Polychlorinated Biphenyl Emission from Fluorescent Lamp Ballasts

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Polychlorinated biphenyls (PCBs) have been used in a wide variety of industrial and consumer applications over the past 40 years, but only recently did evidence appear that those materials were becoming widely distributed in the environment (GUSTAFSON 1970; DUSTMAN et al. 1971; RISEBROUGH et al. 1968). PCBs are used extensively by the electrical industry as components of certain types of transformers and condensers. An important use is as insulating liquid in ballasts for fluorescent light fixtures. Although light fixtures with ballasts are found in homes, they find greater use in offices, laboratories, or industrial plants. Certain types of ballasts, when they reach the end of their life, may be accompanied by spontaneous leaking, smoking, and a markedly objectionable odor which tends to penetrate throughout the adjacent area.

In ballasts manufactured more recently, thermal protective cut-out switches are usually incorporated into the units to prevent overheating, thus preventing smoking, leaking of fluid, and the accompanying objectionable odor. Ballast life is normally estimated at around twelve years (IES LIGHTING HANDBOOK 1966); however, this is dependent primarily upon temperature of operation. Thus, shorter life or very much longer service can be obtained depending on the circumstances of operation such as the use of heat shields for deflecting heat from ballast. Although worn-out ballasts are usually replaced with newer types having thermal protective switches, a great many of the earlier units without such protective devices are still in use throughout the country.

Because ballast fluids are known to contain PCBs, the occasional burnout of ballasts at this laboratory has stimulated our interest in the problem of PCB emission, not only from the standpoint of potential exposure of people working nearby but also from the potential of the compounds emitted being undesirable contaminants in an analytical chemistry laboratory where analyses for trace amounts of related compounds are being carried out. Prior to 1952 the liquid used as the insulating medium in the types of ballasts under study was Aroclor 1254;[1] however, after that it was replaced by Aroclor 1242 which has better electrical properties and a more favorable dielectric constant (GENERAL ELECTRIC COMPANY 1972).

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The purpose of the present study was to determine if PCBs are emitted when fluorescent light ballasts burn out; to determine which compounds, if any, are involved; to explore the analytical problems encountered in PCB analyses; and to attempt to quantitate any emission at different distances from burned out, defective, or properly operating ballasts.

EXPERIMENTAL

Tests for PCB emission were carried out under several experimental conditions at the Wenatchee Research Station laboratory, U.S. Environmental Protection Agency, Wenatchee, Washington. In one series, samples of air were taken at different distances from a spent ballast that had burned out under actual operating conditions. Sampling was started 5 minutes after objectionable odor and fluid leakage indicated a burnout. This was followed three days later by the collection of additional air samples at the same respective locations. Several weeks later air samples were also taken at different distances from similar ballasts that appeared to be operating satisfactorily in the fluorescent light units.

In a second series of tests, both burned-out and non-burned-out ballasts were heated at various temperatures in 61 x 122 x 122 cm test chamber boxes. Air samples were drawn from the test chambers during 30-minute periods when the temperatures of the lower sides of the ballast casings were approximately 150, 300, and 400°C to determine emission of PCBs and leakage of fluid as related to temperature under artificial conditions.

In the above tests two sizes of ballasts were involved. One was 33 cm in length and the other type was 26.7 cm in length. Each was designed for operation of two 96T12 or two 72T12 fluorescent lamps at 425 or 430 milliamps. All air sampling noted above was accomplished by use of portable battery-powered vacuum pumps connected in series to two midget impingers. Ethylene glycol was used as the trapping solvent. A flow rate of 2.83 liters per minute was employed. Samplers were operated for periods of 30 minutes for the series in test chambers and from 2 to 6 hours following conventional burnout or during normal operating conditions.

A third series of tests to detect low-level PCB emissions from fluorescent lights was carried out at the Colorado Community Study on Pesticides, Greeley, Colorado, using the nylon chiffon screen method of TESSARI and SPENCER (1971). This method involves exposure of an ethylene glycol-treated cloth screen in an area to be tested for the presence of chemicals in air. The screen was left in place for a sampling period of 144 hours during fluorescent light operation, thus allowing contact with a larger volume of air than was utilized

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[1] Use of trade names is for identification purposes only and does not constitute endorsement by the U.S. Environmental Protection Agency.

with the impinger. This made it possible to detect smaller amounts of PCBs than was possible with the impinger technique. Following a sampling period, the cloth screen is extracted with a suitable solvent to be used in chemical analysis. The present study involved exposure of one-half square meter of ethylene glycol-treated nylon chiffon cloth having mesh openings of 0.0477 sq cm, thread size 0.0076 cm, 90 mesh, and 47% open area. This cloth was suspended from a laboratory light fixture so that its maximum distance from the fixture was 35.6 cm. The fluorescent light fixture held two 40-watt bulbs 122 cm long and was equipped with a high power factor lead log ballast 20.3 cm long, 118 volts, 60 cycles, and line current 0.85 amperes.

Sample Work-up: Ethylene glycol from the impingers was transferred to a separatory funnel and the impingers were washed with water. Dilute sodium sulfate solution was added to the combined ethylene glycol-water mixture. The solution was mixed well and extracted 3 times with nanograde hexane. The combined hexane extracts were filtered over anhydrous sodium sulfate and collected in 100 ml volumetric flasks. The solutions of hexane then could either be diluted or concentrated to give an appropriate working concentration for gas chromatographic or thin layer chromatographic analyses.

Details for extraction and work-up of the extract from the nylon chiffon mesh screen are given in the paper by TESSARI and SPENCER (1971).

Gas Chromatography: Air samples obtained from the burned-out ballast and subsequent experimentally heated ballasts, as well as liquid residues from these ballasts, were analyzed by gas chromatography. A Microtek MT-220 gas chromatograph equipped with a ${}_1H^3$ (tritium) electron capture detector was used. Columns employed were 4% SE-30/6% QF-1 on Chromosorb W, H.P. 80/100 mesh and 1.5% OV-17/1.95% QF-1 on Chromosorb W, H.P. 100/120 mesh. Additional confirmation of PCBs from the cloth screen was obtained by gas chromatography on a 3% OV-1 column using a chlorine specific Coulson electroconductivity detector system.

Thin Layer Chromatography: The gas chromatographic analyses were confirmed by reverse phase thin layer chromatography according to the method of DE VOS and PEET (1971). Uniplate TLC plates were used. Liquid residues were analyzed with appropriate dilutions, directly on the TLC plates, concurrently with Aroclor standards.[2] Air samples, in some cases, required concentration of the hexane extract before visualization could be accomplished. More specific identification of PCBs from the cloth screen was by the thin layer chromatography procedure according to MULHORN *et al*. (1971).

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[2] Provided by Monsanto Chemical Co., St. Louis, Mo.

TABLE 1

Distribution of Polychlorinated Biphenyls in a Room After Burnout of Light Ballast[a]

Sample no.	Air sampling time[b] (hrs)	Distance of Air sampler from ballast (M)	Amount of PCB[c] recovered (μg)	Calculated air concentration (mg/M^3)
1	4.5	1 (below)	90.4	0.118
2	4.5	1 (below)	127.0	0.166
3	2.0	2 (laterally)	10.6	0.031
4	3.0	2 (laterally)	23.2	0.046
5	4.0	3 (west side of room)	12.2	0.018
6	4.5	4.5 (N.W. corner of room)	9.1	0.012
7	4.5	6 (S.W. corner of room)	10.5	0.014

[a] 33 cm ballast for operation of two 96T12 or two 72T12 fluorescent lamps at 425 MA (without protective thermal trip device).

[b] Air sampling started 5 minutes after ballast started to burn out.

[c] Identified as Aroclor 1242.

RESULTS AND DISCUSSION

Results of analyses of the volatile emissions from a burned-out fluorescent light ballast indicated a preponderance of Aroclor 1242 formulation of polychlorinated biphenyls. Certain other peaks characteristic of polychlorinated biphenyls were noted, but were not identified. Analysis of samples of the dark, oily fluid which dripped from this same ballast during its time of malfunctioning yielded an average assay value of 6.2×10^5 ppm (62%) Aroclor 1242 with no evidence of other polychlorinated biphenyls.

The approximate distribution of PCBs emitted from a burned-out ballast in a laboratory room is shown in Table 1. Calculations based on results of air samples collected during a 4-1/2-hour period starting 5 minutes after detection of ballast burnout indicated a level of 0.166 mg/M^3, the highest level found in this series of tests. This was at a point 1 M below the fluorescent light fixture and ballast, and approximately nose height level for workers in the area. Air samples taken at the same height but 2 M from the ballast showed a maximum value of 0.046 mg/M^3. At 3 to 6 M distance at the same height the values were from 0.012 to 0.018 mg/M^3. All values are below the 1.0 mg/M^3 threshold limit established for Aroclor 1242 by the American Conference of Governmental Industrial Hygienists (1972). Thus, unless several ballasts burn out at approximately the same time, health hazard to persons exposed in the area should be minimal.

In order to determine if there was any persistence of PCBs in the room after a period of 3 days, another series of air samples were collected at the same locations as given above (Table 2). In general, Aroclor 1242 was still detectable but at very low levels. One meter below the ballast the highest concentration found at that time was 0.004 mg/M^3, and at the 2 M distance it was 0.002 mg/M^3. At 4.5 to 6 M distance the values were 0.001 mg/M^3.

Several weeks after the original burnout occurred, no PCBs could be detected (lower limit of sensitivity of test was approximately 0.0005 mg/M^3 in air samples taken during a five-hour period (1019 liters per sample) at different distances from properly operating fluorescent light ballast units in the laboratory building. One of the samples was taken within 5 cm of a ballast casing having a bottom surface temperature of 72°C. Bottom surface temperatures of 10 normally operating ballasts in the laboratory ranged from 67°C to 72°C.

Results of analyses of artificially induced PCB emissions from ballasts heated at various temperatures in a test chamber are shown in Table 3. Samples 14 and 15 involved additional heating of the same ballast that emitted PCBs in the laboratory as reported in Tables 1 and 2. PCB samples 16-18 and PCB

TABLE 2

Distribution of Polychlorinated Biphenyls in a Room 3 Days After Burnout of Light Ballast[a]

Sample no.	Air sampling time (hrs)	Distance of air sampler from ballast (M)	Amount of PCB[b] recovered (μg)	Calculated air concentration (mg/M^3)
8	6	1 (below)	5.1	0.001
9	6	1 (below)	4.3	0.004
10	6	2 (laterally)	2.4	0.002
11	6	2 (laterally)	1.9	0.002
12	6	4.5 (N.W. corner of room)	0.7	0.001
13	6	6 (S.W. corner of room)	0.9	0.001

[a] 33 cm ballast designed for operation of two 96T12 or two 72T12 fluorescent lamps at 425 MA (without thermal protection switch).

[b] Identified as Aroclor 1242.

TABLE 3

Artificially Induced PCB Emission from Ballasts Resulting from Heating[a]

Sample no.	Air sampling time (hrs)	Description of ballast[b]	Temp. heated (°C)	PCB[c] recovered (μg)	Air concentration in test chamber (mg/M^3)
14	0.5	33 cm burned-out ballast. Some leakage of fluid (during heating). Previously burned-out (ruptured) in laboratory.	300	144	1.696
15	0.5	Same as 14	400	2,400	28.268
16	0.5	Same ballast type as 14 (nonruptured)	150	none	el[d]
17	0.5	Same as 16	300	54	0.636
18	0.5	Same as 16	400	230	2.709
19	0.5	26.7 cm burned-out instant start ballast (nonruptured). Some leakage of fluid during heating.	150	none	el[c]
20	0.5	Same as 19	300	65	0.765
21	0.5	Same as 19	400	580	6.833
22	0.5	Same type as 19 (nonruptured) but had not burned out. Leaked black fluid above 300°C.	150	none	el[d]
23	0.5	Same as 22	300	47	0.553
24	0.5	Same as 22	400	214	2.521

[a] On hot plate in test chambers.

[b] Designed for use with two 96T12 or 72T12 fluorescent lamps at 425 MA without protective thermal trip devices.

[c] Identified as Aroclor 1242.

[d] Below lower limit (0.0005 M^3) of sensitivity of test.

samples 19-21 represent two additional ballasts which had previously burned out. PCB samples 22-24 represent a ballast that had been removed from a properly operating light unit that had not burned out. As can be seen in Table 3, no identifiable PCBs could be detected at 150°C. At 300°C the values ranged from 0.553 to 1.696 mg/M^3 for Aroclor 1242 in the test chamber and at 400°C the values ranged from 2.521 to 28.268 mg/M^3. It can also be seen in comparing these data that the heated ballast that had not burned out yielded results similar to the burned out ballasts. The above temperatures were chosen in an effort to bracket the possible temperature during which an actual burnout may occur. These results indicate that emission of PCBs from ballasts that have become defective and burned out occur at temperatures in the range of, or greater than, the higher temperatures used in the experiment. This can be considered a safety factor when compared to the average surface operating temperature of approximately 67°C to 72°C we found for fluorescent light ballasts that appeared to be operating normally. At the higher temperatures in the test chamber much smoke and fumes were emitted and black, thick, tar-like fluid seeped from the ballast casings. This material on cooling became hardened like tar as contrasted to the dark, oily liquid which dripped from the unit during actual burnout. Analysis of the cooled tar showed no PCB content.

In the present study each of the samples were run concomitantly with all suspected Aroclor formulations (1242, 1248, 1254, and 1260). Although in some air samples certain other PCB peaks were noted, only Aroclor 1242 was reported because the few additional peaks were very small.

In the study using the cloth screen technique, compounds identified as PCBs were detected in the range of 4.5 to 4.8 μg depending on the method of calculation. Using the method of TESSARI and SPENCER (1971) to estimate the level of the contaminant in air utilizing values obtained in the cloth screen tests, approximately 3 to 15 ng/M^3 could be calculated as present at the sampling zone. Determination of lower levels than were found with the impinger was possible because the cloth screen was subjected to a larger volume of air during the test period.

The results of the present paper, even though based on limited testing, indicates that PCBs are emitted during burnout of certain types of ballasts contained in fluorescent light units. Even though the levels detected in air were well below the level which might present a health hazard to persons working in a contaminated area, the PCBs may be undesirable contaminants in certain laboratories where detection of trace amounts of related compounds is necessary. Dripping of oily materials, tars, and PCBs from ballasts onto a workbench and glassware where samples are being prepared could present even more serious problems in the analyses of such samples by gas chromatography.

Results also indicate that emission from "normally operating" fluorescent light units is very low. The levels found are insignificant in comparison to the established threshold limit of 1 mg/M^3 for Aroclor 1242 (AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS 1972). It is possible that new fluorescent light ballasts may have no PCB emission and that certain older ballasts in "normally operating" light units may emit even more than was indicated in our tests; however, this could not be clarified with the limited experimentation conducted.

In recent years manufacturers have incorporated thermal protective switches in ballasts to prevent overheating and burnout. Thus, units now used as replacements should not overheat, rupture, and emit PCBs. However, because of the long life of ballasts (12 yrs average) many older thermally unprotected units are still in operation. Where PCB contamination may be a serious problem, resulting from ballast burnouts, consideration should be given to replacement of such nonprotected units with thermally protected units before burnouts occur. If a burnout should occur in a laboratory where trace amounts of PCBs may cause interference in analytical results, all glassware and surfaces exposed to either contaminated air or to liquid emission should be thoroughly decontaminated before use.

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