Distribution of Polychlorinated Biphenyls in an Aerated Biological Oxidation Wastewater Treatment System

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Polychlorinated biphenyls (PCB) have received considerable attention over the last decade because of the slow biodegradability and the possible toxicity to various ecosystems including human beings (HOLMES et al. 1970; RISEBROUGH et al. 1968; JENSEN et al. 1969; KOEMAN et al. 1969; PRESTT et al. 1970; BIROS et al. 1970; PEAKALL and LINCER 1970; WILDISH 1970; VOS and KOEMAN 1970; NIMMO et al. 1971; HANSEN et al. 1971; VILLENEUVE et al. 1971; REHFELD et al. 1971; KURATSUNE et al. 1971; MOSSER et al. 1971). PCB is distributed to the environment mainly through various water courses. PCB in waters, wastewaters, and coastal waters has been reported elsewhere (DUKE et al. 1970; AHLING and JENSEN 1970; HOLDEN 1970; SCHMIDT et al. 1971). However, the fate of PCB in water and wastewater treatment systems, especially in a secondary aerated oxidation system has not been studied. A knowledge of PCB distribution in this particular pathway to the environment is of interest from the standpoint of its ultimate control. This study aims at determining the PCB distribution in a secondary aeration system and examining the effect of the substance on the system's performance.

Material and Method

A secondary sewage treatment laboratory system consisting of an aeration tank (volume: 2340 cm^3 at normal operating conditions) and a clarifier (volume: 2450 cm^3) was employed in this study (see Figure 1). The feed rate was adjusted to provide 5-10 hours mean residence time. The air flow rate was adjusted to keep the dissolved oxygen level in the aeration tank at about 4 ppm or higher.

The wastewater employed for feed of the system was a natural wastewater collected from the effluent of primary treatment in a municipal sewage treatment plant (Jackson Pike Plant, Columbus, Ohio). A synthetic wastewater was not considered to be appropriate for use in the treatability study although it might give an advantage of reproducibility of experimental results. PCB spiking into wastewaters was carried

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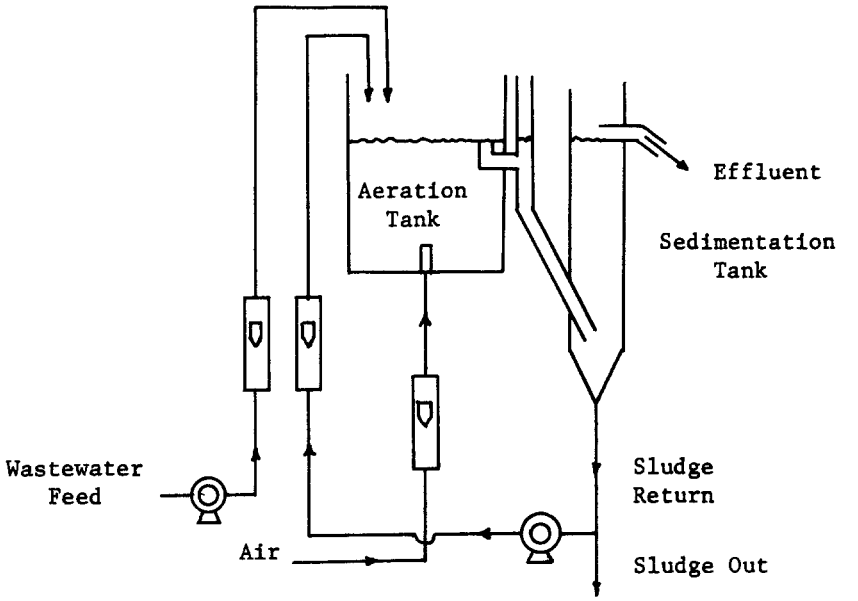


FIGURE 1. DIAGRAM OF A SECONDARY BIOLOGICAL OXIDATION SYSTEM

out using an ultrasonic emulsifier; i.e., PCB (Aroclor 1254) was first dissolved in a certain amount of n-Butanol, and then, the mixture was emulsified in wastewater by treating with ultrasound at 0.2 - 0.3 ampere for 4 to 6 minutes.

The quantitative analysis method for PCB has been delineated (REYNOLDS 1969; ARMOUR and BURKE 1970; ZITKO et al. 1971; ROTE and MURPHY 1971; SNYDER and REINERT 1971). A gas-liquid-chromatographic method was employed in this study. Separation of PCB from other interfering substances was made by extracting it with methylene chloride in the presence of hydrochloric acid and sodium chloride, concentrating the mixture, and separating it through a silica gel column. A gas-liquid-chromatograph, utilizing an electron capture detector and a 6' x 1/4" O.D. ($\sim$ 2 mm I.D.) glass column packed with 1.5 percent OV - 17/1.95 percent QF-1 on supelocoport was employed under operating conditions as follows: column temperature, 195°C; injector temperature, 220°C; detector temperature, 210°C; carrier gas, helium, carrier gas flow rate, 30 ml/min; volume injected, 2$\mu\ell$. The calibration of the chromatograph was carried out and the chart was prepared for the quantitative measurement.

In a typical experimental run, the secondary biological oxidation system shown in Figure 1 was operated for 5 to 11 days to reach a steady state condition, and then PCB was introduced for a period of 2 to 3 days. Four to eight days of final

operation was followed after the termination of the PCB introduction. The operating conditions of the system were as follows: feed rate, 3.91 cm^3/min; sludge return rate, 3.44 cm^3/min; sludge output rate, 0; mean residence time in aeration tank, 9.98 hours.

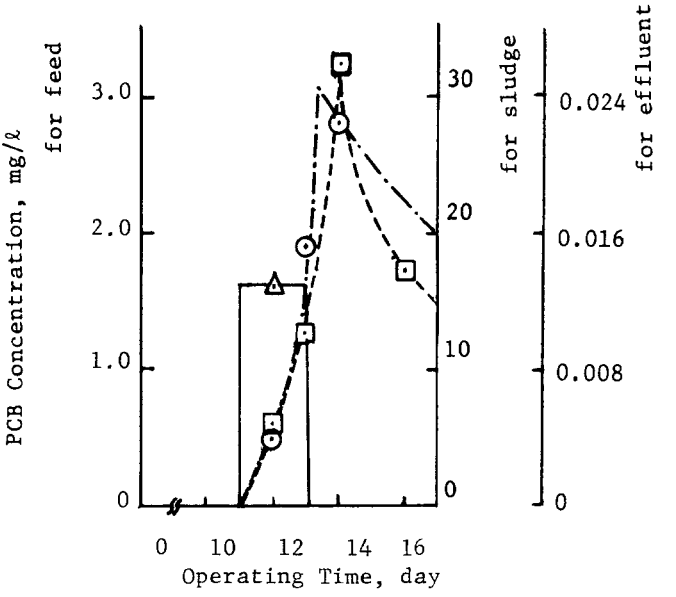
Results and Discussion

Two experimental runs were conducted after completion of several preliminary runs needed for adjustment of the operating conditions. The results are shown in Figure 2 and indicate that a considerable amount of PCB accumulated in sludge. For Experimental Run (1) concentrations in sludge of 6.14, 12.75, 32.33, and 17.33 ppm were found 1, 2, 3, and 5 days after PCB introduction, respectively. The feed concentration was 1.63 ppm. For Experimental Run (2) concentrations in sludge of 36.2, 109.6, 152.0, 105.6, 112.0, and 84.0 ppm were found respectively 1, 2, 3, 5, 6, and 10 days after PCB introduction at the level of 16.88 ppm. Effluent solution, on the other hand, contained relatively small amounts of PCB. For Experimental Run (1) the concentrations of 0.004, 0.0153, and 0.0225 ppm were found 1, 2, and 3 days after PCB introduction, respectively. For Experimental Run (2) the effluents contained PCB concentrations of 0.006, 0.015, 0.042, 0.032, 0.022, and 0.015 ppm respectively, 1, 2, 3, 5, 8, and 10 days after the PCB introduction. PCB concentrations in feed, effluent, and sludge were 0.009, <0.001 and 0.07 ppm, respectively when PCB was not spiked into the wastewater.

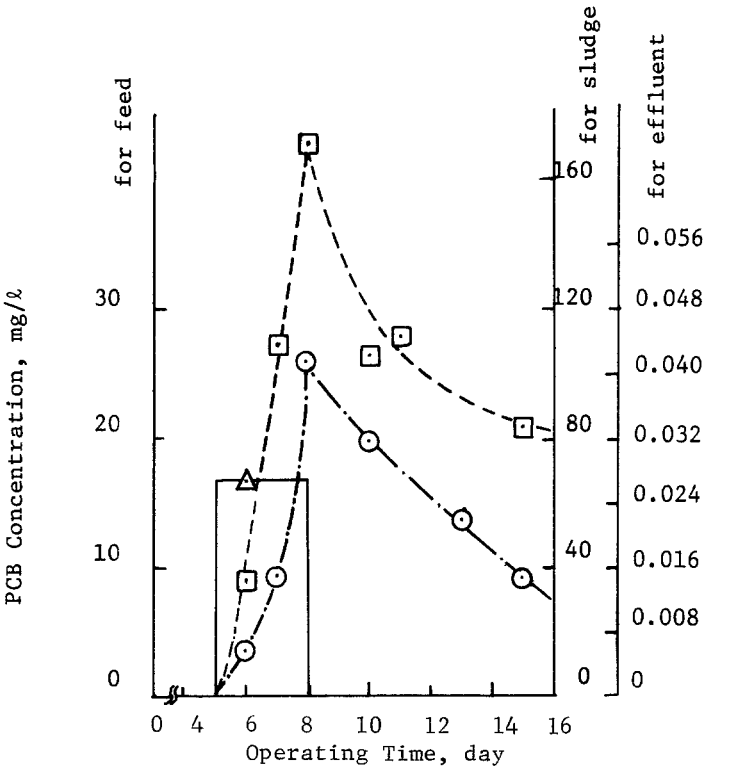
The interference of PCB on the system's performance in terms of BOD, COD, and TOC removal efficiencies was not clear. Microbiological studies are required to obtain further information on this matter.

Another view of the results involves consideration of the dynamic concentration response of PCB in effluents and sludges for the impulse type PCB input. As shown in Figure 2, PCB concentration in effluents and sludges rapidly increased with a step increase of PCB in feed, and then, decreased rather slowly with the same step size decrease of PCB in feed. The response of the system comprising a completely mixed tank and a tank without a stirrer could be approximated by a second or higher order dynamic model although the response was complicated due to the sludge return and a lack of knowledge on the degree of mixing in the second tank.

According to the results, the secondary aerated biological oxidation system removes a high percentage of the PCB contained in wastewater. The treatment system, however, is



(a) Experimental Run (1); Low Level PCB Introduction



(b) Experimental Run (2); High Level PCB Introduction

FIGURE 2. PCB CONCENTRATION RESPONSES IN EFFLUENTS AND SLUDGES OF A SECONDARY AERATION TANK SYSTEM FOR A PCB INPUT (Symbols: △, feed; ⊙, effluent; ⊡, sludge)

not believed to biodegrade or convert PCB to lower molecular weight or other types of chemical substances which are readily degradable. Instead, PCB is expected to be dissolved in fats present in sludge, adsorbed at the surface of the suspended material in sludge, or ingested by microbial cells in sludge. A combination of all of the above effects probably are operative in the concentration of PCB in sludge. Further study should be conducted to expand upon the results since this knowledge is essential in modifying current sludge handling methods. Simultaneously, landfill, land spread, and ocean dumping of sludge should be reexamined to keep PCB under control if the quantity of PCB discharge to streams increases. In addition, sludge incinceration should be reviewed to determine the fate of PCB in that system. Finally, a tertiary treatment system such as activated carbon, should be studied to effect further removal of PCB from secondary effluents.

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