Field Studies on Operator Monitoring for Pesticide Exposure in Desert Locust Control Operations – Field Validation of Methods

Prepared by:
R. Aston
A. O. El Hadj
M. O. El Hadi

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Summary

In order to investigate the potential for routine systems of operator monitoring to exposure to pesticides, spray operators were monitored using the acetyl cholinesterase technique. In the control operation monitored, 4 people of the 12 involved in ground spraying teams showed depression of AChE or PChE at levels that warranted removal from contact with organophosphate pesticides. Of these, one operator showed depression of PChE at reading 1, and depressed AChE at reading 2. The remainder of the positive results were recorded at the end of the operation.

There was an indication from the data that one particular type of spraying machine (the Kionetz) led to greater operator contamination that the Micronair AU7110 and AU8110/5 used by the other teams, although the data are confounded by a significantly different time of exposure due to the nature of the spraying machines.

Two of the ground crew of the aerial team also exhibited AChE reductions that caused concern. Although the data are incomplete, there are indications that the reason for this was the absence of the correct loading equipment, perhaps coupled with a lack of training on correct pesticide handling techniques.

The nature of locust control appears to be markedly different from other control operations, as there appear to be periods of spraying interspersed with non-spraying periods. It is therefore difficult to extrapolate from other crop protection programmes on the potential nature of the exposure faced by locust control operators. There is a need therefore to concentrate efforts on monitoring operators under locust control conditions, to assess the true extent of exposure (and recovery from exposure).

Although the AChE technique is relatively simple, it only gives an overall indication of exposure, and does not identify when and how operators are exposed to pesticides. Better research techniques exist for examining the causes of pesticide exposure, and for assessing the effects of changes to equipment and operating procedures designed to reduce operator contamination.
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1 Introduction

1.1 Introduction

During pest control operations of whatever type, the use of agrochemicals can have adverse health impacts on the operators. One group of pesticides, the organophosphates (OP) exhibit their effects on humans (and on other animals) through a depression of acetylcholinesterase (AChE) levels. Routine systems of monitoring for the impact of OP use on operators, through regular monitoring of AChE levels, are well established, and are a requirement by law in some countries. In Morocco, measurement of blood AChE is an established part of locust control operations.

However, in Mauritania, the use of AChE monitoring as a regular feature of locust control operations has not yet been implemented. Preliminary work by Mullié (1997) in Mauritania discussed the potential for monitoring of operators during control operations, using the AChE technique. As part of this visit, a doctor and a nurse were trained in the techniques of AChE measurement, and the relevant equipment obtained. However, due to the shortage of control operations, only baseline data was collected. For a discussion of the medical impacts of OP use, and the theory behind monitoring for AChE refer to Appendix 1.

In order to successfully implement routine monitoring of pesticide users, there is a need for a reliable, robust method of data collection, data analysis and decision making based on field operations. The measurement of AChE is a straightforward technique that has been designed for field use, and there is no doubt as to its accuracy and reliability. However, the use of this technique has two potential drawbacks for routine use in desert locust control operations in Mauritania. Firstly, in times of outbreak, large numbers of staff are involved who are often recruited at short notice and dispatched to the field rapidly. Secondly, during operations, control teams may be operating in a large geographical area, which implies that the time required to reach and sample the teams may be correspondingly high. Because of the wide geographical spread, teams are often operating far from established bases. These factors together pose logistical and managerial problems that need to be resolved before the technique can be used routinely. In addition to the logistical and managerial problems highlighted, other areas of uncertainty in routine monitoring of spray operators have been identified: i) data management and decision making; ii) identification of who should carry out the monitoring; iii) the role of qualified medical staff; iv) issues related to sustainability, particularly financial; v) an investigation of systems and procedures, other than regular monitoring of AChE which could serve the same purpose (of minimising adverse health effects of pesticide use).

In order to examine some of the areas identified above, the opportunity was taken to collect data from a crop protection operation undertaken in Mauritania from May 1999. This operation used similar equipment, techniques, and in some cases the same staff as a locust control operation. The programme was directed at controlling grain eating birds, which are considered a serious problem in rice growing areas close to the Senegal River. This control operation was used as a model for monitoring of spray operators, and the role of the project was confined to collecting data on operator exposure. The control operation was under the direct control of DDRAP, who were ultimately responsible for the management of the
operation – this included decision making as to when operators should be removed from control operations as a result of decreased AChE levels.

Mullié et al (1998) have discussed the background to operator monitoring. Their study was based on the WHO Standard Protocol for field surveys (monitoring) of exposure to pesticides (WHO 1982). They describe 6 data sets that should be collected:

1. Times of exposure;
2. The quantities of pesticide applied by each person;
3. Details of protection used;
4. The amount of pesticide coming into contact with the exterior of clothing, beneath clothing and exposed skin;
5. Quantitative tests of absorption and excretion of parent compounds or metabolites;
6. Details of any effects of exposure.

In the case of this study, the aim was to examine the potential for implementing health monitoring, and it was not considered necessary (nor was it feasible) to measure the amounts of pesticide coming into contact with the operators (number 4, although see Discussion), nor tests of absorption and excretion (number 5). Other data were collected as carefully as possible, although as discussed later, some of the data are incomplete.

Mullié, in the paper cited above, discussed a number of other measures that could be implemented to reduce the potential health effects of pesticide on operators. These included removing workers from the operation after a set time period, after a set amount of pesticide had been applied by an operator, or based on AChE readings. Their data showed that, under Senegalese conditions, operators typically exhibited levels of AChE depression which warranted removal from the control operation after the application of 1700 kg of active ingredient of OPs, which equated to about 24 working days under typical conditions in Senegal. In order to examine the feasibility of these options, Section 2 of this report uses historical data (from the 1994 control operation in Mauritania) to model each of these options and consider the implications.

As part of the ongoing “Analysis of Current Practices”, project activity D2.2, a series of workshops are being conducted with spray operators in order to understand the limitations to the adoption of best practice. The opportunity was taken during field visits to this operation to run such workshops.
1.2 Aims of the Study

The aims of the study were:

1. To validate the use of AChE measurement as a robust tool for routine monitoring of operator exposure under field conditions in Mauritania.

2. To develop simple, effective data management techniques for timely decision making.

3. To consider the implications of routine AChE measurement in a desert locust control operation and potential systems for implementation in Mauritania and other locust affected countries.

4. To gather data on the operational procedures and other factors which lead to operator contamination for use in developing future research and development.

5. As time permitted to run operator perception workshops with field staff.
2 Methods

2.1 Study Organisation

A physician and a nurse, who had previously been trained in the AChE technique were employed by the project for the duration of control operations. The terms of reference for these staff are provided in Appendix 2. Essentially, the role of the nurse was to take blood samples from the spray operators, and, using the Testmate OP kit, to analyse the samples for AChE and PChE (PChE is plasma acetylcholinesterase, see Appendix 1). The role of the doctor was to provide medical supervision of the study, and through medical examinations and evaluation of the AChE data, to advise DDRAP through the CLAA on the medical implications of the findings. Although not in the terms of reference, the doctor also contributed to raising the awareness of spray operators to the impact of pesticide use through organising and participating in workshops.

Before the operation, control staff were briefed on the role of health monitoring, and given forms to complete on previous history of pesticide use, experience and training. They were also asked to keep a record of the amount of product applied, together with other details of the operation.

Daily totals of amounts sprayed per team were gathered from radio messages transmitted to DDRAP as part of routine operations. At regular intervals, the teams were visited in order to take blood samples for analysis. Data on AChE and PChE levels were collated into computer, and the results passed to the relevant authorities where action was required. Medical examinations were conducted at the start, once during and at the end of the operation.

2.2 Staff Briefing

Before the start of the operation, control staff were briefed on the health monitoring operation. This involved a basic description of the technique, the aims of the study and how the data was to be used. It was stressed that the medial records of staff were confidential, and that all data generated by the trial would be coded. Any decisions taken which were the result of the data collected were the responsibility of DDRAP, and not of the project. All of the people involved in the operation were happy to be part of the monitoring operation. Despite this briefing, it became clear during the programme that a number of staff involved in the operation were confused and uncertain about the monitoring programme. As a result of this uncertainty, a workshop was arranged for prospectors from the CLAA during which the physician gave a presentation on the theory behind AChE/PChE monitoring. He also gave a seminar to the military agricultural aviation wing on a similar theme, which also included a general introduction the health effects of pesticide use.
2.3 Description of the Control Operation

Control operations against grain eating birds have many similarities to locust control operations. Application is by ULV sprayers, and takes place early in the morning or late in the evening when the birds are at the roost site. The spraying equipment used was identical to that used in locust control (with one exception), and the method of drift spraying is the same.

The overall area in which treatment is required is defined by the extent of the cultivated land. Within this large area, individual targets to spray are identified by survey following reports of large concentrations of birds. Each control team usually worked alone, with co-ordination provided by a mobile co-ordination team.

The operation was under the overall management of DDRAP who supplied equipment, chemical, vehicles and funding. However, the senior control staff were on secondment from the CLAA, and were highly experienced locust control staff.

The control operation ran from May until July 1999

2.3.1 Control Teams

Two types of control teams were used in the operation; ground spraying and aerial spraying. A co-ordination team was in overall charge of day to day management of the operation.

2.3.2 Ground Teams

Each ground team had the following staff:

1. A prospector, who was the team leader responsible for locating, selecting and delimiting the targets for spraying. In all teams, the prospector was a highly experienced full time employee of the CLAA
2. A driver, who drove the vehicle, both in normal use and during spraying operations. Drivers were usually full time employees of the CLAA, and often had many years of experience.
3. An applicator, who was responsible for loading, using the spray equipment and cleaning the machinery. Applicators were usually employed on a temporary basis, although all but one had previously worked on control.

Although the above suggests a clear distinction in the roles of each team member, in practice there was overlap related to pesticide handling. Discussions with the teams confirmed that often the driver and prospector would be involved in loading or spraying. It is therefore difficult in the analysis of the data to identify whether one particular role consistently results in higher pesticide exposure than another; this makes interpretation of the results somewhat difficult in terms of identifying the underlying causes of pesticide contamination.

Each three man team was equipped with a pickup vehicle on which was mounted the sprayer. This was the only vehicle in the team, and was therefore also used to carry camping equipment and other items necessary for operations. Three of the teams were equipped with small Toyota type vehicles; one used a larger Unimog flat bed truck. All the vehicles had enclosed cabs.
Each team was provided with protective clothing (boots, gloves, coverall, and a respirator), and were asked to keep a record of what was used during application. However, adequate records of this were not kept by all teams.

2.3.3 Aerial Control Team

The aerial control team were from the Mauritanian airforce. The team comprised two pilots, mechanics and ground crew. The original contract for the operation was for 10 flying hours, later extended to an additional 10 hours. The aircraft used was a Defender, the military version of the Brittan Norman Islander twin engine aircraft.

For initial operations, the aircraft was based at the strip near to Rosso; however, the airstrip became unusable due to waterlogging, and later operations were conducted from Nouakchott.

2.3.4 Spraying Equipment

Three of the ground teams were equipped with Micronair AU7110 or AU 8110/5 ground sprayers. These are air assisted sprayers, which use a rotating cage to produce the droplets. The airstream moves the droplets vertically into the air (2 - 3 m) before natural air movement carries the droplets to the target. During applications, the operators remained inside the cabs, although the windows were usually left open due to the heat. Loading of this machine is relatively easy, although unfortunately, pumps were not available to the teams.

The fourth ground team was equipped with a Kionetz. This machine is a direct spray device, rather like a gun. The pesticide is emitted at high pressure from the nozzle, and an operator standing beside the machine on the back of the vehicle directs the spray to the target. This machine was mounted on a Unimog vehicle.

Calibration of the equipment took place before the operation. This was done by the control expert from the co-ordinating team. No further calibrations took place during operations, and therefore no staff were exposed via this route.

The aircraft was fitted with underwing mounted spraying pods, one under each wing. Each pod contained a tank and a single Micronair AU4000 rotating atomiser. The aircraft was fitted with a cockpit mounted tachometer (to monitor the RPM of the atomisers) and a flow monitor. During operations conducted from the airstrip at Rosso, the aircraft was loaded by staff from the ground teams, if they were present at the site. If not, loading was done by the aircraft team stores people. Again, no pump was available at Rosso for aircraft loading. The Micronair spray pod is very difficult to load safely without a pump, as the opening is very small and is about 1.5 m off the ground. It is also awkwardly located.

After spraying (which took place in the evenings), the aircraft was secured for the night. External cleaning of the aircraft took place the following day by aircraft mechanics of the aviation team.
2.3.5 Products

The only agrochemical product used during the operation was fenthion, formulated as Quelatox ULV formulation, with a concentration of 600 g ai per litre. This product was supplied in good quality 25 l containers, each clearly labelled (in French) to the required international standard. The levels of protection required for this chemical as given by the label are:

During loading and application:

Gloves, coverall, boots, face protection and a hat.

There is no label requirement for the use of a respirator, although it appeared that most operators wore one during operations.

Application of this product is by the ULV drift spray technique. The machines are driven cross wind, and the natural wind movement taking the small droplets (ideally 20 - 40 µm) into the roosting sites. If correct technique is followed, contamination of the operators should be minimal.

2.4 Acetyl Cholinesterase Measurement

In order correctly interpret the change in AChE/PChE levels, a pre-exposure baseline reading is required. As there is great interpersonal as well as intraperson variation, it is recommended that two baseline readings, at least 72 hours, but no more than one week apart are taken. If the difference between these two readings exceeds 15%, a third reading is required. In this operation, because of the shortage of time between the initiation of the research and the start of the operation, two baseline readings 48 hours apart were taken.

For ground teams, samples were taken on the following dates:

Baseline : 13-15\textsuperscript{th} May
1\textsuperscript{st} Reading : 13\textsuperscript{th} June
2\textsuperscript{nd} Reading : 8\textsuperscript{th} July
3\textsuperscript{rd} Reading : 9\textsuperscript{th} August

Baseline and final readings were taken in Nouakchott and the intermediate readings taken during operations in Rosso.

For the Aerial Team:

Baseline : 3-5 \textsuperscript{th} June
1\textsuperscript{st} Reading : 13\textsuperscript{th} June
2\textsuperscript{nd} Reading : 13\textsuperscript{th} July

Baseline and final readings were taken in Nouakchott and the intermediate reading in Rosso.
Following the recommendations of Mullié (1997) blood samples for analysis were taken by syringe from a vein in the arm. This was done by the qualified nurse. The analysis for AChE and plasma cholinesterase, together with haemoglobin followed the procedure laid down in the EQM Tesmate manual. For all samples, analysis was performed within 2 hours following blood sampling.

One reading in the series, of haemoglobin levels in the case of two operators, gave particular cause for concern at the low level recorded. In response to medical advice, these operators were sent for a blood test at a medical laboratory in Nouakchott. This more precise test indicated that there was in fact no abnormality in their haemoglobin levels, and therefore the Testmate machine or the reagents used were suspect. This seemed to be confirmed by other abnormal readings during this sampling round. To examine this, the Testmate machine and the reagents were calibrated against a new version of the machine used by Locustox in Senegal. This calibration showed that the AChE or PChE measurements were acceptable, but that the correlation for blood haemoglobin was poor. Therefore there was enough doubt on the data collected during this visit that all the results from this have been excluded from the analysis. This data corresponds to reading 2 (July, ground teams taken in Rosso). It is now thought that there was a problem with blood coagulation for this particular series. The other data collected in July (the aerial team) is considered satisfactory.

Calibration of the Testmate machine was undertaken in collaboration with Locustox. This was done during the regular programme of monitoring established by Locustox, in the Thiés area about 70 km north of Dakar. Blood samples were taken from operators as part of the normal procedure, and tested in both the Locustox machine (the new version of the Testmate system) and with the project machine. Because the data output from the new machine is different, the data from the two machines were compared by regression analysis.

The recommendation for monitoring for AChE levels is that the first reading should be taken 1 week to 10 days after operations begin, and then monthly or longer depending on the results obtained. In the case of this study, there was great irregularity in the amount of pesticides being applied, largely because of the weather. In this study, readings were taken at monthly intervals; however, as discussed above, one set of reading has been rejected, which leaves three sets of readings for analysis (baseline, after 2 months, and at the end of the operation).

### 2.5 Data Collected

The following data were collected before the operation commenced:

- The history of pesticide use of each person, including training received, level of training and any history of pesticide poisoning.
- A medical examination
- Baseline AChE/PChE measurements.

During the operation the following data were collected:

- The amount of pesticide applied by each person (or more accurately the team total).
- AChE/PChE readings
- Medical examinations
The data collection forms are attached as Appendix 3.

2.6 Medical Examinations

Medical examinations were undertaken by the physician of all people involved before the start of the operation, once during the operation and at the end of the operation. The medical examinations were designed to find any signs or symptoms of pesticide intoxication.

2.7 Database and Data Analysis

In order to manage the large volume of data generated during this study, a simple database was constructed, in which all the data was input. The aim of the development of this data base was to aid in the routine collection and analysis of monitoring data, and therefore it was designed to be as simple as possible. During operations, what is required is a simple yes/no output, as to whether any particular operator is suffering depression of AChE that warrants withdrawal from spraying operations. More advanced data analysis, although desirable for research purposes, is not required for routine monitoring.

Further analysis for this study has been undertaken using Unistat statistical software.

2.8 Medical Confidentiality

The collection of medical data (both the AChE/PChE and examination information) should remain confidential to the operator and the physician. However, the nature of this study, particularly the fact that all the data was collated and analysed by project staff, meant that this was not the case. This issue needs to be addressed for routine use of the technique.
3 Results

3.1 Experience and Training

Of the people involved in the ground teams, only one person was new to control operations; this was an applicator. The other three applicators had between 3 and 7 years experience of operations. The drivers in the control teams were also highly experienced, with a minimum of 6, and a maximum of 19 years working on control. The surveyors were also highly experienced - none had fewer then three years experience, and one had 29 years of practical experience of pesticide application.

In terms of training, 5 classes of training are used to identify the level:

- Level 1 - a one day (or less) course on pesticide use
- Level 2 - a training course of between 1 day and 1 week
- Level 3 - a course of between 1 week and 1 month
- Level 4 - a course of between 1 month and 1 year.
- Level 5 - a training course on crop protection, pesticide use and related topics lasting more than one year.

Immediately obvious from the training history records are that no drivers reported having had any formal training in pesticide use. Of the applicators, three had received training (all that had worked before) of level 2. All of the surveyors were trained to Level 5 - each had undertaken an advanced course in crop protection or a similar field. The application specialist for the operation was also level 5 trained, in this case 2 years spent in Morocco.

The situation was less good for the aerial team. For 4 of the 8 people involved, this was their first control operation. Of the others, the two pilots had 2 and 12 years experience; two of the mechanics had significant experience in pesticide applications (8 and 12 years).

However, none of the aerial spraying team reported having any formal training in pesticide use. (This was confirmed by the seminar given by the physician to the aviation group following the operation).

Two of the ground team members reported having suffered pesticide intoxication in the past; one twice (once in 1973 and again in 1994) and one a single incident in 1994. Both reported having had atropine administered. Table 1 summarises the experience and training of the staff involved.
Table 1 Training and Experience of Operators

Ground Teams

<table>
<thead>
<tr>
<th>Role</th>
<th>Training Level</th>
<th>Experience (Years)</th>
<th>Previous intoxication</th>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
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<td>5</td>
<td>29</td>
<td>Yes</td>
<td>1973, 1994</td>
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<tr>
<td>Prospector</td>
<td>5</td>
<td>7</td>
<td>No</td>
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</tr>
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<tr>
<td>Prospector</td>
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<td></td>
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<td>5</td>
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<td></td>
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<td>Driver</td>
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<td>9</td>
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<td></td>
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<tr>
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<td>3</td>
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Aerial Team

<table>
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<tr>
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<th>Training Level</th>
<th>Experience (Years)</th>
<th>Previous intoxication</th>
<th>When</th>
</tr>
</thead>
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<tr>
<td>Pilot</td>
<td>0</td>
<td>12</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Pilot</td>
<td>0</td>
<td>2</td>
<td>No</td>
<td></td>
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<td>Aviation Mechanic</td>
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<td></td>
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<td>0</td>
<td>12</td>
<td>No</td>
<td></td>
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<td>Storeman /Loader</td>
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<td>0</td>
<td>No</td>
<td></td>
</tr>
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<td>0</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Storeman /Loader</td>
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Co ordination Team

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<th>Experience (Years)</th>
<th>Previous intoxication</th>
<th>When</th>
</tr>
</thead>
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<tr>
<td>Driver</td>
<td>0</td>
<td>1</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Sprayer Technician</td>
<td>5</td>
<td>9</td>
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</table>

3.2 Application During Operations

3.2.1 Ground Teams

There was a great deal of difference between the amount of chemical applied by each of the ground teams, from a minimum of 300 l for Team 4, to a maximum of 1040 l for Team 2. In terms of exposure, Team 2 was the most exposed per working day, applying on average 32 l of product each day spent spraying. Where data are available (for Teams 2 and 3) there is a huge difference in the exposure per hour spent spraying (ie the time during the day that spraying operations were in progress). Team 2 sprayed a total of 1040 l of pesticide over 32 days; however, in total, during those 32 days, the amount of time spent spraying was only 9.3 hours, giving an exposure rate of 111.8 l per hour spraying. In contrast, Team 3, required 36 hours to apply 735 l, giving an hourly exposure of 20.4 l/ha. This reflects the nature of the machines used by the teams - Team 2 were equipped with a Micronair AU8110 sprayer, whereas Team 3 used a Kionetz directed spray machine. The technical differences between these machines are discussed in Section 1.3.7.

One further factor examined from the data was the period that the operators applied without a rest (defined as at least one full day not conducting spraying operations - although it must be noted that during these non-spraying days the teams were likely to be undertaking other tasks related to control operations - maintenance, repair, cleaning etc). This is defined as the mean time between rests, and varied from as little as 3.4 days for Team 4 to 7.75 days for Team 2. These data are up to the last day of spraying operations, not until the last AChE reading.

From these data alone, one could suggest that Team 2 were likely to suffer greater exposure to pesticide during operations, as the amount applied per spraying hour was high, and the time between rest periods was also high. On the other hand, the time actually spent exposed to the pesticide (only 9 hours) was lower than that of Team 3.

Table 2 presents the operational data for each ground team.
3.2.2 Aerial Team

The aerial team sprayed a total of 1150 l of pesticide. This total was applied in two sessions. The first (in which 750 l was applied) took place between the 11\textsuperscript{th} and the 14\textsuperscript{th} of June (3 sorties in total). The remaining 400 l was applied on the 9\textsuperscript{th} and the 11\textsuperscript{th} of July – 2 sorties, each of 200 l.
Table 2 Operational Data – Ground Teams

<table>
<thead>
<tr>
<th>Team</th>
<th>Total applied (l)</th>
<th>Days spraying</th>
<th>Average applied per day (l)</th>
<th>Total time of exposure (hr)</th>
<th>Average hourly exposure (l)</th>
<th>Mean Time Between Rests (days)</th>
<th>Average amount applied between rests (l)</th>
<th>Maximum applied between rests (l)</th>
<th>Minimum applied between rests (l)</th>
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</thead>
<tbody>
<tr>
<td>EA1</td>
<td>919</td>
<td>34</td>
<td>27.0</td>
<td>N/A</td>
<td>N/A</td>
<td>7.5</td>
<td>153.16</td>
<td>350</td>
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<tr>
<td>EA2</td>
<td>1040</td>
<td>32</td>
<td>32.5</td>
<td>9.3</td>
<td>111.7</td>
<td>7.75</td>
<td>207.2</td>
<td>475</td>
<td>75</td>
</tr>
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<td>EA3</td>
<td>735</td>
<td>35</td>
<td>21</td>
<td>36</td>
<td>20.4</td>
<td>4.83</td>
<td>105</td>
<td>175</td>
<td>35</td>
</tr>
<tr>
<td>EA4</td>
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<td>14</td>
<td>21.42</td>
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<td>N/A</td>
<td>3.4</td>
<td>37.5</td>
<td>75</td>
<td>15</td>
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</table>
3.3 AChE Results

3.3.1 Ground Teams

The results of the readings for all teams combined are shown in Figures 1-4, which express the readings as a percentage of the original value of AChE (or PChE) against the amount of pesticide sprayed, or cumulative days spraying (i.e., the days actually in spraying operations). In no case is there a clear correlation, or indeed obvious trend, between the time in contact with the pesticide (expressed as days), or the amount sprayed with the change in AChE or PChE levels. In Appendix 4 the data for all the teams individually are presented. Again, there is no obvious trend in any of these data.

For AChE readings, 5 workers showed depression of greater than 30% (considered to be the action threshold) at some point, whereas only a single worker exhibited a decrease in PChE that warranted action. Of the 5 workers showing levels of AChE depression at the action threshold, there was only one instance of this at the first reading, with the remainder at the last reading; this indicates that there is likely to be an exposure/time response, although there are no simple trends to support this in the data from this study. However, of the four workers with depression of AChE, two of these were using the Kionetz sprayer, which indicates that this sprayer is more prone to causing operator contamination than the Micronair equipment used by the other teams. In the case of the Kionetz team, it was the driver and the operator with reduced AChE levels; the prospector of this team did not have any indications of pesticide intoxication as measured by this technique.

It is tempting to conclude from the above analysis that the Kionetz machine is intrinsically less safe to the operator than the Micronair units. This assumption would be supported by the nature of the machine – with the operator standing exposed during operations. However, it must also be borne in mind from the data of this study that the time of exposure (36 hours in spraying operations) is very different from comparable data from the Micronair unit. It is therefore not possible to say, with any degree of certainty, that the Kionetz machine is less safe – had those using the Micronair units been exposed for the same length of time, then it is possible that the results of AChE would not have been dissimilar.

Although the data are limited, further analysis does indicate some areas of interest. For only two teams (2 and 3) are detailed data available on the time spent in spraying operations (i.e., minutes of application). This data is shown in Figures 5 and 6. Although not statistically significant, for at least for the AChE readings there is an apparent trend of decreased reading with increased time of exposure; there is one outlier in this data, which is that of a prospector. There does not appear to be a similar trend for the PChE data.

The effect of weight of the operator has also been examined from the data (Figures 7 and 8). Again, although not statistically significant, there is an indication that the heavier the operator, the less the change in AChE readings. Further, this can be expressed as exposure per unit bodyweight (Figures 9 and 10), which is an attempt to take into account the weight of the worker and the exposure faced. There is a clear trend which shows that there is a depression of AChE readings which is proportional to exposure (in terms of litres of product applied), if the weight of the operator is allowed for.
Not surprisingly, these data confirm that the larger the operator (in terms of body mass) the higher the exposure before there is an effect on AChE readings.

A repeated measures analysis of variance, using arsine transformed data of readings, identifies only one statistically significant relationship, which is that there is an effect of Team on PChE readings, with Team 3 showing a significantly lower PChE reading than Teams 2 and 4.

There appeared to be no correlation between experience, training or previous exposure history on levels of AChE or PChE recorded during this study. Nor could any effect of the roles of the team members be identified. As discussed above, this may be due to the fact that the roles are blurred during operations – all team members help with pesticide handling, and none seems to be at greater risk than any other. The one interesting result from Team 3 was that the prospector was the only person of the three man team showing no exposure at the last reading.
Figure 1 Change in AChE levels as a function of amount of ai applied

Figure 2 Change in PChE levels as a function of amount of ai applied
Figure 3 Change in AChE levels as a function of days sprayed

Figure 4 Change in PChE levels as a function of days sprayed
Figure 5 Change in AChE level as a function of minutes of spraying operations

Figure 6 Change in PChE levels as a function of minutes in spraying operations
Figure 7 Change in AChE levels with bodyweight at each reading

Figure 8 Change in PChE levels with bodyweight at each reading
Figure 9 Change in AChE readings as a function of amount of ai applied per unit bodyweight

Figure 10 Change in PChE Readings as a function of amount of ai applied per unit bodyweight
3.3.2 Aerial Team

The data for the aerial spraying team is presented in Table 3. No operator showed levels of depression of AChE or PChE at the first reading which warranted action. However, at the second reading, one person had a significant reduction in AChE level, and one other a reduction of PChE. Of these, one was classed as a storeman, the other as a mechanic. Unfortunately, it is difficult to be precise as to the roles; it is probable that the storeman was involved in the loading operation (when the aircraft operated from Nouakchott) – in the operational report this is classed as “aircraft preparation”; the mechanic was likely to be one of the staff who cleaned the aircraft after spraying operations.

The reading showing these high levels of depression occurred immediately after an application, indicating that there was a significant risk to operators arising from pesticide use, at least during ground operations (ie loading and cleaning).

In response to a request from the military, the physician involved in this study gave a seminar on pesticide safety to the aviation group. This seminar was well received, and the feedback from the seminar, together with the data obtained from this study, highlights the lack of training of the ground staff in correct and safe pesticide handling techniques.

Table 3 Aviation Team – Change in AChE/PChE Readings

<table>
<thead>
<tr>
<th>Role</th>
<th>Change in AChE Reading 1</th>
<th>Change in PChE Reading 1</th>
<th>Change in AChE Reading 2</th>
<th>Change in PChE Reading 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>4.96</td>
<td>-1.32</td>
<td>65.01</td>
<td>-27.31</td>
</tr>
<tr>
<td>Pilot</td>
<td>2.23</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviation Mechanic</td>
<td>22.45</td>
<td>2.44</td>
<td>24.78</td>
<td>-18.54</td>
</tr>
<tr>
<td>Aviation Mechanic</td>
<td>2.16</td>
<td>25.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviation Mechanic</td>
<td>20.78</td>
<td>6.15</td>
<td>49.35</td>
<td>-45.79</td>
</tr>
<tr>
<td>Storeman /Loader</td>
<td>5.63</td>
<td>6.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storeman /Loader</td>
<td>40.92</td>
<td>9.22</td>
<td>-8.94</td>
<td>-12.62</td>
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<tr>
<td>Storeman /Loader</td>
<td>39.53</td>
<td>6.46</td>
<td>-44.19</td>
<td>-14.45</td>
</tr>
</tbody>
</table>
3.4 Medical Examination

In none three of the medical examinations were any clinical signs or symptoms of pesticide poisoning noted in either the ground teams or the aerial teams (Appendix 5).
4 Discussion

4.1.1 Study Results

A primary aim of this study was to examine systems of data management which could permit decision making. The data base developed for this study (a simple input form, which automatically calculated changes in AChE and PChE readings), written in Lotus Approach (on a Dbase IV skeleton), was easy to use once it was organised correctly. Unfortunately, the coding system did not work particularly well. The problem is that before data entry, the data should have been coded. However, both the physician and the nurse employed by the project were employed only as needed, and therefore the nurse handed over the data after measurement in an uncoded format. Ideally, the doctor should take the responsibly for management of the data, but this was not possible in this study. This argues for the need for a full time medically qualified person to take responsibility for monitoring.

There was an indication that Team 3 showed greater contamination than other teams (a statistically significant reduction in reduction in PChE compared to the other teams, and two of three team members showing medically important reductions in AChE readings); although these data are not conclusive, it would appear that the nature of the spraying machine (ie directed spray with an operator close by) could lead to greater levels of contamination than the other machines, where the operators are able to stay in the cab during application. However, the confounding of two factors (machine type and time spraying) precludes firm conclusions being drawn. One of the problems with an operational study of this type is that it is difficult to control all the factors, and so confounding of effects becomes a problem in statistical analysis.

One of the problems of using the AChE technique as a research tool is that it only gives a broad measure of contamination, and, although the data obtained in this study suggests that that the Kionetz machine may be less safe than the Micronairs used by the other teams, there are no data to indicate why this should be so. During most application of pesticides, the majority of exposure occurs during the loading procedure. It is at this stage that large spillage can occur, with a consequent high dose exposure. Thus obviously, the greater the number of times that loading is required, the greater the risk of operator contamination. This is borne out by the data from the aerial team, where two of the team, both involved in ground handling operations, showed significant effects of pesticide exposure.

The data obtained in this study does not convincingly explain the role of experience, training or previous intoxication history on predicting exposure. There are indications that the lack of training in the aerial team may have contributed to exposure, but there may be more obvious explanations – eg poor loading technique as a result of the lack of pumps.
4.1.2 General Points

A number of significant points arose from this study which have importance for routine monitoring.

The method discussed by Mullié (1997) of blood sampling of spray operators calls for blood samples to be taken from a vein in the arm, which of necessity requires a syringe. In order to do this a qualified medical practitioner is required. This practice was established by Mullié because of the fear of contamination of the sample from pesticides on the fingers of operators which would give an erroneous reading. Normally, blood samples for AChE measurement are taken from a finger prick, as only a very small quantity of blood is required (10 µl). After the start of this study, it was discovered that Mullé has since modified the procedure used in Senegal to one of blood sampling from a finger prick. This is obviously much more convenient, as it does not require a nurse to draw the sample, as well as being less traumatic for the people being sampled. It also reduces the cost, in that the need for the disposal syringes and needles is removed.

A further practical problem with taking veinous blood samples is that on one occasion, when sampling took place in the evening, the nurse found it difficult in the available light to locate the veins.

The importance of having a qualified medical doctor involved in the system of operator exposure monitoring cannot be overemphasised. The need for independent, expert evaluation of the data is obviously important, as it removes any pressure on the campaign organisers to ignore medically important findings. Secondly, medical examinations, at the very least before operations commence is vital to detect persons suffering from any complaint which makes them particularly susceptible to intoxication. The third area is less tangible, but perhaps of even more importance. Spray operators work under difficult conditions - it is hot, hard and uncomfortable work. In order that they follow the correct safety procedures, they need to feel that there is someone taking an interest in their well being. The involvement of a doctor, who has responsibility for health monitoring, partly fulfils this role. A related factor is that if operators are aware that they are being monitored, both through AChE monitoring and medical examinations, and that the result of failing these tests is removal from the programme (and consequent loss of earnings) they are more likely to adopt safe pesticide use practices.

Data collection by the teams was reasonably satisfactory, although better data collection by some teams would have permitted a more thorough analysis. However, during routine operations, it appears that the data as presently collected (perhaps with slight modification) by control teams is sufficient for the purpose of routine monitoring.
4.2 Routine Monitoring During Locust Control Operations

Historical data (in this case from the 1994 locust control operation, Aston 1999) has been used as a model for examining the implications of various strategies for reducing operator exposure. The three strategies examined are: removal of spray operators after a set amount sprayed, a set time limit or based on AChE/PChE levels. For the reasons discussed in the report, the most appropriate strategy to utilise in desert locust control operations in Mauritania at the current time is one based on routine monitoring of AChE/PChE levels. On the assumption that this will be done, consideration needs to be given to the resource implications of this approach, both in the short and in the long term.

4.2.1 Medical Supervision

In Mauritania, qualified medical practitioners are required to work in the public sector for at least part of the time, and permitted to undertake private practice for the remainder. The way this is often done is that the doctor will work for the government in the mornings, and in a private clinic in the afternoons. The Ministry of Health is responsible for assigning doctors to public duties, and the opportunity may exist for the CLAA to request the assignment of a doctor to the Centre as the public element of his work. If this is agreed, then the medical supervision of spray personnel would become the primary public duty of this doctor. This permanent posting to the CLAA will allow the doctor to develop particular expertise in the health effects of pesticide use. He would be able to develop an appropriate training system to sensitize operators to the dangers of pesticides use.

In a similar way, the CLAA can request the assignment of a qualified laboratory technician to the centre. This person would be able to undertake the sampling for AChE monitoring as a routine procedure. It is also possible that this medical monitoring team could work with the plant protection department during periods of low workload for the Centre. Thus the systems developed by the CLAA and the project could have a wider impact on the health of spray operators in Mauritania. In both cases, the salary of the person would be paid for by the Ministry of Health; the CLAA would only be required to cover per diems for the time spent in field operations.

Although this is a longer term route to sustainability of operator monitoring in Mauritania (and in other desert locust affected countries where similar systems exist), in the short term this is not an option. Further work on this topic will need to be carried out within the auspices of the current project.

4.2.2 Management and Funding

It has to be recognised that the implementation of a health monitoring policy in locust control in Mauritania will incur costs. As discussed in Section 2 of this report, had health monitoring been undertaken in 1994, the costs of monitoring alone (excluding the costs incurred if operators were replaced) would have been about US$14000. By far the majority
of this is in vehicle use; the costs of each test (US$3, 1999 prices) is not large, but the reagents have to be bought in advance from overseas. There is also an expiry limit on the reagents, and therefore constant restocking is required. These funds have to be in place at the right time to allow for the 4 - 8 week lag in delivery.

The management implications of routine monitoring operations need to be considered. This has two clear aspects. Firstly, the organisation, funding and deployment of the monitoring team. Secondly, the requirement for additional staff in order to replace exposed workers.

The deployment of a monitoring team in the short term is not a significant hurdle, given that the next phase of operator monitoring under field conditions is a defined project activity. In the longer term, this requirement can be budgeted for and funding sought (either locally or internationally). However, the problem occurs should operators be found who exhibit low levels of acetylcholinesterase following exposure to pesticides. The number, frequency and roles of these operators will only be revealed during a control operation, and at this stage, without experience of operations in Mauritania, it is impossible to predict. This makes forward planning difficult, and may make acting on the results obtained during the next operation (until experience has been gained) impossible.

4.2.3 Staff Recruitment

Even though this study was primarily a research exercise, it proved impossible, owing to time constraints at the beginning of the operation, to collect baseline data as thoroughly as would have been ideal. This will be compounded in a control operation, where staff are recruited and dispatched to field operations very quickly.

One way to reduce this problem is to ensure that samples can be taken by a number of different people (not solely the monitoring team). Thus trained staff and equipment will be required at the CLAA (or other operational centre) on order to collect baseline AChE levels. Medical examinations can be carried out either by the physician attached to the programme (if he is present at the time), or by other qualified medical doctors who have been previously identified by the CLAA as willing to carry this out.
4.2.4 Further Work

Although routine monitoring of spray operators should be a requirement for all operations, there is little point in the project continuing to monitor non locust control operations. As discussed in this report, the questions that arise related to operator monitoring in locust control are those of logistics and management, and the actual exposure faced in locust control operations. These questions can only be addressed in a locust control operation.

The nature of AChE monitoring means that its use as a research tool is limited; better techniques exist for measuring operator contamination and for developing methods of reducing contamination. Bearing these points in mind, the following further work is required:

1. Implementation of monitoring during locust control operations. This will be undertaken as soon as operations commence.

2. An investigation of the sources and magnitude of operator contamination during the pesticide handling process. This will be done using simulated pesticides containing marker dyes.

3. The further development of the database as a management tool, and the linkage of this to other operational databases maintained by the locust centre.
5 References


Appendix 1

Acetyl Cholinesterase Measurement

The principle behind the measurement of AChE is relatively straightforward. Organophosphate insecticides exert their effect through the nervous system of the target organism. In an unaffected organism, nerve impulses are transmitted across the nerve synapses instantaneously by the release, in large quantities, of the enzyme acetyl choline. As soon as the impulse has been transmitted, this enzyme must be degraded rapidly, or else the synapse will keep “firing”. The enzyme acetylcholinesterase (AChE) is responsible for inactivating the acetylcholine. The organophosphate insecticides work by binding preferentially to acetyl cholinesterase thus preventing it from reacting with acetyl choline. As a result of contact with organophosphate insecticides, the levels of AChE are diminished. It is this reduction in AChE levels which are used as a basis for measuring the degree of poisoning of an operator.

In humans, there are two types of acetylcholinesterease. The first of these is found in the erythrocytes, and is thus designated erythrocyte acetyl cholinesterase. This form (referred to in this study as AChE) is relatively long lived, and regenerates slowly. The second type of acetyl cholinesterase originates in the liver, and has a preference for butylcholine, rather than the acetylcholine of the erythrocyte AChE. It is designated plasma acetyl cholinesterase (PChE), and is much shorter lived than AChE, and reacts more rapidly to pesticide intoxication – it is thus a better measure of acute toxicity. However, because it recovers more quickly, it is less reliable as an indicator of chronic exposure. It also has lower specificity than AChE, and diseases of the liver, and other causes – eg malnutrition - can affect the levels of PChE.

The normal recommendation is that AChE is the preferred measure for the routine monitoring of spray operators.

In order to measure the levels of AChE or PChE, The EQM Testmate Kit uses a colourimetric reaction. Essentially, the blood to be tested is mixed with a substrate. The mixture will change colour depending on the amount of AChE present. The colour can then be measured, and this can be converted to give the quantity of AChE present. In order to measure PChE, a different substrate is used, although the principle is the same.

For further details on the technique, see the Testmate Op operating manual.
Appendix 2

Project GCP/INT/651/NOR

Activity D4.1.1

Measurement of AChE of Spray Operators

Medical Team

The medical team will be composed of one qualified medical doctor and one nurse.

Terms of Reference

Under the overall supervision of the study director and the Director of the CLAA, and following the study plan, the medical team will, bearing in mind the need for patient confidentiality and medical ethics:

1. Take blood samples of designated spray operators, and other staff as required, according to standard medical practice, before the commencement of spraying, and at regular intervals thereafter until spraying operations have ceased or the study is terminated.

2. Analyse blood samples for AChE (blood and plasma) levels as per the methodology contained in the TEST-MATE OP Kit handbook, and in accordance with the Background Document «Aide mémoire pour les médecins et les infirmiers impliqués dans le suivi des manipulateurs des pesticides inhibiteurs de cholinestérase.», and keep records of all the test results.

3. Undertake medical examinations before, during and after spraying.

4. Report, in confidence to the Director CLAA, and to those nominated by him, on medical findings of staff involved in the programme which may be of medical cause for concern at any time during the programme.

5. Prepare an interim report (20 days after the initial readings), and a final report within 10 working days of the final sample, indicating detailed results of AChE readings and medical examinations, and other medical findings of significance to the study.

6. In the final report comment on the practical implications of the routine use of AChE measurement from a medical viewpoint, particularly related to the level of training required for routine staff use, and the degree of qualified medical support required;
Appendix 3

Field and Laboratory Forms
Appendix 4

Data on Change in AChE and PChE for Ground Teams

<table>
<thead>
<tr>
<th>Team</th>
<th>Role</th>
<th>Change in AChE – Reading 1</th>
<th>Change in PChE – Reading 1</th>
<th>Change in AChE – Reading 2</th>
<th>Change in PChE – Reading 2</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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Appendix 5

Final Medical Report