INDUSTRIAL TOXINS AND THE COMMUNITY

The Michigan PBB Incident

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One of the problems that must be faced is the consequence to the community of useful chemicals getting into the wrong places. We are accustomed to considering the consequences of producing or using a chemical in terms of its proper intended use. However, when chemicals are misused there may be dire consequences to our communities and to the general public. This paper describes an incident that has caused widespread and serious problems within the State of Michigan (1,2).

DESCRIPTION OF INCIDENT

Among the chemicals produced at the Michigan Chemical Company were two having somewhat similar appearances but widely different properties. This company was a major producer of polybrominated biphenyl (PBB). This product was made by the bromination of biphenyl compounds and has been used as a fire retardant substance, particularly in plastics. It is an extremely stable substance that is relatively insoluble in water but highly soluble in fat. Since it is ordinarily incorporated into finished products the exposure to the general public of this product is ordinarily of no consequence.

Another chemical produced at the company was magnesium oxide. It has been found that magnesium oxide in many instances will stimulate milk production, and it is therefore a useful additive to some special dairy cattle feeds. Thus, this compound enters the food chain, and the potential for an undesirable exposure of the public if the magnesium oxide were mistakenly replaced by or contaminated with a harmful chemical is very great.

In early 1973, because of a paper shortage, there was a delay in the receipt of preprinted bags by the chemical company. During this period, the trade names of the compounds were stenciled on the plain brown bags used. PBB was sold under the trade name of

Fire Master and magnesium oxide under the trade name of Neutra-Master. At this time an estimated 10 to 20 fifty pound bags of Fire Master were sent by mistake to the Farm Bureau Services as fulfillment of an order for Neutra-Master. This mistake was not recognized, and the PBB was used in the production of feed for dairy cattle.

In the fall of 1973, some dairy farmers began experiencing health problems with their cows but the difficulty was not generally recognized for some time. One of the dairy farmers, who had been a chemical engineer, was convinced that the feed was the problem and persisted for months in an attempt to determine what harmful compound might be in it. It was not until April 1974 that analysis confirmed the presence of PBB in the milk and feed from the suspected farm. The earlier mix-up was then quickly discovered. Because the mistake was not discovered for approximately one year, there was extensive contamination of food products.

As expected, PBB was discovered in beef and also in milk and milk products such as cheese and butter. In addition, because of the contamination of farms and incidental uses of the feed, there was also contamination of swine, sheep, chickens, and eggs. Attempts were made immediately to begin removing contaminated products from the market, but it was not until late 1974 or early 1975 that the market was essentially cleared of products containing PBB at concentrations above the FDA guideline. There still remain rare samples of beef with traces of PBB, but the significant exposure through our food chain is essentially past.

EFFECTS OF PBB ON COWS

The effects of PBB on dairy herds were rather complex and confusing because of the uncertainty of the effects of other intercurrent health problems (3). However, among those highly exposed, it was clear that toxic symptoms in cattle included refusal of feed, decreased milk production, acute anorexia, shrinking of the udders, breeding problems, extension of gestation period, and stillborn calves. In addition, many of the cows had lameness, swollen joints, abnormal hoof growth, and hyperkeratosis. Some had matting of hair, hair loss, hematomas, and superficial abscesses. In severe cases there was weight loss, wasting of muscles, particularly in the hind limbs, coma, and death. Experimentally, heifers were not affected by a dose of 250 miligrams per day for 60 days but were

affected by 25 grams per day (4). Those heifers receiving the higher dose showed anorexia, excessive lacrimation and salivation, diarrhea, emaciation, dehydration, depression and abortion. Signs developed progressively in these heifers. Thus, it is clear that higher doses of PBB are toxic to cattle.

EXPOSURE OF PEOPLE

The extent of the exposure of the people within the State of Michigan to PBB has gradually unfolded. Efforts in 1974 were concentrated on those farms with demonstrated contamination of their cattle with PBB, the quarantined farms. In the initial studies of these farms, PBB blood levels were determined for a sample of quarantined farm families and in a sample of nearby farm families that served as a comparison group.

Table 1. Blood PBB levels in participants of 1974-75 study

PBB blood levels*	Quarantined farms				Nonquarantined farms			
	Adults		Children		Adults		Children	
	No.	%	No.	%	No.	%	No.	%
0	3	3.7	-	-	21	28.4	-	-
0.002 - 0.019	43	52.4	8	28.6	52	70.3	29	96.7
0.02 - 0.09	19	23.2	10	35.7	1	1.4	1	3.3
0.1 - 0.49	11	13.4	3	10.7	0	0	0	0
0.5 - 2.26	6	7.3	7	25.0	0	0	0	0
	82	100.0	28	100.0	74	100.1	30	100.0

*Measured in parts per million (ppm)

On the quarantined farms, only three of 110 persons tested had blood levels below the level of quantitation. Thirteen of these individuals had levels over 0.5 ppm with the highest being 2.26 ppm. Clearly, this group had a substantial exposure. However, on the non quarantined farms, there were only 21 of 104 subjects tested that had blood levels below the level of quantitation. The remainder had levels below 0.1 ppm. Thus, the level of exposure was lower on the non quarantined farms, but there was still a substantial number of persons with documented exposure to the chemical.

In early 1975, we began offering routine PBB analysis of specimens submitted by physicians. The circumstances that prompted physicians to submit specimens have varied greatly, and there is a mixture of individuals with and without symptoms, and persons with and without known exposure to PBB-contaminated food. In this unselected sample, about half of the individuals had PBB blood levels below our level of quantitation, 1 ppb. However, some individuals had levels as high as 2 ppm. Such blood testing made it apparent that a substantial portion of the population had been exposed to the compound.

A little reflection on the nature of PBB leads one quickly to appreciate that a fat soluble substance like this will tend to concentrate in the fat at much higher levels than would be found in the blood. Fortunately, many of the specimens submitted by physicians were fat biopsies. This enabled us to examine the relationship between the PBB in the blood and in the fat biopsies taken on the same day. A total of 181 such paired specimens have been analyzed. In this group there were 66 specimens in which the blood level was quantifiable at 1 ppb or greater. Analyses of the paired specimens on these individuals show that there is a very high correlation (R = .96) between the blood and fat levels (Fig. 1).

We now feel that, in general, the concentration in the fat will be approximately 300 times the concentration in the blood, but of course the fat to blood ratios may vary by individual. The adipose PBB levels varied from non detectable to 1.2 ppm in the other 125 individuals not having a quantifiable level of PBB in their blood.

Table 2. Adipose tissue PBB levels for persons having 1 ppb blood PBB

Adipose PBB Level (ppm)	No.
<.03	11
.03	59
.2	32
.4	15
.6	4
.8	1
1.0	3
1.2+	-
Total	125

Most were below 0.6 ppm, with only 8 being above this. Only 11 of this group did not have detectable levels of PBB in their fat. If this were a random sample of our population, it would indicate that approximately 95% of the population had been exposed to PBB.

An additional estimate of the occurrence of PBB exposure in the population has come from analysis of milk samples from nursing mothers. PBB was first detected in breast milk when samples taken for a national study of other chemicals were later analyzed for PBB. Finding PBB in these samples, and in some others obtained for confirmation, led to a study of a random sample of nursing mothers in the state. For this purpose, the state was divided into the Upper Peninsula and Lower Peninsula. Of 53 mothers sampled in the Lower Peninsula, PBB was not detected in the milk of only 2 women.

Table 3. PBB levels in breast milk of women in Lower and Upper Peninsula

PBB range in breast milk Fat in ppm	Number of women in study	
	Lower Peninsula[1]	Upper Peninsula[2]
Total	53	39
Non-detectable	2	23
Detectable up to 0.05[3]	16	13
0.05 up to 0.1	17	2
0.1 up to 0.5	15	1
0.5 up to 1.0	2	-
1.0 and above	1	-

1. The study was restricted to women who delivered between August 15 and August 21, 1976, in one of 147 Lower Peninsula Hospitals.
2. The study was restricted to women who delivered in August 1976 in one of 20 Upper Peninsula Hospitals
3. Counts include 6 Lower Peninsula and 9 Upper Peninsula samples with a trace of PBB

One woman had a value above 1 ppm. In the Upper Peninsula, 23 out of 39 women sampled did not show PBB, and none had values above 0.5 ppm. We estimate that the level in breast milk is approximately 100 times that in the blood, so that this is a more sensitive method of determining than is blood sampling. This study

agrees with the estimate that approximately 95% of the persons in the Michigan's Lower Peninsula have had exposure to PBB in sufficient quantity to have detectable levels.

One question that must arise is the significance of the exposure to PBB in 1973 and 1974 to the present concern for the health of the public. One of the characteristics of PBB is its stability and slow excretion rate. The blood PBB levels of 148 persons studies in 1974 was compared with their levels in 1977 (Fig. 2). The results indicate that there is very little, if any, decline in these individuals' blood PBB levels over this 2- to 3-year period. It is difficult to be certain that this actually measures the rate of excretion, because we cannot be sure that there has not been some further exposure in the meantime.

There is some evidence that levels measured in serial fat samples on the same individuals show a declining level. We hope that further studies will confirm this, but it is clear that there is a continuing exposure internally from PBB ingested 2 or 3 years ago. Thus, if there are effects that are slow in appearing, we are not yet in a position to know the final outcome of this exposure.

EFFECTS ON PEOPLE

Initial attempts to determine the health effects of PBB exposure were begun promptly in 1974 when the exposure was discovered. Rapid health assessments and analyses of blood chemistries for such effects as liver function abnormality did not reveal any ill effects. A study involving 50 families from quarantined farms and 50 from nonquarantined farms was begun in 1974. The only health problems affecting more than 5% of the study group were headaches, fatigue, balance problems, anxiety, and some increase in rashes. The frequencies of these problems were not significantly different statistically in the two groups.

When analyzed by PBB blood levels, there was generally a higher frequency of the complaints listed above in subjects having greater than 20 ppb in their blood regardless of quarantine status, but, again, the differences were not statistically significant. Our conclusion was that there was no disease or symptom complex that occurred consistently in those exposed, but that

the sample was too small to exclude less frequent, serious problems, or chronic problems that might develop later.

In 1976, a long-term study was begun with a goal of enrolling 4,000 exposed individuals. Enrollment is almost complete at present, but there has not been sufficient time to analyze the data. Preliminary analyses suggest there may be some increased frequency of tiredness and fatigue, neurological complaints such as numbness and tingling, skin problems such as rashes and nail defects, and complaints associated with the joints. It is not clear if these are actually occurring in abnormal frequency or if there is a relationship to PBB exposure.

In November 1976, an intensive examination was done on over 1,000 exposed individuals by the Environmental Sciences Laboratory of Mt. Sinai Hospital, directed by Dr. Irving Selikoff. Final analysis of this study is not yet available, but there were findings of increased frequency of certain symptoms, particularly of gastrointestinal system and joints. Dermatological examinations suggested an increased frequency of rashes. Of particular interest was the frequent finding of a general neurological problem characterized by hypersomnolence, easy fatigability, and loss of memory and of the ability to maintain concentration. These symptoms were not associated with specific neurological signs, but their occurrence was quite striking. Another finding of potential importance was a deficiency in the numbers and functional ability of lymphocytes, particularly T-type lymphocytes, in a sample of 45 persons. The significance of these findings is still under investigation.

The general health assessments of the exposed farmers are that, although many of them have had no significant health problems and have been able to work normally, some have had deterioration in their ability to carry on their usual work. Some farmers have sold their farms because of their inability to continue their work. Some of these farmers have operated farms for many years and have noticed changes only since 1973. Even though the nature and significance of the health changes have not been defined objectively, it is imperative that the studies be continued to determine what effects are due to PBB and what can be done about them.

DISCUSSION

Despite the work that has been done to date to elucidate health problems associated with PBB, we still cannot define with certainty what health effects have occurred due to PBB exposure. We must assume, however, that the complaints and health problems exhibited by exposed individuals may be due to PBB until other explanations are found, or the health effects of PBB are determined. The greatest problem is that people were exposed over a long and variable period, and that people cannot be divided into exposed and unexposed groups. This means that all the health events that normally occur because of a variety of reasons confound the problem of determining the effect of PBB. This is a very difficult problem, but we feel that progress is being made.

The total impact of this mix-up in the shipment of 10 to 20 fifty pound bags of chemical is immense. There has been a large loss of food-producing animals and animal products: approximately 30,000 cattle, 4,500 swine, 1,500 sheep, and 1.5 million chickens have been destroyed. Over 800 tons of animal feed, 18,000 pounds of cheese, 2,500 pounds of butter, 5 million eggs, and 34,000 pounds of dried milk products have been destroyed. Settlements for over 38 million dollars in damages, including loss of animals, have been made, and there are many suits still unsettled.

In addition to the adverse health effects experienced within Michigan that have been attributed to PBB, there has been widespread anxiety among the general public because of the uncertainty of the full significance of this exposure. The state has appropriated at least fifteen million dollars per year for three years to test animals for traces of PBB so that contaminated animals can be destroyed. It is not at all clear what the final cost will be of this incident.

One of the questions that such incidents raise, which is not yet answered, is how to prevent such occurrences. Increased regulation may be useful in some instances, but in our large and complex world it is difficult to see how this can be completely successful. We must somehow make the producers and users of chemicals aware of potential health problems not only from their normal use, but also from incidents of unexpected contamination. This requires

intimate knowledge of production processes and handling of the chemicals, and an understanding of potential health effects if the community should be exposed.

Who is best suited to act for the community in this regard? Who is in a position to know what chemicals are processed and how? Who is in a position to appreciate the health significance of the unexpected contamination of compounds often used by the public, with chemicals not intended for public use? Who can understand the covert and overt health effects of chemicals with which industries deal? I propose that the persons attending this meeting, occupational health physicians, are in a position to fulfill these functions.

If the responsibilities and the vision of physicians working in industry can be broadened to consider the potential community effects of chemicals and the possibilities of unplanned community exposure, then industry itself would be in a position to take steps to prevent such occurrences. It is true that not all industries have access to physicians, but yet those with access could perform a service by establishing a continuing review of their operations with the risk to the community in mind. Industry must realize the problem, and physicians working in industry must realize the problem. Unless we establish such methods and responsibilities, we are doomed to future repeated insults to our peoples' health and to our economy by repetition of deplorable incidents like this.

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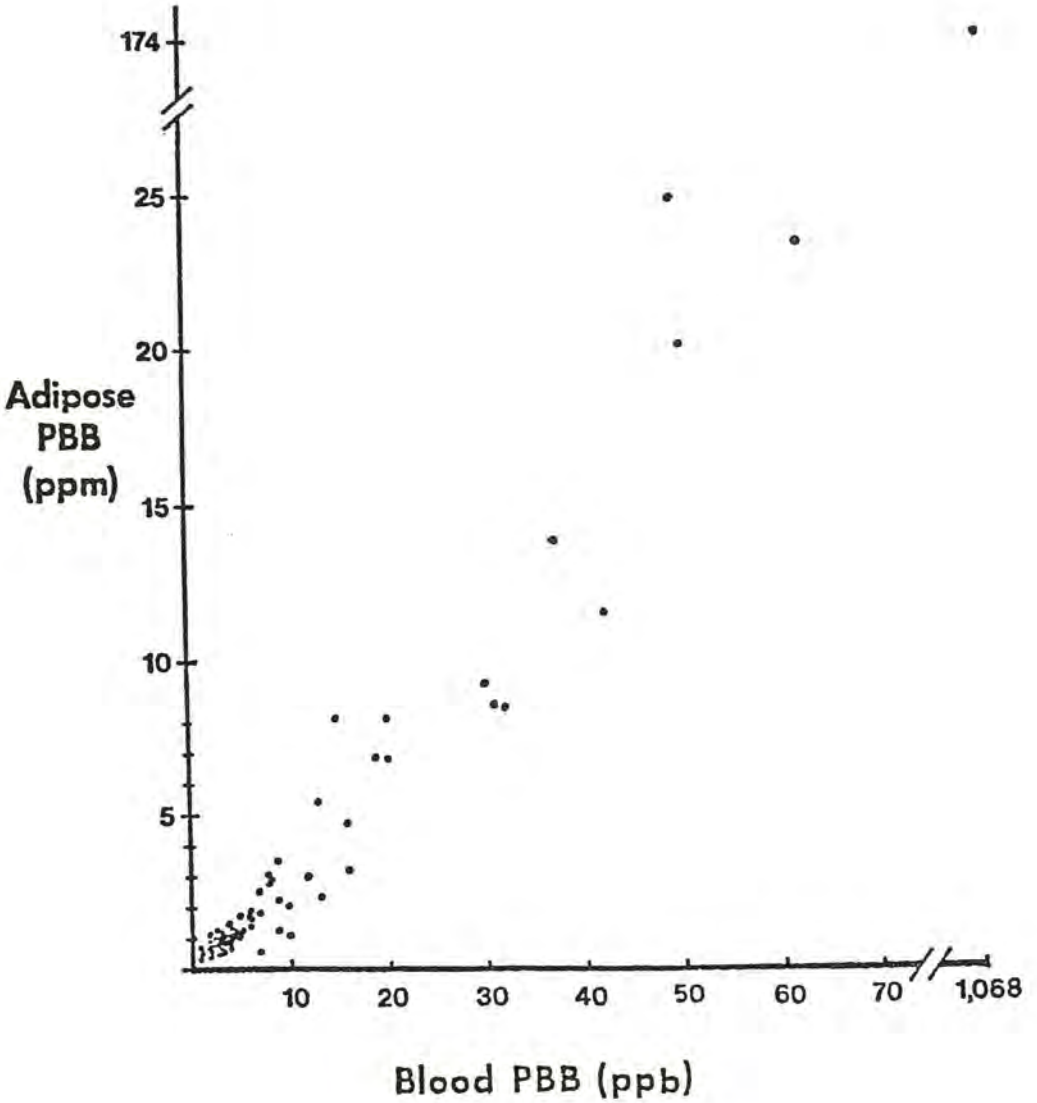

Figure 1. THE MICHIGAN PBB INCIDENT
Relationship between Blood PBB levels
and Adipose PBB levels
(Includes only the 66 subjects whose PBB
values were 1 pbb or greater)

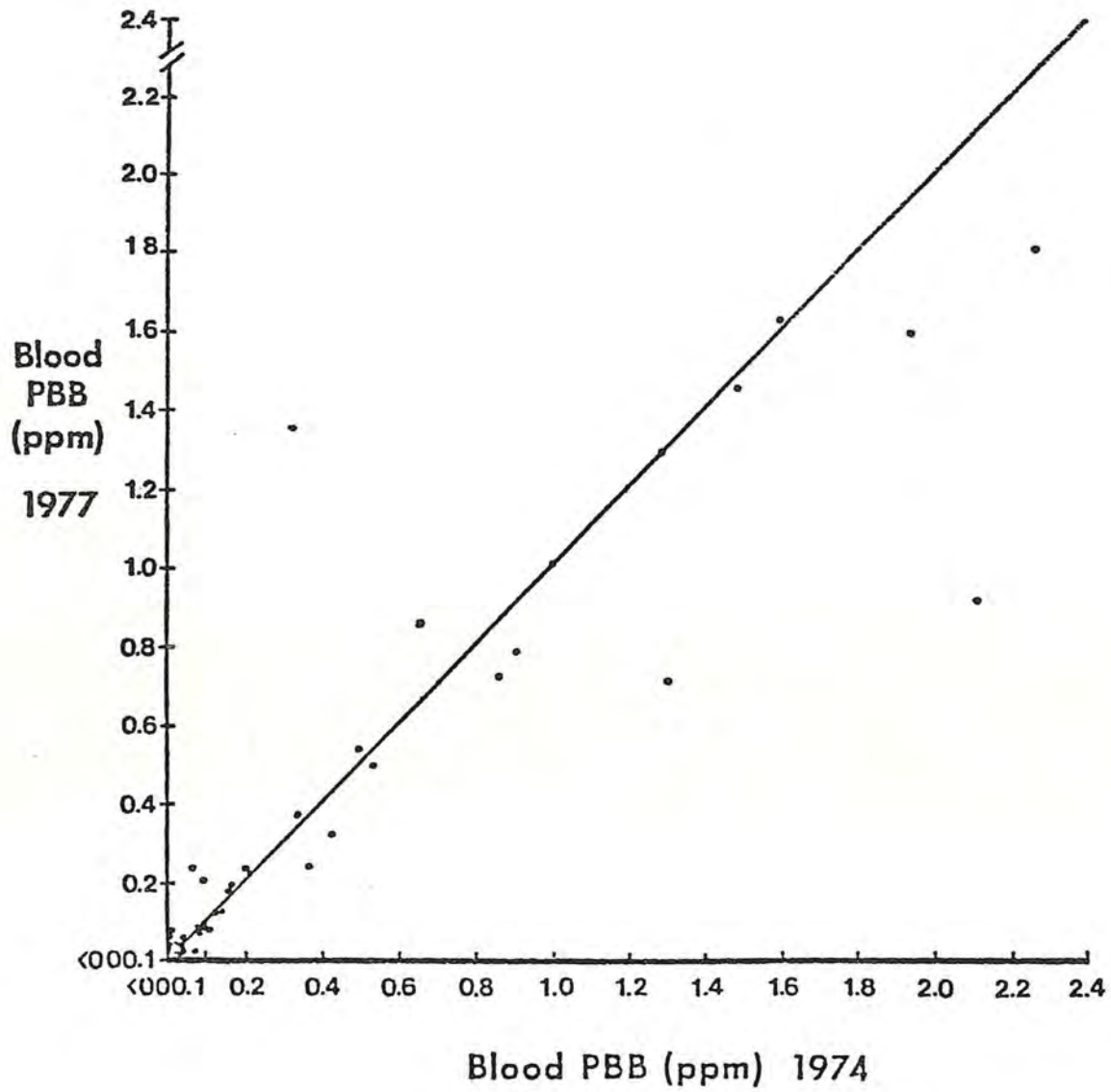

Figure 2. THE MICHIGAN PBB INCIDENT
Blood PBB values for the same subjects
in 1974 and 1977

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