2006-1185: DEVELOPMENT AND IMPLEMENTATION OF AN INTERNET-ENABLED ENVIRONMENTAL ENGINEERING EXPERIMENT

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Development and Implementation of an Internet-Enabled Environmental Engineering Experiment

Abstract

Some degree of laboratory experience is desirable for a comprehensive education in environmental engineering. While it would be advantageous for all students to obtain hands-on laboratory skills in a laboratory class on campus, it is not feasible for some students to attend lab courses either because of time constraints (*e.g.* part-time students) or physical limitations that preclude access to a laboratory. There should be an opportunity for all engineering students to be exposed to laboratory experiences. This project was initiated with the hypothesis that remote laboratory experiments controlled via the internet may enhance the educational experience of students who would otherwise not have a laboratory opportunity. The internet-enabled experiment can be implemented for undergraduates and graduates, distance-learners and on-campus students, as well as for physically-challenged students.

Adsorption phenomena and the need for the experiment

Adsorption of contaminants to granular activated carbon is a common process used to remove contaminants from air and water. It is frequently employed to assist in the remediation of contaminated sites, recovery of polluted waters, treatment of industrial wastewaters before discharge, treatment of potable water, etc. The equilibrium relationship between the aqueous concentration and mass of concentration adsorbed per mass of activated carbon is described by various isotherms (Langmuir, Freudlich, and others) and is a relatively straightforward concept for students to grasp. However, the behavior of contaminants when in a dynamic system such as a fixed bed contactor is somewhat difficult for students to understand by illustrating breakthrough curves in class; a "static" teaching approach to a "dynamic" problem. Contaminants must pass through four steps, two of which are relatively slow, to transfer from being in the bulk solution to being adsorbed. Figure 1 illustrates the four steps: (1) bulk advection (fast), (2) film diffusion (slow), (3) pore diffusion (slow), and (4) surface adsorption (fast)[1]. Passing contaminated water and air through fixed bed contactors is a widely-applied technology for environmental remediation, so it is important for students to understand the mass transfer limitations with this process.

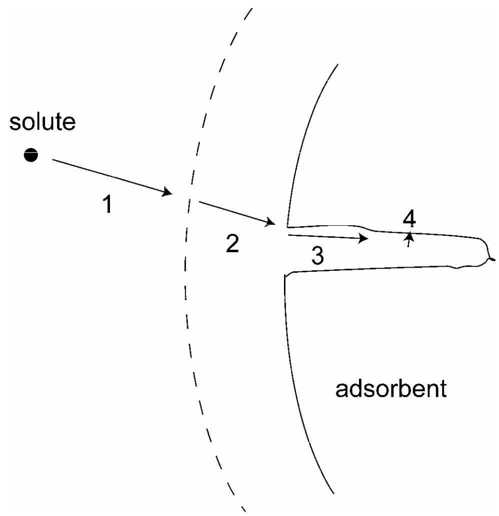

Fig. 1. Adsorption steps.

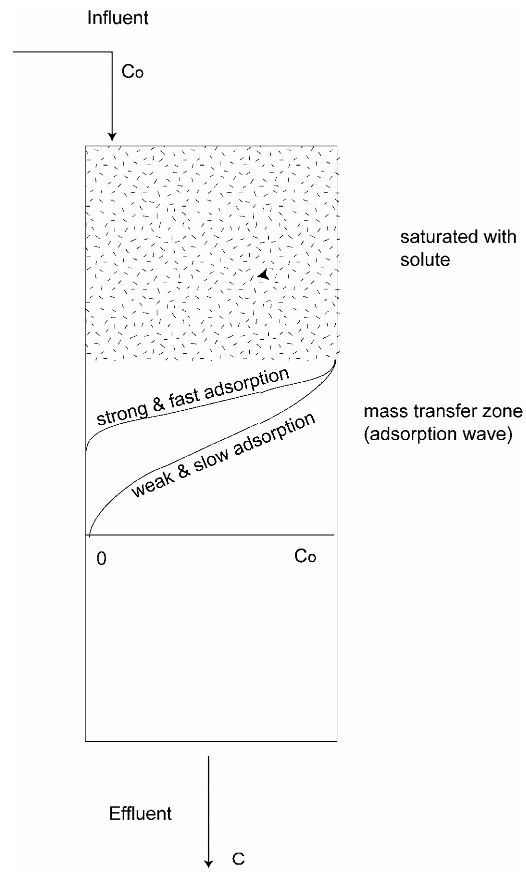

Fig 2. Mass transfer zone in fixed bed contactor (adapted from Snoeyink and Summers[1]).

The slow mass transfer in steps one and two produce a mass transfer zone or an adsorption wave during adsorption in fixed bed contactors as shown in Figure 2. During a complete adsorption cycle where the carbon starts "clean" and is contacted until it is completely saturated with contaminant, the effluent from the fixed bed contactor would have a period of time where there is negligible concentration of contaminant in the effluent, a period where there is a measurable and increasing concentration (when the mass transfer zone has reached the effluent), and finally the column will be completely saturated (the concentration in the effluent will be equal to the concentration in the influent). The mass transfer zone length is dependent on many governing parameters, including the contaminant diffusivity and the superficial velocity of the water through the contactor as well as the source and type of activated carbon. The length of this mass transfer zone is important for operation, and can affect the design of the system. It may influence the ultimate overall carbon usage and efficiency of the system.

Students may more fully understand the behavior of a fixed bed contactor by running an experiment with a fixed bed contactor and measuring the effluent contaminant concentration with time. Unfortunately, it may be difficult to have students run experiments in the lab because of logistic difficulties, including time constraints of the course and instructors. In addition, students with physical difficulties may have trouble accessing the laboratory and the experimental apparatus. An experiment that can be controlled remotely allows students to experience the experiment, while providing flexibility for students to run the experiment asynchronously from any location via the internet. While others have created simulations of processes that can be accessed over the internet, and analytical instrumentation has been accessed remotely by students[2], in this work an adsorption experiment was developed that can be remotely operated by students with no on-site assistance (except for periodically refilling the fluid reservoirs).

The experiment

The experiment consists of hardware set up to obtain data on adsorption of methylene blue to granular activated carbon in a packed bed contactor, as illustrated in Figure 3. The experimental hardware is interfaced to a data acquisition card on a computer server running National Instruments "Labview"™ software, utilizing the wiring schematic in Figure 4. A virtual instrument (VI) was developed that allows on-site and remote control on the server computer and provides a continuous read-out of effluent absorbance on the VI. An Axis 2110 network camera provides a continuous video to the user's computer on the browser so visual indications can be monitored. A remote user can access the IP address of the server with a browser, download a Labview runtime, and run the experiment. See Figure 5.

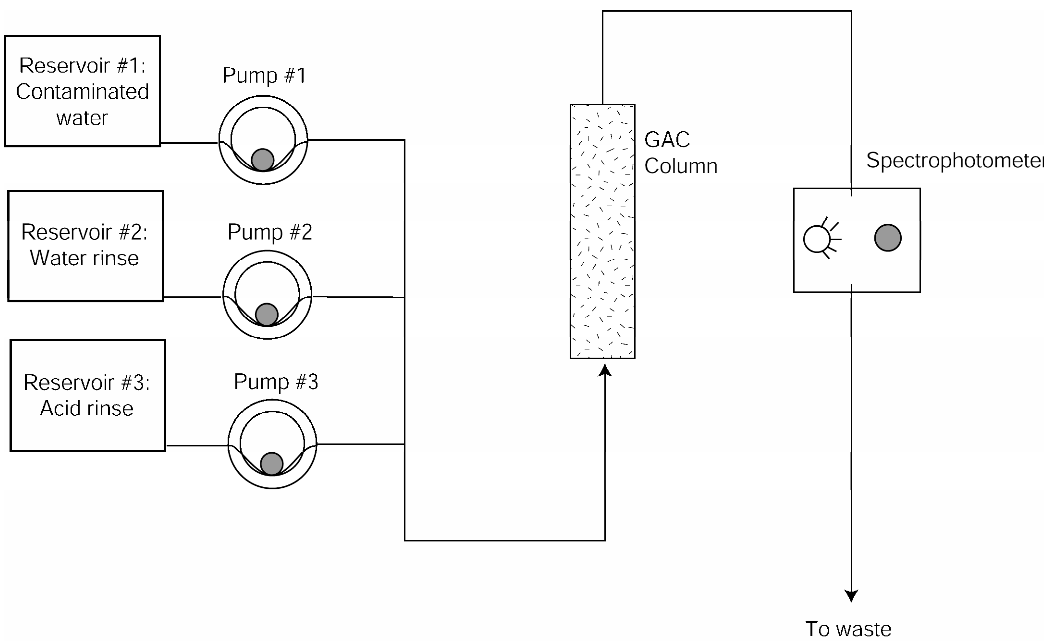

Fig. 3. Experimental hardware.

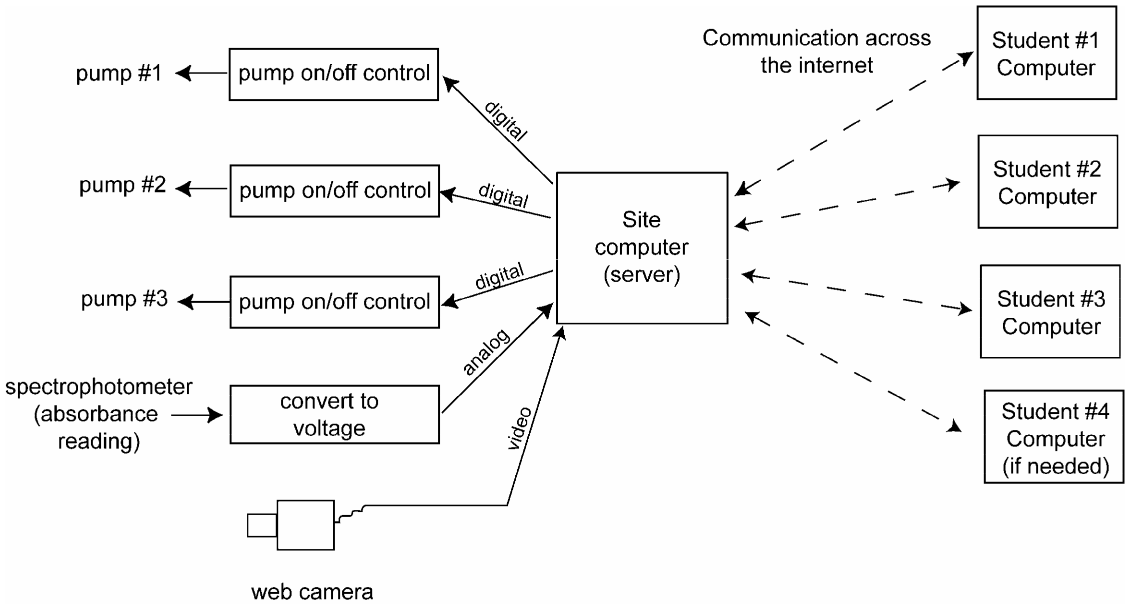

Fig. 4. Control and data acquisition scheme.

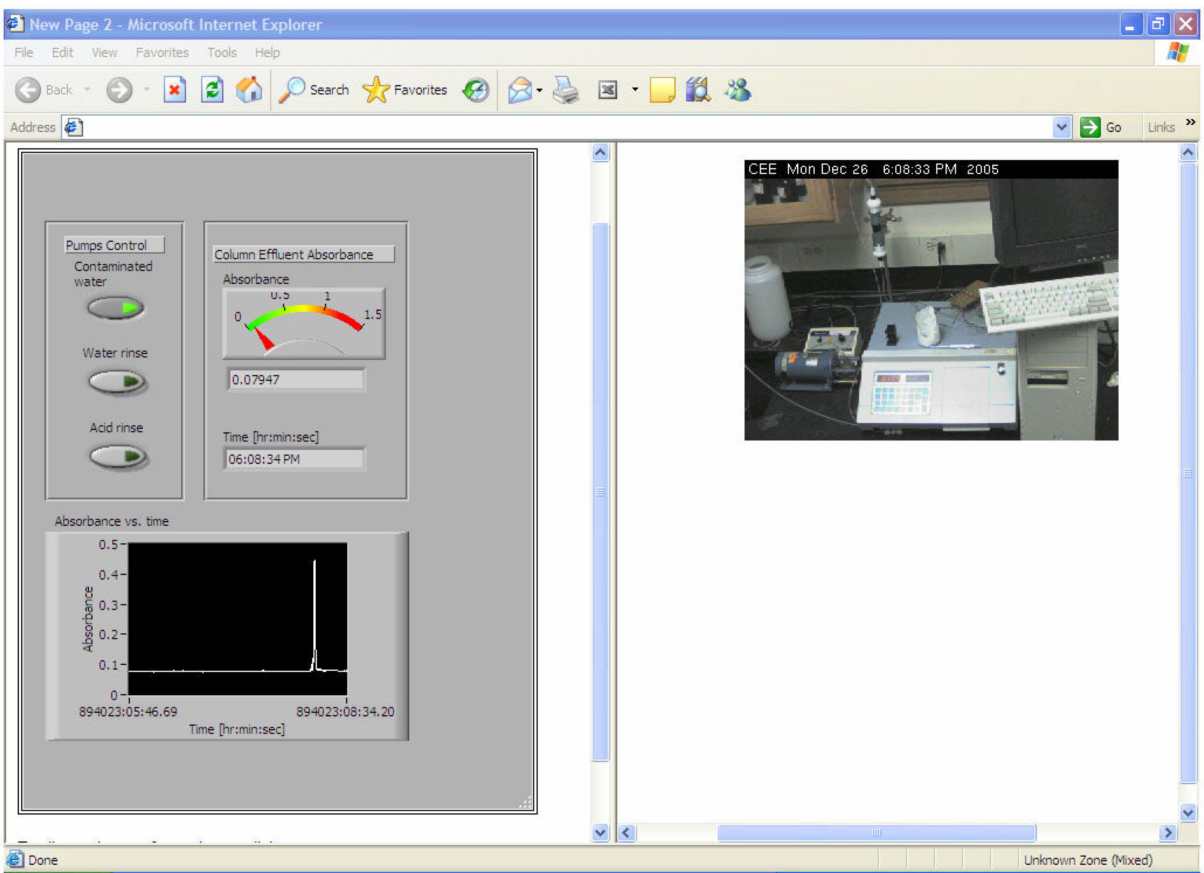

Fig. 5. Remote user interface in browser showing the "Labview" VI running on the server and the AXIS network camera video.

As water passes through the packed column of activated carbon, the methylene blue is removed from solution by adsorption to the activated carbon. Effluent concentration is continuously measured with light absorbance using a Hach UV/vis spectrophotometer. Remote students are able to view the hardware through the internet with a permanently-installed camera. From absorbance data, students can evaluate the effectiveness of removal of the contaminant under predetermined conditions (*i.e.* contaminant concentration, water superficial velocity).

The procedure for running the experiment is: (a) open a browser to the server's IP address; (b) download the "Labview" runtime (automatically prompted for download and installed if it is not already installed on the user's computer); (c) rinse the contaminant from the media with a dilute acid solution (~10% HCl) for about 30 s by pushing the "acid rinse" pump toggle switch to initiate the acid rinse, and pushing it again to stop; (d) flush the acid from the media by flowing clean rinse water (purified water) through the column for 2 min by using the "rinse water" pump toggle switch; (e) initiate flow of contaminated water to the activated carbon by pushing the "contaminated water" pump toggle switch; (f) record absorbance versus time as the effluent concentration (absorbance) increases; (g) when the effluent absorbance remains constant (absorbance greater than approximately 0.4) secure the "contaminated water" pump toggle switch (off); (h) rinse the media with the dilute acid solution for about 30 s; (i) flush the acid from the media by flowing rinse water through the column for 2 min; and (j) make sure all pumps are off, and then close the browser.

Results

Typical breakthrough curves are shown in Figure 6 for two different superficial velocities. The periods where the mass transfer zones are exiting the effluent can be clearly seen (between about 400 s and 1000 s for run 1). And the difference in acceptable runtimes for the two flow rates can easily be discerned from the data. From this experiment, students can gain a better understanding of the behavior of a dynamic system comprised of an activated carbon adsorber. Assessment of learning outcomes is being collected, which will include a specific comparison of experiences for on-site students to remote students.

The experiment is currently planned for implementation in two undergraduate courses in Spring 2006. Future plans are to add the ability to adjust flow rate remotely, provide for using two different "contaminants", and allow one of two different activated carbons to be selected. Other internet-controlled experiments are being considered.

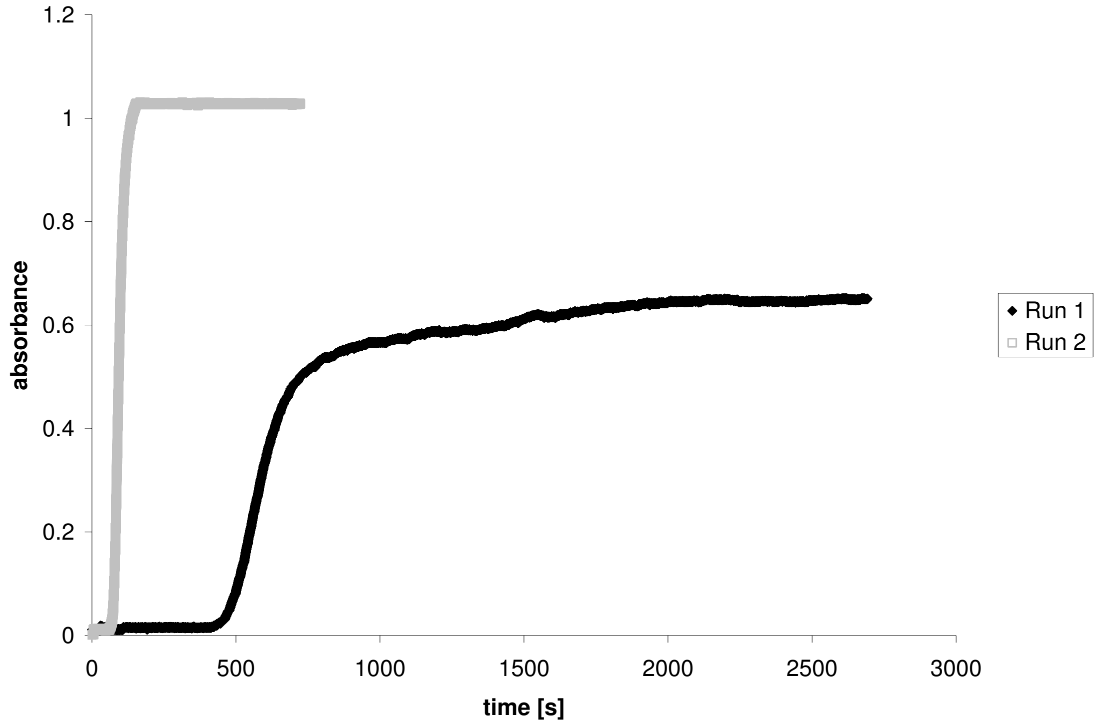

Fig. 6. Typical breakthrough curves obtained remotely.

Conclusions

An activated carbon column adsorption experiment that can be controlled via the internet was developed and is being implemented in environmental engineering courses. This project will illustrate the effectiveness of an internet-controlled experiment in undergraduate and graduate courses, and will provide information favorable to the development of additional remote experiments to provide a laboratory experience for environmental engineering students.

Bibliography

1. Snoeyink, V. L. and Summers, R. S.; "Adsorption of Organic Compounds", Ch. 13. In: *Water Quality and Treatment - A Handbook of Community Water Supplies*; 5th ed.; Letterman, R. D., Ed.; McGraw-Hill: New York, **1999**.

2. Baran, J.; Currie, R. and Kennepohl, D.; *Journal of Chemical Education,* **2004**, *81*, 1814.