

CONTROL OF POLYCHLORINATED BIPHENYL POLLUTION
IN THE UNITED KINGDOM

An official paper by the U.K. Government,
In consultation with Monsanto, a version of
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to the OECD sector group on the Unintended
Occurrence of Chemicals in the Environment.

From the desk of

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Introduction

In 1966 Jensen⁽¹⁾ established that 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 the previously widely observed but unidentified compounds in wild animals in the British Isles, were identical with PCBs. This work not only confirmed that they were, but also that they were geographically widespread. Monsanto Chemicals Ltd., the sole manufacturer of PCBs in the United Kingdom, announced that from March 1, 1971 they would accept no further orders for PCBs except for "certain specified controllable uses." 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 control measures were introduced in 1971 was that although the major uses of PCBs sold in the United Kingdom were in the electrical industry, a substantial proportion was 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.

Properties and Analysis

The PCBs are a series of chlorinated biphenyl compounds, the differences stemming from the degree of chlorination and the large number of possible homologues and isomers which can be formed. These different homologues and isomers may have different properties. Commercial products contain large numbers of 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 4ml/kg. In other tests on small mammals levels of 1-10 mg/kg in feedstuff had no significant toxic effects, but at 100 mg/kg 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 mg/kg for Aroclor 1248 compared to 0.003 mg/kg for DDT⁽⁴⁾. It has also been shown that at low levels PCB, like DDT, can induce steroid hydroxylating enzymes in the liver of pigeons (*Columba livia*) and so may affect their breeding capability⁽⁵⁾.

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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 owing to the varied nature of the component parts.

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 Department of Agriculture and Fisheries for Scotland; the Ministry of Agriculture, Fisheries and Food; the Government Chemist; and the Nature Conservancy (Natural Environment Research Council). This close liaison between the analytical chemists engaged in the investigatory work and the early establishment by them of agreed 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 (it is emphasized however that the results obtained are only indicative of the order of the amounts present rather than being quantitatively accurate).

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 in the food chains and because their diets include a wide range of different organisms, can be used to indicate whether or not organochlorine compounds 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. PCBs 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 C.900 mg/kg of PCBs in the liver, the arithmetic mean of PCBs in the livers of 16 adults examined being 98 mg/kg. The levels present in 101 eggs of this species ranged from those in which no PCBs were detected, to a maximum level of 80 mg/kg - the arithmetic mean being 5 mg/kg. Similarly, the fish-eating Great Crested Grebe (*Podiceps cristatus*) and Kingfisher (*Alcedo atthis*) contained up to 40 mg/kg. In contrast the level in tissues of omnivorous and herbivorous terrestrial species rarely exceeded 5 mg/kg, with the bird-feeding terrestrial predators coming between the two⁽³⁾.

Further confirmation of the presence of PCB compounds 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 aalga*) of unusually high levels of PCBs." During this investigation the level found in seawater (53 samples) was $< 0.01 \mu\text{g/l}$; in zooplankton (7 samples) $< 0.01 - 0.03 \text{ mg/kg}$; in mussels (whole, less shell, c 100 specimens) $0.01 - 1.8 \text{ mg/kg}$; and in 11 specimens of Norway lobster (*Nephrops*) $< 0.01 - 0.1 \text{ mg/kg}$. The levels in the livers of fish and seabirds went up to

2.6 mg/kg in herring (*Clupea harengus*): 27,000 in whiting (*Merlangius merlangus*); 50 mg/kg in cod (*Gadus morhua*) and up to 800 mg/kg 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 seal (*Halichoerus grypus*) pups. The PCB levels in 11 specimens examined were found to be relatively high (17-90 mg/kg in the liver, and 118-187 mg/kg in the blubber). It was concluded however that PCBs were not a contributory cause of death, which was attributed to normal juvenile mortality⁽⁷⁾. A later more extensive study⁽⁸⁾, which included both the common seal (*Phoca vitulina*) and the grey seal, has demonstrated that considerably higher residues of PCBs (mostly exceeding 100 mg/kg), are found in the blubber of adult seals from the coasts of southern Britain (southwest and east England and Wales) than are found in seals from the coasts of northern England and Scotland. In the extreme north of Scotland the PCB residues did not exceed 30 mg/kg. Also in the seals from southern Britain, the PCB levels greatly exceeded the total DDT concentrations. The opposite was found to be the case in seals from the Gulf of St. Lawrence in North America, where industrialization is not so intensive.

Pollution and Manufacturing

These discoveries led to consideration as to how the residues of PCB were getting into the environment. The high 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⁽⁹⁾. 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.

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°C is maintained for at least 10 seconds.

The Control Measures

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 Laboratory of the Government Chemist of the Department of Trade and Industry, 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 and of other industries where the actual analytical work was being carried out. They also maintained contact with voluntary bodies, such as the British Trust for Ornithology and the Royal Society for the Protection of Birds, who helped with the field studies and with the collection of many of the specimens. In this way they were able to discuss progress and methods with the scientists engaged in the work and keep themselves informed of the development and progress of the investigations. An important result of all this liaison was that they were able to draw conclusions from the results at an early stage.

The need for some form of control became apparent once it had been demonstrated that the PCBs were widespread in the natural environment and that the concentrations 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 flammability, 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 largely be avoided and also that satisfactory

methods of disposal 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 March 1, 1971 Monsanto, without any directive from the U.K. Government, introduced a voluntary ban on all uses where PCBs were not confined to a closed system. Recognising the problems of disposal of PCBs, Monsanto have undertaken to make arrangements whereby collection and 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 U.K. 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 U.K. was already in existence, so that suitable methods for analysing the PCBs were agreed at an early stage; and (c) there were existing arrangements for the collection of suitable biological material for analysis from a large number of different geographical localities. Without these circumstances, even an industrialised country like the U.K. 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.

Other important factors in the U.K. approach to the problem included the close co-operation that exists between industry and Government (reflecting the responsible attitude of industry in Britain to pollution problems), and the well-informed public attitude that exists which provides support and understanding for measures introduced to help combat pollution. In this particular case Monsanto were able to take independent and effective action at a much earlier stage than would have been possible had the necessarily protracted negotiations had to be undertaken with Government Departments, if it had been decided that legislation was necessary. A complicating aspect is that as long as PCBs are manufactured in other states, including both Western and Communist countries, the possibility exists of Monsanto's voluntary restrictions on sales of PCBs being undermined by imports. Their action in the U.K. was only practicable because they were a monopoly manufacturer. 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 could 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 levels. 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 U.K. 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. The U.K. would also welcome discussions about the economic aspects of this limitation of sales of PCBs by Monsanto. A similar restriction has also been imposed by Monsanto in the U.S.A. and it seems likely that other manufacturers may follow Monsanto's example or some Governments may contemplate the introduction of legislation.

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