Draft

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CONTROL OF POLYCHLORINATED BIPHENYL POLLUTION IN THE UNITED KINGDOM

Introduction

In 1966 Jenson[1] established that residues of polychlorinated biphenyls (PCBs) were present in pike (Esox lucius) and a white-tailed eagle (Haliaeetus albicilla) in Sweden. This discovery, largely arising by chance during studies in progress on DDT and other organochlorine insecticides, was the first intimation that this group of synthetic organic chemicals may have become widely distributed in the environment. Immediately following their identification in Sweden a programme of research was started in the United Kingdom to ascertain if these same compounds were also present in wild animals in the British Isles. This work not only confirmed that they were present but also that they were widespread. Following this discovery Monsanto Chemicals Ltd., the sole manufacturer of PCBs in the United Kingdom, introduced a ban early in 1971 on all non-controllable use of the PCBs. This paper gives an account of the investigations carried out in the United Kingdom to deal with the PCB problem, in the hope that the experience gained may help other countries which may be faced with this type of problem arising from the manufacture and use of these and other similar synthetic organic chemicals which are now being manufactured in increasing amounts in many parts of the world.

Manufacture and Use

The manufacture of PCBs was first started by Monsanto in the United States of America in the early 1930s and in the United Kingdom, at one plant in Monmouth in South Wales, in the early 1950s. Prior to 1951 all the PCBs used in the United Kingdom were imported. Initially these compounds were used almost exclusively in electrical transformers and then later also in capacitors. Because of their outstanding properties as a cooling and heat transfer fluid, combined with extremely low combustability, their principal use has remained in the electrical industry where they replace the more combustible oil products. The position before the ban was introduced in 1971 was that about half the PCBs sold in the United Kingdom went into the electrical industry, the remainder being used as additives in plastics, resins, rubbers, adhesives, paints and in heat transfer systems and hydraulic fluids. There was also latterly some use on an extremely small scale in vacuum pumps and in speciality lubricants.

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Properties and Analysis

The PCBs are a series of compounds, the differences stemming from the large number of homologues and isomers which are possible. These different homologues and isomers may have different properties. Commercial products contain large numbers of the different compounds in varying proportions. PCBs are very stable chemical compounds resistant to degradation by oxidation both chemically and biologically. They are relatively insoluble in water but are miscible with natural oils and fats. Only limited information is available on their toxicity. The acute LD 50 value to rats, using a commercial product containing 42% chlorine, was found to be about 4 ml/kg. In other tests on small mammals levels of 1-10 ppm in feeds of had no significant toxic effects, but at 100 ppm there were some indications of long-term effects[2]. The estimated dose rate for 50% mortality at 56 days feeding Aroclor 1254 to the Bengalese finch (Lonchura striata) has been shown to be 254 mg/kg/day, suggesting that in this species this particular PCB has only 1/13 the toxicity of DDT[3]. In the marine brown shrimp (Crangon crangon) the LC 50 for acute toxicity in 48 hours proved to be 0.3 ppm for PCB compared to 0.003 ppm for DDT[4]. It has also been shown that at low levels PCB, like DDT, can induce steriod hydroxilating enzymes in the liver of pigeons (Columba libia) and so may affect their breeding capability[5].

The PCBs thus have many of the physical and chemical properties of the organochlorine insecticides and appear to produce similar toxic effects in a number of animals, although generally apparently having a somewhat lower toxicity. It should be appreciated, however, that because of the large number of PCB compounds, and combinations of these, that are now available, the toxicity of different types may vary considerably.

Analysis for PCBs has been by use of gas chromatography, using electron capture detection with occasional identification and structure confirmation by gas chromatography mass spectrometry. Because of the need to measure PCBs at extremely low levels (e.g. 1 in 10^7 or less), and the similarity of their chemical structure to that of the organochlorine insecticides which were frequently also present in the tissues of wild animals undergoing analysis, great care was needed in the development of a reliable standard technique that could be employed by separate laboratories to give comparable results. This was achieved in the United Kingdom by close liaison between the laboratories of the Natural Environment Research Council; the Ministry

of Agriculture, Fisheries and Food, the Department of Agriculture and Fisheries in Scotland, and the central laboratory of the Government Chemist in London. This close liaison between the analytical chemists engaged in the investigatory work and the early establishment by them of standard methods to be followed, was a major factor in the rapid confirmation and subsequent surveillance of the distribution and levels of PCBs in the British Isles.

Distribution

As they are persistent and fat soluble the PCBs, like the organochlorine insecticides, are retained in the tissues of animals. It was decided therefore that a good indication of the extent to which they had become dispersed in the British Isles could be obtained from an examination of fish, marine invertebrates and predatory birds (predators, because of their position at the top of food chains and because their diets include a wide range of different organisms, can be used to indicate whether or not residues are present in a very wide range of organisms).

Another factor which influenced the type of surveys undertaken was that work was already in progress in several of the government laboratories to investigate the levels of organochlorine insecticides present in fish and predatory birds. It was, therefore, a relatively straightforward matter to extend the analytical procedure to include the PCBs. During the late 1960s over 500 predatory birds and their eggs, together with large numbers of fish and invertebrates from many parts of the British Isles were examined for PCB residues. Some residues of PCB were found to be present in most of the specimens examined from a wide variety of localities, including remote mountain regions of Wales and Scotland as well as industrial areas. The amounts present were not found to be correlated with any particular geographical locality, but with habitat, the larger residues being present in aquatic species - both freshwater and marine. Thus the amounts present in the tissues of the essentially freshwater fish-feeding heron (Ardea cinerea) included one specimen with as much as 900 ppm of PCBs in the liver, the arithmetic mean of the 16 adults examined being 98 ppm. The levels present in 101 eggs of this species ranged from 0 to 80 ppm with an arithmetic mean of 5 ppm. Similarly, the fish-eating Great Crested Grebe (Podiceps cristatus) and Kingfisher (Alcedo atthis) contained up to 40 ppm. In contrast the levels in tissues of non-predatory omnivorous and herbivorous terrestrial species rarely exceeded 5 ppm, with the bird-feeding terrestrial predators coming between the two[3].

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Further confirmation of the presence of PCB residues in the sea was obtained in the autumn of 1969 during an investigation into the mass mortality of over 12,000 seabirds in the Irish Sea. While no single cause for these deaths was established, the report of the incident concluded that "one of the most striking finds of the analytical programme was the presence in the livers of most of the dead guillemots (Uria aalgae) of unusually high levels of PCBs". During this investigation the levels found in seawater (53 samples) was $< 0.01 \mu g/l$; in zooplankton (7 samples) $< 10\text{-}30 \mu g/kg$; in mussels (whole, less shell, c 100 specimens) 10-800 $\mu g/kg$; and in 11 specimens of norway lobster (Nephrops) $< 10\text{-}100 \mu g/kg$. The levels in the livers of fish and seabirds (expressed as $\mu g/kg$) went up to 2,600 in herring (Clupea harengus); 27,000 in whiting (Merlangius merluccius); 50,000 in cod (Trisopterus minutus) and up to 800,000 in guillemot[6]. During the same period an investigation was carried out off the Cornish coast in the south-west of England into the deaths of about 40 grey seals (Halichoerus grypus) pups. The PCB levels in 11 specimens examined were found to be relatively high (17-90 ppm in the liver, and 118-187 ppm in the blubber). It was concluded however that PCBs were not a contributory cause of death, which was attributed to normal juvenile mortality[7]

Pollution and Manufacturing

These discoveries led to consideration as to how the residues of PCB were getting into the environment. The highest levels being found in freshwater and marine species suggested that contamination of inland waterways and direct contamination of the sea must be major factors. The most obvious ways in which this could come about are through pipelines from factories, as a result of atmospheric pollution following inefficient incineration (the PCB residues eventually being washed out with rain and again ending up in waterways and the sea), and in sewage sludge dumped into the sea[8]. The results of the surveys of the distribution of PCB residues however gave no indication as to which, if any, of these particular sources may have been primarily responsible for the existing pollution of the British Isles and while higher levels have been found in the estuary of the river Clyde and off the south west coast of Scotland generally, there is no outstanding use of PCB products in this area to explain this.

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The residues most commonly found in animal tissues have been of the highly chlorinated type. It should not be concluded from this however that there has been a greater use of this form of PCB and thus by using less chlorinated types pollution by PCBs could be avoided. These results are more probably a reflection of the pattern of decomposition of PCBs once they enter the natural environment and probably all the PCBs contribute to environmental pollution.

The manufacturing process of PCBs is "dry", so that aqueous effluent is not a by-product. Contamination of waterways from industry must therefore have come about as a result of carelessness or accident, or possibly because until recently those concerned were unaware that these compounds could result in environmental contamination and so made no special provision for dealing with wastes containing PCBs. Provided that sufficient care is taken to contain spillages and leakages during manufacture, and after manufacture during handling e.g. when the PCBs are being loaded into drums or tankers, losses into drains and waterways can be avoided. The installation of sumps and interceptor pits in the factory drainage system, coupled with a regular monitoring of all effluent, should enable any loss from factories to be kept at an absolute minimum. Complete destruction by incineration can be achieved if a temperature of 800°F is maintained for at least 10 seconds.

The Ban

Following the discovery of PCBs in the environment, the Monsanto Company itself is believed to have spent well over half a million pounds on its own programme of research into methods of analysis, identification and measurement of PCBs. From the beginning the company maintained close liaison with the Central Unit on Environmental Pollution of the Department of the Environment, the Natural Environment Research Council of the Department of Education and Science, the Ministry of Agriculture, Fisheries and Food and the Department of Agriculture and Fisheries in Scotland - the Government Departments most directly concerned with the control of environmental pollution and for conducting research into environmental problems. In addition Monsanto staff visited the laboratories of these Government Departments where the actual field investigations and analyses were being carried out and discussed progress and methods with the scientists engaged in the work. They were thus informed of the development and progress of the investigations and were able to draw conclusions from the results at an early stage.

The need for some form of ban became apparent once it had been demonstrated that the PCBs were widespread in the natural environment and that the levels present, particularly in certain aquatic species, had reached the point where undesirable effects may be expected. Because of their stability and their miscibility with natural oils and fats, it could reasonably be concluded that continuation of their use, even on the present scale, would result in further increases in the levels present in a wide range of animals, including some used as food by man.

The fact remained however that because of their industrial properties, particularly their low inflammability, they still had some important (possibly vital) uses in industry, for example in certain electrical equipment covered by safety regulations which require the use of non-flammable fluids. A sudden complete withdrawal for all uses, in the absence of suitable replacement products, could therefore have serious consequences to industry and to human safety.

Fortunately, for most uses of this type, the PCBs can be enclosed in sealed systems. This, coupled with the fact that by exercising care during manufacture and transport losses could be largely avoided and also that satisfactory methods of both biodegradation and incineration have been developed, led to the conclusion that a partial ban affecting only non-controllable uses would be sufficient to safeguard the environment. Accordingly from 1st March 1971 Monsanto, without any directive from the UK Government, introduced a voluntary ban on all uses where PCBs were not confined to a closed system. They also made arrangements whereby in those cases where PCBs would continue to be used the responsibility for final disposal, after working life was over, would remain with the Monsanto Company and arrangements have been instituted whereby the equipment is returned to Monsanto for destruction of the PCBs under controlled conditions.

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Correct

Recognising the problems of disposal of waste PCBs Monsanto have undertaken to carry arrangements whereby collection & disposal facilities are available in the UK.

Discussion

The initial discovery that the environment was becoming polluted with PCB residues came about largely as a result of chance. Until Jensen's discovery, nobody had suggested or even suspected that these compounds may be a possible source of environmental pollution and had the research on the organochlorine insecticides - during the course of which the discovery of the PCBs was made - not been in progress, it is most probable we would still not yet be aware that a PCB problem exists. As the manufacture of PCBs is now undertaken in a number of countries, this leads to the question: what other countries have a PCB problem? This question can only be answered by an appropriate scientific investigation. To carry out an investigation of this type is an elaborate procedure, involving the employment of highly trained scientists and expensive, complex apparatus. Even when and where these are already available, there is the need to develop a new analytical and evaluation procedure, which must then be agreed and adopted by different laboratories so that their results can be compared.

In the UK the relatively rapid manner in which the investigation of this problem was accomplished was very largely due to certain existing circumstances. These included the fact that (a) investigations into similar problems involving the organochlorine insecticides were already in progress in several Government laboratories, with the important result that chemists and appropriate apparatus were already available; (b) a liaison committee representing analytical chemists in the UK was already in existence, so that agreement over a standard method of analysing the PCBs was established at an early stage; and (c) there was in existence a well-established scheme for the collection of suitable biological material for analysis from a large number of different geographical localities, including areas affected by unusual incidents involving large numbers of casualties. Without these circumstances, even an industrialised country like the UK would have had to undertake extensive time-consuming and expensive procedures before investigations could be started. In the case of a developing country the task would be formidable.

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The close co-operation between Industry and Government that exists in the UK was another important factor in the approach to this problem. In this particular case Monsanto were able to take independent action at a much earlier stage than would have been possible had the necessarily protracted negotiations had to be undertaken with Government Departments before legislation could have been introduced. One aspect that may require further attention exists because PCBs are manufactured in a number of other states, including both Western and Communist countries. It would obviously be unacceptable if the ban instituted in the UK by Monsanto was rendered useless by the importation of PCBs from elsewhere. A further complicating factor in this question of imports and exports could arise because PCBs are often incorporated in electrical and other goods. If a country banned the use of PCBs, including their importation, this would have the result of disqualifying a whole range of products from being imported into that country. Discussions have already been held between some of the international manufacturing companies and in Britain the Government is watching the situation. But the trade implications of this specific problem, and the possible creation of non-tariff barriers if Governments find it necessary to impose statutory controls, merit discussion at intergovernmental level. OECD has already instituted, for a trial period, an "Early Warning System" for controls or restrictions instituted by Governments on the sale or use of certain chemicals, although this does not cover unilateral action by industry unsupported by statute. The United Kingdom would welcome a discussion with other member Governments of the PCB problem, and a consideration of whether the "early warning" scheme could usefully be extended to this type of industrial policy. OECD has, in addition, supported a working party on the analysis of organochlorine substances in the environment, and this group might be invited to consider what programmes of monitoring are desirable to determine how far the ban applied in the UK (and likely to be followed by others elsewhere in Europe) is effective in reducing the levels of PCB in the environment.

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