pH of the vats every 15 min. Once every hour, the DAS initiated a mixing cycle for 30 sec. The DAS also simultaneously runs a microclimate system and monitors a Technicon Auto Analyzer (Parsons et al., 1980).

Results and Discussion

The system has functioned well, however, we found that certain specifications must be met. The soil added to the reaction vat must be maintained in suspen-

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[3] Mention of product names is for description only and not an endorsement by USDA-SEA-AR.

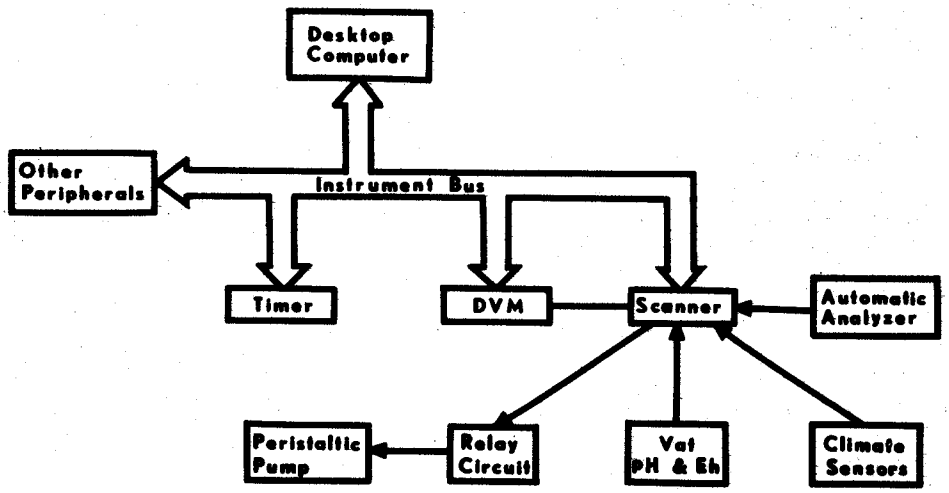

Fig. 2—System configuration.

sion. For Norfolk sandy loam (Typic Paleudults) we found the optimum soil-water ratio was 200 g to 2500 cm^3. This provided a 500 cm^3 air space, which was small enough to prevent dilution of produced gases beyond detection limits of our instrumentation (HP 5750 flame ionization detector gas chromatograph). Soil particles greater than about 50 μm in diam should not be used because they cause suspension and abrasion problems. Settling of soil particles around the peristaltic pump head inhibits normal pumping operations. This problem can be avoided by elevating the pump above the vats and allowing the soil particles to settle. Also, the peristaltic pump tubing must have no constrictions because of tube clogging by the soil particles. By using a desktop computer or an inexpensive microprocessor and selenoid valves, one could automatically control the system by controlling the mixing of liquids or gases to maintain Eh at desired levels.

Figure 3 shows the mean *Eh* of duplicate vat systems containing the less than 50-μm fraction of a Norfolk sandy loam with 0.5% organic matter, as monitored by the desktop computer over an 11-hour period. One vat was greatly reduced, whereas the other was oxidized, clearly indicating two distinct systems. The impact of the 30-sec/hour mixing can be seen in the periodic reductions of the oxidized vat and the slow increase in *Eh* of the reduced vat. Thus, the system allows the investigation of processes that involve the input of products from a more reduced zone or microsite to one less reduced and visa versa. This assessment is not possible if one is only studying an experimental system in which the redox condition is always increasingly reduced. However, it must be recognized as a batch-mixing process. This method does not simulate continuous *Eh* gradients or allow for reactions fostered by the continuous input of unstable intermediates.

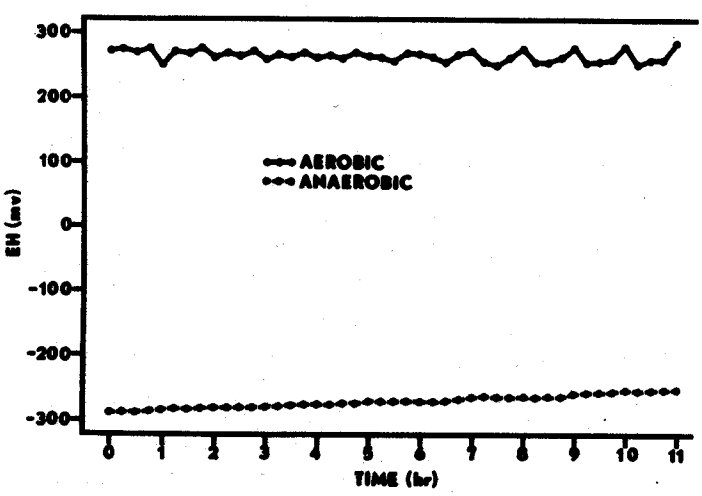

Fig. 3—Oxidation-reduction potential of aerobic and anaerobic soil suspensions during a period of intermittent exchanges between suspensions.

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