



PESTICIDES IN ZIMBABWE

Toxicity and Health Implications

Edited by
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Organophosphate Exposure in Pesticide Manufacturing Factories in Zimbabwe

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Summary

The prevalence of excessive exposure to organophosphates in pesticide manufacturing factories in Zimbabwe is high. It is possible, through simple and inexpensive measures such as reduction in smoking at the workplace, improvement in personal hygiene and basic worker education programmes, to significantly reduce the prevalence of excessive organophosphate pesticide exposure at the workplace. Since symptoms are a poor indicator of exposure to organophosphate, the importance of biological monitoring and using the simple and relatively inexpensive World Health Organisation (WHO) cholinesterase kit is of utmost importance in identifying workers at risk.

Although the industrialised countries utilise about 80 per cent of the world's agrochemicals (GIFAP, 1993), it is estimated that these countries only experience 1 per cent of all deaths due to acute pesticide poisoning (Jerayathnam, 1986). This leaves a staggering 99 per cent of all deaths from acute pesticide poisoning occurring in developing countries.

In Zimbabwe, over 60 per cent of the workforce is employed in or dependent on agriculture (CSO, 1985). Since independence in 1980, both the formulation and packaging of pesticides has risen sharply, as depicted by pesticide input costs which have risen from Z\$12 million in 1980 to 40 million by 1985 (CSO, 1985). Although the principal ingredients are imported from Europe and North America, the majority of pesticides are formulated and packaged locally in Zimbabwe. By 1986, there were 489 registered pesticide formulations in Zimbabwe. The majority were the organophosphates (OP), followed by the organochlorides, carbamates and triazines (CSO, 1985).

The precise descriptive epidemiology of pesticide exposure in Zimbabwe has yet to be fully elucidated. However, several studies have documented pesticide poisoning in workers on commercial farms (Bwititi *et al.*, 1987), hospital admissions due to poisonings (Nhachi, 1988) and pesticide poisoning elsewhere (Baloyi *et al.*, 1986). By studying organophosphate poisoning in pesticide manufacturing factories, this study sought to complement the existing national database on pesticide poisoning in Zimbabwe.

The objectives of the study were principally two-fold:

1. To ascertain the prevalence of pesticide exposure in OP pesticide formulating and packaging factories in Zimbabwe;
2. To identify and elucidate factors associated with exposure to OPs in pesticide formulating and packaging factories in Zimbabwe, with the view of using the information acquired there in proposed future programmes to limit exposure levels to OPs and other pesticides at the workplace to acceptable standards.

Organophosphates were chosen for investigation for the following reasons:

1. OPs are the most commonly used pesticides in Zimbabwe (CSO, 1985 and Baloyi, 1986)
2. OPs are thought to be responsible for about half the morbidity and mortality from pesticide poisoning in Zimbabwe (CSO, 1985 and Baloyi, 1986)
3. The majority of the most toxic pesticides are OPs
4. The availability of a WHO spectrophotometric field kit for on-the-spot analysis of blood cholinesterase (ChE) levels provides an easy, quick and reliable means of analysis.

The earliest recorded account of the synthesis of an organophosphate (OP) was in 1854 (Taylor, 1985). A decade later, Jobst and Hesse synthesized physostigmine from the West African plant, *Physostigma venenosum* (Taylor, 1985). On the eve of the Second World War, Schrader of Farbenindustrie synthesized, on a large scale, potent OPs, initially as insecticides, then as "nerve gas" during the War and subsequently as insecticides (Taylor, 1985).

Four factories in Harare, the capital of Zimbabwe, were identified as being responsible for the formulation and packaging of 90 per cent of OPs in the country. Initially, all four factories agreed to participate in the study. Subsequently, it was not possible to conduct the study in the fourth factory, factory 4, because of the temporary absence of the technical manager with whom all negotiations had been concluded. In addition, in the third factory, factory 3, management advised against taking blood samples for analysis of ChE levels, even though the workers were prepared to have their blood analysed.

The following workers were identified as those engaged in the formulation and immediate packaging of OPs: 23 workers from factory 1, 23 workers from factory 2 and 20 workers each from factories 3 and 4.

In all, 85 workers had been asked to participate in the study. Of these, 20 workers (from factory 4) were not able to participate in the study, thus making a response rate of 65 workers, that is, 76 per cent.

However, of the 65 workers studied, only 45 workers had their blood analysed for ChE levels, since management in factory 3 advised against their employees having blood tests.

A cross-sectional study was conducted in each of the three factories under investigation. The investigation consisted of four parts:

1. A general factory inspection (a walk-through survey) combined with interviews of management. The brief factory inspection examined general aspects of factory housekeeping and industrial hygiene, but no quantitative environmental monitoring was conducted.
2. A simple, operator-administered questionnaire with close-ended questions was administered to each of the 65 workers. Subjects were asked about the type of chemicals handled, use of protective clothing, smoking history and habits at workplace, health status (in particular the presence of any symptoms suggestive of OP poisoning), knowledge of the health effects of pesticides and other factors in the preceding four weeks which were thought to affect OP pesticide exposure.
3. The following anthropometric measurements were taken from every worker subjected to the questionnaire:
 - (i) height: to the nearest centimetre, using a standard tape measure.
 - (ii) weight: to the nearest kilogramme, using a calibrated bathroom scale.

The results were then used to compute "weight-for-height per cent", using Cole's Growth Assessment Slide Rule. "Weight-for-height per cent" was used as an index of nutritional status.

4. Blood ChE estimation, using the WHO spectrophotometric field kit, was carried out on 45 of the 65 workers who had been subjected to the questionnaire. The kit uses the method of Limperos and Ranta (1953) as modified by Edson (1985), and the results obtained have been shown by Limperos and Ranta (1953) to be consistent with those obtained by the electrophotometric method of Michel (1949). Blood samples from the researchers and other non-exposed individuals were analysed separately as the "reference" samples, so as to standardise the test. The reference blood samples all recorded ChE activity levels of 100 per cent. In the 45 workers tested, blood samples were taken in the afternoon, towards the end of the working day, after near maximal exposure to OPs. The pinprick (0,1 ml) blood samples from the tip of the index finger were analysed on the spot. The standard Lovibond comparator disc measures ChE activity in increments of 12,5 per cent, that is, a scale of zero to eight.

The results of the blood ChE were then matched against some of the factors which had been enquired about in the questionnaire. For example, the average ChE activity of smokers was compared with the average ChE activity of non-smokers. In each instance where a comparison had been made, the independent t-test was employed. A significance level of 95 per cent ($p \leq 0,05$) was taken as significant and a significance level of 99 per cent ($p \leq 0,01$), as moderately (borderline) significant.

The study was conducted in September 1989 in preparation for ploughing season, September being the month when pesticide factories are in near-maximal production.

In factories 1 and 2, where blood was analysed for ChE activity, ventilation appeared satisfactory and the formulation process was significantly automated. However, in factory 3, where management advised against taking blood samples, the OP plant consisted of an open "dip tank" where the liquid pesticide was formulated. This was then transferred to huge drums for temporary storage. From the drums, the liquid OP was then packaged into smaller containers for wholesale retailing. The drums containing liquid OP were stored in huge sheds made of corrugated roofing material, with negligible ventilation. It was in this shed that packaging took place, manually. Whereas the workers in the formulation process wore respirators, those in the packaging section wore cloth masks. In all three factories, age and educational status were not deliberately employed as criteria for job allocation.

Of the 65 workers interviewed, all were male, 46 or 69 per cent were full-time, six (9 per cent) had not received any formal education, 36 (55 per cent) were smokers and their average age was 32 years (see Table 1). Seventeen (26 per cent) were engaged in formulation and the remainder in packaging. The average blood ChE activity was 75 per cent in the 45 workers from the first two factories. This was significantly lower than the lowest (December) average blood ChE of 87 per cent in a similar study by Bwititi *et al.* (1987) in commercial farms in Zimbabwe. (see Tables 2 and 3).

Table 1. Educational status of the workers interviewed

Educational status	No of workers	Percentage
No. schooling	6	9,2
Primary education	33	50,8
Secondary education	6	40,0
TOTAL	65	100,0

Although all the workers said that they were provided with, and wore all necessary protective clothing, 49 workers (75 per cent) fully understood the importance of protective clothing. Only 32 workers (49 per cent) understood fully the meaning or order of the triangles and colour codes used in Zimbabwe for hazardous substances and 35 workers (54 per cent) had complete knowledge on the health effects of pesticides and the relevant elementary first aid. However, 54 workers (83 per cent) understood fully why and how to dispose of empty pesticide containers. When full-time and part-time workers were compared, more full-time workers had complete knowledge of the importance of protective clothing. (see Table 4).

Table 2. ChE activity levels in workers from factories 1 and 2

ChE (% Std) of workers	No. of workers N = 45	Percentage
37,5	4	8,9
50	4	8,9
62,5	12	26,7
75	6	13,3
87,5	5	11,1
100	14	31,1
(Average: 75,3 %)	100	

Table 3. Comparison of average blood ChE in farm workers in 1985 with average blood ChE in pesticide factory workers in 1989.

Year	No. of workers	ChE activity (% Std)
1985	105	86,9 (SE: 1,72)*
1989	45	75,3 (SE: 3,13)*

*Significant difference between mean ChE activity in agricultural pesticide sprays and pesticide factory workers; $t = 3,6$; $p < 0,01$.

Table 4: Percentage of full-time and part-time workers with full knowledge of pesticide warning signs, disposal and health-related issues and the importance of protective clothing.

Complete knowledge of:	Full-time workers (%)	Part-time workers (%)
Triangle order and meaning	50	53
Disposal of empty containers	85	84
Importance of protective devices	80	68
Health effects of pesticides	7	53

Of the six workers who had not received formal schooling, only two were from the first two factories where blood ChE estimations were performed. Hence, although it would have been interesting to compare those who had not received formal education with those who had, a comparison was made between those who had received primary education together with those who had not received any formal schooling on one hand and those who had received secondary education or more on the other hand. Those who had received primary education or no formal education had marginally significant lower

blood ChE levels when compared with those who had received secondary education (see Table 7).

The total number of symptoms reported by each worker (excluding bleeding) were added and then divided by the number of workers in the various groups to give an average "symptom index" (see Tables 5 and 6). Table 7 summarises statistical significance (t-test) results when average blood ChE results were compared after considering the following factors: smoking history, eating of snacks during work, nature of job, educational status, number of hours at pesticide containers, importance of wearing protective clothing and the health effects of pesticides, whether full-time or part-time, nutritional status, medical history and whether the workers found their jobs boring or stressful.

Table 5: Symptom index matched against average ChE activity

No. of symptom	No. of workers	Average (SD ChE (%))
0	10	(20)
1	13	(23)
2	8	(27)
3	6	(21)
4	7	(17)
5	1	(-)

Table 6: Symptom index matched against smoking, working status and factory

Factory under consideration	Average symptom t-value index	p-value
Smokers (36) vs Non-smokers (29)	2.4 vs 1.8	1.5 > 0.1
Full-time (45) vs Part-time (20)	2.5 vs 1.5	2.0 < 0.05
Factory 1 (23) vs Factory 2 (22)	2.0 vs 1.6	1.0 > 0.1

(Symptom index for factory 3: 3.44)

There was a very significant reduction in the blood ChE activity of smokers when compared to non-smokers. Of the 22 smokers from the first two factories who had their blood ChE estimated, six admitted to smoking during working hours and had lower ChE levels when compared with other smokers and non-smokers combined, but the difference was not statistically significant. Paradoxically, when the number of cigarettes smoked daily was investigated, those who smoked less than ten cigarettes daily had lower blood ChE activity than those who smoked ten or more cigarettes daily, but the difference was not statistically significant.

Table 7: Comparisons of the average ChE activity of various factors using the "independent t-test"

Comparison of various factors (No. of workers shown in brackets)	Average ChE (%) activity	t-value	t-test p-value
1. Smokers (22) vs Non-smokers (23)	64 vs 86	4,3	<0,001
2. Eat during work (3) vs others (42)	50 vs 77	2,2	<0,05
3. Formulation (6) vs Pack (39)	60 vs 78	1,9	<0,1
4. Primary ed. (24) vs Secondary (21)	70 vs 82	1,9	<0,1
5. 180 hrs (23) vs 172 hrs (22)	70 vs 81	1,7	<0,1
6. Factory 1 (23) vs Factory 2 (22)	70 vs 81	1,7	<0,1
7. Partial knowledge of triangle meaning/other (17) vs those with full knowledge (28)	71 vs 78	1,69	>0,1
8. Full-time (27) vs Part-time (18)	71 vs 81	1,6	>0,1
9. Partial knowledge of health effects of pesticides (16) vs full knowledge (29)	82 vs 72	1,6	>0,1
10. Weight/height (per cent): 75-100 (16) vs 100-150 (29)	69 vs 79	1,6	>0,1
11. Smoke during work (6) vs other smokers & non-smokers (39)	65 vs 77	1,3	>0,1
12. Job boring/stressful (6) vs others (39)	66 vs 77	1,3	>0,1
13. History of malaria (29) vs no history of malaria (16)	72 vs 80	1,2	>0,1
14. On medication (16) vs not on medication (29)	71 vs 78	1,0	>0,1
15. Smoke 10 cigarettes/day (8) vs < 10 cigarettes/day (14)	67 vs 61	-	>0,1
16. Partial knowledge of protective clothing (9) vs full knowledge (36)	75 vs 75	-	>0,1
17. Partial knowledge on disposal of pesticide containers (6) vs full knowledge (39)	83 vs 74	-	

Those who admitted eating snacks whilst working had significantly lowered blood ChE when compared with those who did not. Formulation (as opposed to packaging), primary schooling and not schooling (as opposed to those with secondary schooling) and longer hours at work resulted in lower and marginally significant blood cholinesterase activity.

Of the three workers who admitted to a past history of liver disease, two (from factories 1 and 2) had their blood measured for ChE activity: one had 37,5 per cent activity and the other 100 per cent activity (Not significant difference from other workers).

Six workers reported a history of "injury" with pesticides, for example, spillage onto body, in the preceding four weeks. Of these, only two workers were in the two factories where blood ChE was measured: one recorded 87.5 per cent activity, the other 75 per cent activity (Not significantly different from the other workers).

A cross-sectional study such as this one only gives information concerning the state of affairs at a single point in time. More information would have been obtained from a series of cross-sectional studies over time or a longitudinal study. However, given the limitations of time, a cross-sectional study was the most appropriate study design. The survey was conducted in September when the factories were in a state of semi-maximal production of organophosphates in preparation for the ploughing season. Hence, the results obtained should be interpreted as reflecting near-maximal exposure levels to OP pesticides.

Although the response rate was 76 per cent, it is unfortunate that it was only possible to perform blood ChE analysis in 70 per cent of the respondents in particular since the quality of the study rested principally on the results from the objective biological monitoring of exposure to OP pesticides. It is tempting to speculate that had blood samples from workers in factory 3 been analysed, the average ChE obtained would probably have been lower than in the other two factories, given the presumed higher exposure to OP pesticides in the manufacturing process, the apparent poor state of ventilation in both the formulation and packaging areas and the increased time spent at work because of overtime. The higher "symptom index" in factory 3 (see Table 6) lends support to this view. However, there was poor correlation between symptoms and ChE activity (see Table 5). Hence, in the absence of objective environmental and biological monitoring in factory 3, not much credence can be placed on the assumption of higher exposure in factory 3. Regrettably, little more is known about factory 4 other than that the workers were all male and of similar age group and socio-economic status as the workers from the three factories which participated in the study.

In view of the normal variation in blood ChE activity already alluded to, it would have been preferable to have pre-exposure baselines to compare against the exposure ChE levels. In addition, it is probable that some workers could have been exposed to OP pesticides elsewhere, such as from application of OPs in their vegetable gardens. However, in this study, it was assumed that the overwhelming significant exposure to OPs would be that acquired at the workplace. The normal standard ChE activity of 100 per cent was thus taken as the reference (or control) ChE activity level. Furthermore, as discussed by Limperos and Ranta (1953) and by Edson (1955), ChE activity of 75 per cent was taken as the critical value, all those with ChE activity of 75 per cent or less being regarded as having been exposed to excessive amounts of OPs and requiring removal from further exposure. On that premise, it was thus calculated that 58 per cent of the workers had been exposed to excessive amounts of OP pesticides.

In this study, there was poor correlation between symptoms and ChE activity levels. This is consistent with established data (Limperos and Ranta, 1953 and Edson, 1955). Summerford and his colleagues (1958) suggested that the rate of decline of ChE activity was a better predictor of whether symptoms would appear or not, as opposed to the absolute ChE activity. However, serial ChE measurements were not performed in this study.

Of all the factors examined, smoking was found to be most significantly associated with reduced ChE activity. This is most likely to be related to contamination of cigarettes with OP pesticides when the cigarettes are in the worker's overalls and contamination from hands when smoking before washing, that is, poor hygiene. In addition, many workers in Zimbabwe roll their own cigarettes, thus increasing the potential for exposure via contaminated paper, lack of appropriate containers to shield the tobacco from possible OP contamination and further exposure from unwashed hands during the "rolling" process. The lack of correlation between the number of cigarettes smoked and ChE activity would be due to one of the following reasons or both: perhaps some workers were not honest about the number of cigarettes smoked; and, perhaps those who smoked less were smoking "rolled" cigarettes, as opposed to packaged cigarettes. It was also found that those who admitted to smoking during work had lower ChE activity than other smokers and non-smokers combined. Again, it is tempting to suggest that perhaps there were more workers smoking during work but were not prepared to admit this, particularly since smoking on the job is rigorously discouraged in all three factories.

It was of interest that one worker specifically asked about snuff taking. Snuff taking is relatively common in Zimbabwe and in view of the greater possibilities of handling the tobacco with contaminated hands, this should have been enquired specifically in the questionnaire. This would help clarify, perhaps, the discrepancy in the ChE activity and the number of cigarettes smoked. Some workers may be taking both snuff and cigarettes.

Tobacco contains nicotine. Nicotine poisoning is known to produce the following symptoms: nausea, vomiting, chest pains, salivation, abdominal pains, diarrhoea, dizziness, sweating, faintness, convulsions, paroxysmal atrial fibrillation and paralysis of respiratory muscles (Reynolds, 1989). These are symptoms very similar to those found in OP pesticide poisoning. Hence, one would expect the smokers in this study to complain of more symptoms. However, Table 7 reveals that although smokers had a higher symptom index when compared to non-smokers, this difference was not statistically significant.

The implications of these observations for workers in the OP industry in a tobacco-growing country like Zimbabwe are clear: reduction or preferably cessation of smoking will significantly reduce OP exposure.

The three workers who admitted to taking snacks during work had significantly lower ChE levels compared with other workers. The importance of personal hygiene therefore needs to be further emphasized as a means of significantly reducing exposure to OP pesticides.

Workers engaged in formulation had lower and marginally significant ChE levels compared with those engaged in packaging. With the relatively high degree of automation in the formulation process in both factories 1 and 2 (see Table 5), and the greater care taken in wearing of protective clothing during formulation (see Tables 2 and 5), one would have expected those engaged in formulation to be less exposed to OPs. Workers working a fixed shift of 180 hours per four week had lower and marginally significant ChE levels than their colleagues who were working a fixed shift of 172 hours per four weeks. It is therefore suggested that reduction in duration of exposure at work would significantly reduce OP exposure to the worker. However, in this study, those working the two shifts were from two different factories, thus adding other factors as being responsible for the observed differences in blood ChE activity. In factory 3, workers were able to work overtime and therefore it would have been possible to study the effect of time/duration of exposure at work whilst controlling the work environment.

Also of interest was the observation that workers who had received secondary education had higher ChE levels than those without secondary education. The implications of this finding in a country like Zimbabwe where the literacy rate is significantly rising every year are welcome. In addition, the borderline significance in the difference in the ChE of those workers with complete knowledge of the pesticide warning hazard signs used in Zimbabwe also suggests that an intervention study encompassing an educational input would elucidate further the degree to which worker education campaigns would reduce exposure to OP pesticides.

It is interesting to note that although workers said that they were provided with protective clothing, only 75 percent of the workers fully understood why particular protective clothing should be worn. This factor, in addition to the high temperatures attained in summer in Zimbabwe, may explain why some workers do not fully comply with the wearing of the full gear when the foreman is not around. This suggests that more education seminars appropriate for the particular group of workers need to be conducted, in addition to greater emphasis on engineering control measures as opposed to personal protective devices. The futility of wearing cloth masks needs to be emphasized to both management and workers. The difficulty in obtaining foreign currency to purchase respirators in sufficient quantity is to be regretted. The Hazardous Substance and Articles Act of 1978: Protective Clothing; Pesticides Regulations; Statutory Instrument 205 of 1985 correctly make it compulsory to wear a respirator when dealing with certain types of pesticides. If foreign currency is available for the importation of the raw ingredients for the formulation process, there is no reason why foreign currency cannot be put aside for the importation of respirators to protect the worker. Furthermore, it is known that xylene dissolves rubber gloves (GIFAP, 1993; Baloyi *et al.*, 1986) yet many liquid OP formulations contain xylene (see Table 6). This aspect needs to be considered

in future studies so that appropriate advice about acquisition of gloves of suitable material can be given.

When full-time workers (chronic exposure) were compared with part-time workers, the full-time workers had a significantly higher average "symptom index". This is slightly puzzling since it is assumed that workers chronically exposed to OPs develop some tolerance to OPs (Taylor, 1986, see Table 6.) However, when blood ChE of full-time and part-time workers was compared, there was no significant difference (see Table 7).

Liver disease is known to result in a reduction in the serum ChE component of whole blood ChE. Factors which might lead to liver pathology, including various drugs, for example, anti-tuberculosis treatment, were all investigated but no significant findings were obtained in this study.

Had blood ChE assessments been performed in factory 3 where there was little automation in the formulating and packaging processes and poor ventilation in the formulating and packaging areas, it would have been possible to compare the results obtained with those from factories 1 and 2 where automation and industrial hygiene were of an acceptable standard. Nevertheless, it is now an established principle that engineering control measures at the source of exposure are preferable to, and more effective than, burdening the worker with a multitude of personal protective devices (see Tables 3 and 4). Furthermore, it is probably more important to provide a safe environment as in factories 1 and 2 is than to provide a well-staffed clinic only as in factory 3. Obviously, provision of both factors would be preferable.

It was not possible to objectively ascertain the implications of workers in Factory 2 having to wash their overalls at work weekly. However, one would advise against this procedure as it is likely to result in further OP exposure to the workers.

Fifty-eight percent of the workers who had their blood analysed for ChE activity were found to have ChE activity equal to or below 75 per cent activity, suggesting exposure to OP pesticides. This is a high prevalence, significantly higher than the prevalence of excessive OP exposure in the commercial farms (see Table 3).

The study also partly achieved its second objective, that of identifying and elucidating factors which contribute to increased exposure to OP pesticides at the workplace. Smoking and personal hygiene were found to be significantly related to exposure to OP pesticides. Education and specific knowledge of OP pesticide hazards were found to be associated with lowered ChE activity and moderately significant. These are factors which could easily be controlled without great financial input, resulting in a significant reduction in the prevalence of OP exposure at the workplace.

The study also demonstrated the effectiveness of a simple applied research. The WHO kit allows for immediate feedback of results and is therefore crucial for rapid screening of several at-risk workers. This is of great importance since symptoms are not well-correlated with blood ChE activity, symptoms usually

appearing only when ChE activity is dangerously low (Limperos and Ranta, 1953 and Edson 1955).

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