CONTROL OF WORKING ENVIRONMENT, OPERATION AND HEALTH CARE OF WORKERS IN PCB WASTE PROCESSING

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Abstract
To minimize concentrations of PCBs and related compounds in working environment, containers of PCBs such as transformers and capacitors were washed repeatedly before dismantled by workers. For small capacitors, glove boxes or vacuum thermal recycling was utilized. As a result, PCB concentrations in many areas were less than 0.01 mg/m^3, well satisfying the current Japanese administrative level of PCBs in workplace (0.1 mg/m^3). However, it was very difficult to lower the concentrations of dioxins (coplanar PCBs etc) less than 2.5 pg-TEQ/m^3. Thus, use of personal protective equipment (PPE) was needed. For biological monitoring, high resolution gas chromatography equipped with high resolution mass spectrometer seemed to be suitable because it was sensitive to tri- to pentachlorinated biphenyls that were predominant in the working environment. Biological exposure limit of PCBs was tentatively set to be 25 ng/g-blood. Combination of control of working environment, proper use of PPE and biological monitoring will lead to prevention of health problems of workers engaged in PCB waste processing.

Introduction
Since the first plant of Japan Environmental Safety Corporation (JESCO) was planned in Kitakyushu City in Fukuoka Prefecture, where “Rice Oil” was contaminated with PCBs in 1968 and the largest number of patients with “Yusho” were seen[1], various matters were analyzed in the regional as well as in the central advisory committees including safety and health of workers engaged in the PCB waste processing. Due to importance of the subject, a working group was organized and it was later reorganized as “Advisory Committee for Working Safety and Hygiene” in JESCO to cover possible problems not only in Kitakyushu but also in all plants. In this communication, measures taken to prevent health problems of the workers, which reflect discussions in the Committee, and some results, mainly those in Kitakyushu plant are presented.

Methods
1. Working environment
Working areas were classified as follows depending on the expected levels of PCBs in the environment.
a. Area level 3: The area that must be highly controlled because contamination of the working environment is likely to occur under normal operation.
b. Area level 2: Practically no contamination of the working environment will occur under normal operation because PCBs are separated from the workers, for instance in glove boxes, or PCBs have been almost completely removed by washing etc. Nevertheless, since PCBs of high concentration are indirectly treated (e.g., in glove boxes) or since materials that had contacted with high concentrations of PCBs are handled, appropriate control is needed.
c. Area level 1: Minimal control will suffice because PCBs are contained within apparatus, causing no contamination of the working environment under normal operation.
In addition to the legally required measurement (at least once in every 6 months in level 3 area), “voluntary” measurements of PCBs were carried out extensively with standard methods. Indoor pressures of working areas (level 3 and 2) were controlled negatively, and outgoing air was monitored for PCBs once in every one to few hours. The inlets for this on-line monitoring were placed where the workers work almost all time.

2. Personal protective equipment (PPE)

Workers in areas level 3 and 2 were expected to wear masks, gloves and protective clothes.

3. Biological monitoring

PCBs (and dioxins) can be absorbed into the human body not only through the lungs but also through skin and gastrointestinal tract. Hence, exposures to these chemicals cannot be fully evaluated by measuring their concentrations in the environment. Biological monitoring (determination of PCBs and dioxins in blood) was therefore decided to be carried out for all workers in level 3 area at least once a year and workers in level 2 area who may handle leaking containers or may be engaged in dismantling or washing of PCB wastes. In general, concentrations of PCBs and dioxins differ greatly among individuals. To negate this and possible regional differences, the same person was used as the control, i.e., the blood PCBs and dioxins were measured before a worker was engaged in the PCB processing. Besides, in case of involvement in emergency or contamination of the workplace, blood was obtained from practically all JESCO employees before operation was started and kept at -80^{o}C to examine PCBs and dioxins when it is necessary. All biological specimens were obtained after informed consent.

Results and Discussion

Control of working environment is the basis of safety and hygiene of the workers engaged in PCB waste processing, and every effort was made to minimize the level of PCBs in the working environment. In all plants, the principal method to decompose PCBs is chemical dechlorination. Since the dechlorinating reactions proceed in a completely closed system, there is little chance that workers are exposed to PCBs in this process. However, prior to the dechlorination, PCB containing materials must be removed from the containers such as transformers or capacitors, and the containers must be dismantled (after washing). It is in these processes that workers are likely to be exposed to PCBs. However, when the containers (mainly capacitors) were not too large, these could be carried out in glove boxes, or Vacuum Thermal Recycling (VTR) could be utilized. In VTR, the PCB containing materials were carbonized and remaining metals could be recycled. Furthermore, in the latest model, now in use in Osaka plant, no prior treatments (making holes etc) of capacitors by workers were needed because soldered portions were spontaneously loosened and PCBs were removed (volatilized) through these portions.

Before transformers or large capacitors were dismantled (in primary dismantling area), they were soaked in solvents and repeatedly washed. For instance, the transformers were soaked for 12 hrs and then washed for 8 hrs, and the washing was repeated at least 10 times in Kitakyushu plant. The dismantled parts were washed and then separated, cut or ground into small pieces mainly in hood or in closed apparatuses (in secondary dismantling area), though some were left in open space before processed. In some cases, washing was then repeated. As a result, concentrations of PCBs in many areas were less than 0.01 mg/m^3 including area level 3, well satisfying the current Japanese administrative level of PCBs in workplace (0.1 mg/m^3). Unexpectedly, in Kitakyushu plant (in September through November 2004), PCB concentrations were higher in secondary dismantling area (area level 2) than in primary dismantling area (area level 3), apparently due to higher di- to tetrachlorinated biphenyls in the secondary dismantling area (Fig. 1).

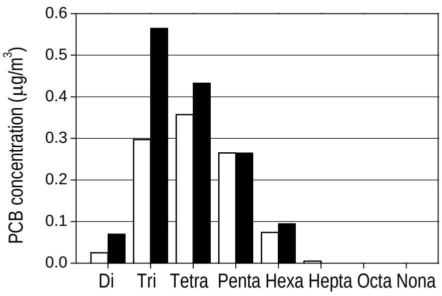

Fig. 1. PCBs in working environment; primary dismantling area (open bar) and secondary dismantling area (closed bar) in Kitakyushu plant, September through November, 2004. Average of 5 determinations.

On the other hand, it turned out to be very difficult to lower the concentrations of dioxins (mainly coplanar PCBs) below 2.5 pg-TEQ/m^3, which is required for the workers engaged in incineration of waste (Ministry of Health, Labour and Welfare Notification No.18, July 21, 1998). Indeed, since the dioxin levels were higher than anticipated in Kitakyushu plant, PPE was strengthened; respirators with higher capacity in areas level 3 and 2, and protective clothing was changed to cover the whole body in area level 3 (Fig. 2).

Fig. 2. PPE used in Kitakyushu plant; area level 3 (left), level 2 (middle), and level 1 (right).

As for the method to determine PCBs in blood, gaschromatography equipped with electron capture detector (GC-ECD) and high resolution gaschromatography equipped with high resolution mass spectrometer (HRGC/HRMS) were compared. When blood from 5 workers was analyzed, all showed higher values with HRGC/HRMS (Fig. 3A). This appeared due to the fact that HRGC/HRMS is more sensitive than GC-ECD method, especially against PCBs with smaller number of chlorines (Fig. 3B). Since PCBs released from materials processed in JESCO plants are largely low chlorine (tri- to pentachlorinated) PCBs (Fig 1), it was considered that HRGC/HRMS but not GC-ECD should be employed.

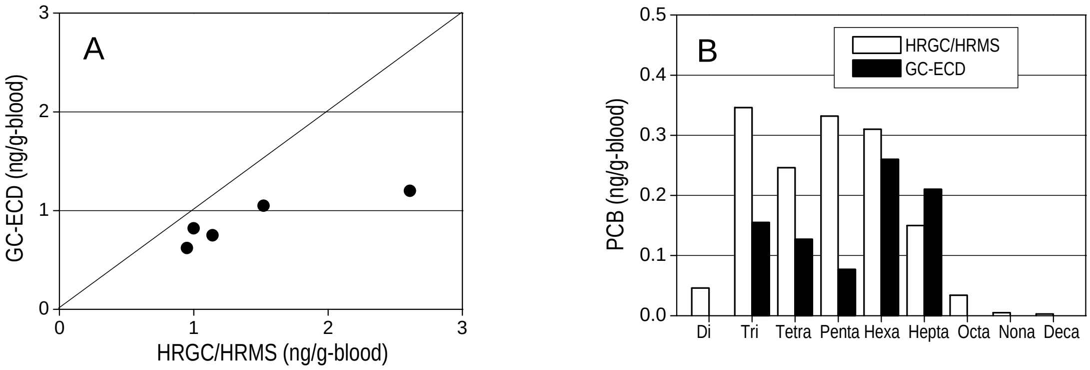

Fig. 3. PCBs in blood from 5 workers determined by gaschromatography equipped with electron capture detector (GC-ECD) and high resolution gaschromatography equipped with high resolution mass spectrometer (HRGC/HRMS). Total PCBs determined by GC-ECD were lower than those measured by HRGC/HRMS (A). Di- to pentacholorobipheyls were apparently lower when determined by GC-ECD method (average of determinations of 5 samples) (B).

Biological exposure limit value was tentatively set by the Committee to be 25 ng (total PCBs)/g-blood, based on the previous findings in occupational exposures to PCBs mainly in Japan[2,3] and Italy[4,5]. Japan Society for Occupational Health (JSOH) proposed the same value as "occupational exposure limit based on biological monitoring" (OEL-B) in 2006[6] and approved it this year. At the same time, JSOH recommended OEL of total PCBs to be 0.01 mg/m^3, lowering from the previous value (0.1 mg/m^3). Although PCB concentrations in working environment in JESCO plants have reached less than 0.01 mg/m^3 in many areas, this indicates that PCBs in some workplace should be more rigorously controlled (this is also necessary to reduce the concentrations of dioxins). To facilitate this, in Kitakyushu plant, it is planned to lower the ambient temperatures.

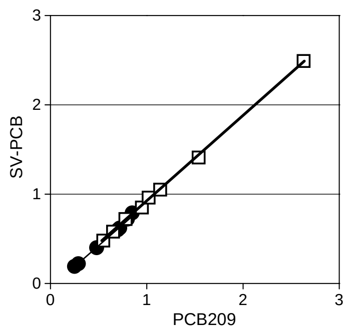

Fig. 4. Correlation of blood PCBs determined by standard method (PCB209) and those by small volume method (SV-PCB). Samples obtained from workers in secondary dismantling area (open square) and workers in primary dismantling area (filled circle). Y=0.9295X (R^2=0.9987) in the former and Y=0.888X (R^2=0.9968) in the latter.

At first, all 209 isomers of PCB were measured in the blood. However, it required relatively large amount of blood (at least 15 ml). Since PCB isomer distribution in blood seemed to be essentially the same as that in the working environment, limiting the isomers to be determined to major ones in the environment, for example, tri-, tetra-, penta-, hexa- and heptachlorobiphenyls, may be appropriate for biological monitoring. Such method (small volume (SV) method requiring 2 ml of blood) was compared with the one that measures all PCBs (Fig. 4). The results of the two methods agreed very well, though total PCB value determined by SV method was smaller by approximately 10%. Hence, total PCBs determined by SV method may be divided by 0.9 when they are to be compared with results obtained by standard method.

Combining control of working environment, proper use of PPE and biological monitoring, these will contribute greatly for the prevention of health problems of workers engaged in PCB waste processing.

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