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Pesticide Residue Analysis Facilities: Experiences from the Natural Resource Institute's Support Program

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Abstract

Pesticide residue analysis is used to support a wide variety of activities including crop protection research, environmental monitoring, consumer protection and legislative enforcement. It is undertaken by research institutes, academic institutions, private laboratories and governmental organizations. In the developed world, pesticide residue laboratories are readily accessible and, on balance, have relatively few problems apart from escalating costs. However, what can be a relatively minor problem to these laboratories may take on a totally different significance to a laboratory in the developing world. National authorities face major problems in introducing routine monitoring facilities. In our search for analytical excellence and improved data quality, are we continually widening the gap, to the point where developing country laboratories cannot compete?

Introduction

Residue analysis is a complex subject, with a large number of potential analytes and a wide range of substrates including food commodities, environmental samples or even post-mortem samples. The analytical requirements are stringent, making well-equipped laboratories with sophisticated (expensive) analytical systems and well-trained staff a necessity. For many laboratories in the more advanced nations of the world, these requirements can be a challenge; for those in the developing world, the difficulties are considerably magnified.

Many will be aware of residue laboratories that have failed in some way or other, either declining in quality or quantity of output, or being forced to close altogether. Those that survive tend to find themselves under considerable strain. The reasons are surprisingly common across establishments.

The Natural Resources Institute (NRI), formerly owned by the UK Department for International Development, but since privatization a research institute within the University of Greenwich, has extensive experience of working with pesticide laboratories, particularly in developing countries. The staff of many of these laboratories have attended training programs in residue analysis either at the Institute (in Chatham, Kent) or conducted by NRI overseas. This has enabled the development of a detailed appreciation of the problems faced by these laboratories. The "Guide to Laboratory Establishment in Developing Countries" published by NRI in 1990, was based upon our observations of the problems, and was an attempt to highlight to senior managers of potential laboratories the difficulties that they should expect. Since publication of that guide, which now needs significant updating, and other related publications (COX, 1994; AKERBLOM and COX, 1996), it is fair to say that the nature of the problems has not changed, and that they are affecting significantly the ability of many organizations, and indeed countries, to undertake serious residue analysis studies.

Common Problems

The major factors that can influence the way in which a laboratory functions can be considered as either infrastructural or technical. These factors affect the way that the laboratory is financed, managed and staffed, the nature of the accommodation and general services, and the way in which it operates. These are areas over which management has direct control. There are, however, other factors which may have an impact on the laboratory relating to International trends with regard to analytical methodology and increasingly stringent requirements for data quality.

Infrastructural Factors

In infrastructural terms, the following elements need to be considered: laboratory financial resources, business stream, management, quality of laboratory staff, accommodation, laboratory facilities and availability of consumable materials.

Laboratory Finances
The cost of laboratory activities and the financial resources available to the laboratory are key considerations. What is the cost of the activity and what will be the income? The harsh reality is that if income does not cover costs, the operation will not succeed.

Funding can be solely from a government department sponsoring the operation, or a fully commercial operation established with private funds and recovering its costs by selling its services. On occasion it may be a combination of the two – a mixture of core funding from the parent body, generally a government department, with a proportion of running costs met by income from contract services.

Even in the most advanced countries, there are few laboratories which continue to be fully funded by government. The experience of the last ten years shows steady increases in the proportion of revenue that laboratories are required to generate. Few governments are now prepared to fully support what is, after all, a particularly expensive form of analysis. In developing countries, the situation is particularly extreme. Those countries with flourishing residue laboratories are generally those with a strong horticultural export sector, wherein such laboratories are required to underpin the industry. Laboratories in countries such as Chile, Egypt, India, Morocco, South Africa and Thailand immediately spring to mind.

In the developing world, there are also a number of laboratories that have been established with funds from donor organizations. These are generally established as part of a broader agricultural program, with a limited commitment to further support for running costs. The period of initial support depends upon the funding agency, after which the running costs revert to the host country. Generally this has not been a happy or successful transition, with governmental funding limitations restricting the maintenance and capacity of the laboratory.

Business Stream
The business stream is the revenue that can be earned by the laboratory by selling services. Business development necessitates good marketing, reaction to external competition, and

the development of good relationships with clients. If clients are not satisfied with the service offered, they will go elsewhere for the same services, even possibly to another country (common in the horticultural trade sector). Client needs must be met in a flexible but professional manner. Clients, and their own clients further down the chain, must have confidence in the results provided by the laboratory, and those results must consistently be delivered within an agreed time-scale. In many developing country laboratories, this is not possible because of short working days (power disruption for various reasons including imposition by local management) and/or lack of staff motivation (inadequate management or poor remuneration). Cultural problems may also need to be addressed.

Management
If a pesticide residue laboratory is to be established, management at all levels must be aware of, and fully committed to, developing and maintaining an expensive unit. Managers must be familiar with the requirements of the laboratory and the potential problems. They must assess the likely demands on the laboratory, the nature of the analyses to be conducted, the likely return on investment and whether the laboratory will be able to be self-supporting. These issues are crucial.

Quality of Laboratory Staff
Operating a pesticide residue to international standards requires a cadre of well trained, well motivated staff. The proper training and supervision of staff is vital. Each staff member must be fully familiar with any operation that he/she is expected to perform. In some laboratories, lack of adequate training or supervision is a problem, but generally staff quality is not an issue.

However, particularly in the developing world, staff remuneration and motivation and staff retention are major problems, restricting the ability of residue laboratories to offer the type of service that would attract the interest of commercial suppliers. The latter, generally in the horticultural sector, are looking for rapid turn-around analysis because they need to move their produce without significant or damaging delay.

Managers at all levels of the laboratory operation must be capable of motivating their staff, paying attention to their morale and working conditions and providing suitable remuneration to ensure retention of trained staff. These people are valuable assets and are often the target of recruitment by outside organizations or other departments within the same organization. Without restricting the opportunities for individual advancement, it is important to retain the best staff for the laboratory, and this requires a structure allowing for reward and motivation.

Accommodation
Laboratory accommodation needs to meet a minimum specification, allowing for separation of activities with adequate space for sample storage, the storage of reference standard solutions, sample extraction, clean-up and analysis. Separate storage space for consumable materials and for laboratory records is also required.

The amount of space required depends upon the range of activities, sample numbers, etc. It must be adequate to permit staff to work safely and efficiently, without risk of interfering with one another's activities. The space available must be fit for the purpose. It is nice to work in brand-new, ultra spacious laboratory suites, but the cost implication (establishment and longer-term maintenance) must be born in mind. Can such facilities be afforded, or will something a little less extravagant be equally sufficient, with the savings made on construction costs and routine maintenance better spent on other activities?

Laboratory Facilities
For safe and effective laboratory operation, there must be access to adequate key services such as fume extraction facilities, electricity and water. For each service, there should be adequate outlets to allow full laboratory operation. Power supplies should be continuous, with appropriate equipment protected against power surges. It is still too common to see analytical equipment, including gas liquid chromatographs with selective or non-specific detectors switched off in the evening because of power limitations or to save gas. By the time that they are switched on the next day and have stabilized, half of the working day may have been wasted, reducing the time for effective use of the equipment with multi-point calibration and/or duplicate injection of test solutions. The use of generators to maintain a constant power supply would be an advantage, but fuel limitations curtail their use in many situations.

The temperature and flow rate of water supplies can also pose problems. Often the water is pumped to roof-space header tanks, with a gravity feed to the laboratories. This can cause reduced flow rates, affecting solvent condensation when used with a distillation system. More importantly, the water can heat up, again affecting solvent distillation and posing the risk of fire if flammable solvents are involved.

Installed piped vacuum and clean compressed air/nitrogen are helpful, although they can be provided by alternative means.

Availability of Consumable Materials
The term consumable materials is rather all-embracing, covering all materials used and replaced on a regular basis. This can include items of glassware, but when consumables are mentioned, most people tend to think in terms of gases (where supplied by cylinder), chemical reagents and solvents. For those of us in developed country laboratories, most of these materials are available within a few days of order, of an adequate purity and competitively priced. Delays in supply are infrequent, even for imported materials, because suppliers tend to hold reasonably large stocks.

In the developing world things are not so good. Although the situation is better than it used to be, with a few professional supply agencies having been established, most consumables of adequate quality still need to be imported. The delays in arranging freight transport from the country of origin, importation and customs clearance takes a minimum of several weeks, with a one to two month delay generally to be expected. Under these conditions, laboratories can only survive through the retention of reserve stocks, good planning or a combination of the two. For laboratories providing an analytical service facility, the reserve must be adequate to cover likely sample throughput including short-notice requests by clients during the reordering and delivery period. Any situation that requires the client to wait for results can mean a loss of business from that source, which few laboratories can afford. On the other hand, many laboratories can only carry a small reserve stock of consumables because of the sums of money involved.

Technical Factors

Technical matters relate to the operational procedures employed by the laboratory and problems associated with equipment supply and maintenance.

Choice of Analytical Procedures
The selection of analytical procedure is governed by a number of factors. The primary consideration should be the nature of the analysis: is it for a single pesticide where a simple procedure may be adequate, or for a situation where the contaminants are unknown and where a full multi-residue screen is required? The latter situation is increasingly becoming

the norm, apart from specific trials with known analytes. Specific procedures (e.g. for dithiocarbamate fungicides or paraquat) will still, additionally, be required.

The analytical procedures used by laboratories world-wide vary substantially, although in Europe and the United States, there is a growing focus on a more limited number of multi-residue procedures. In the developing world, the cost and availability of consumable materials (particularly laboratory reagents) may be prime considerations in the choice of procedure. Laboratories are either discouraged from using analytical procedures requiring large quantities of reagents, or seek to modify them to reduce the quantities of reagents. The local modification of procedures or development of procedures for specific analytes is not a problem in itself where adequate procedural validation is conducted. However, in some laboratories, reagent limitations may mean that procedural validation is not as rigorous as it should be, and this is not acceptable.

Modern procedures are also developed using increasingly sophisticated techniques such as Gas Chromatography-Mass Spectrometry (GC-MS/MS) and Liquid Chromatography-Mass Spectrometry (LC-MS). Where it is difficult to maintain gas liquid chromatographs in effective working condition, what hope is there for the introduction of these more demanding techniques? This is, nevertheless the direction into which laboratories are being drawn, particularly for regulatory purposes. It is clear that many laboratories will never be able to achieve these requirements, with the result that their data will never be acceptable.

The practicality of analysis at the lower limits of determination, required to check for compliance with those national and international pesticide maximum residue limits (MRLs) that are set at the limit of analytical determination, is another problem which must be considered. There is debate as to whether it is routinely possible to analyze to these levels. Many developed country laboratories struggle to achieve these requirements, and it is to be expected that in some laboratories it may not be possible to routinely achieve these levels because of day-to-day variations in the analytical sensitivity of gas chromatographic systems, particularly where power disruption affects the stability.

Equipment and Maintenance

The procurement, installation and maintenance of key items of analytical equipment is a huge consideration for any laboratory. Design, technical performance, compatibility with other equipment and ease of servicing and maintenance are the main issues.

For many laboratories, service and maintenance do not cause significant problems, because service engineers with access to good stocks of spare parts are reasonably close to hand. However, for those laboratories further away from service centers, these problems can be substantial, particularly for those in the developing world where there may not be a trained engineer in the country and he/she has to fly in from elsewhere. This naturally causes delays. But more significantly, there are major cost implications: one is not only paying for the servicing or remedial work but also for the time spent travelling, the cost of that travel and hotel accommodation. In the event that the engineer requires a spare part not available locally, there will be additional delays and expenses.

Unfortunately, these considerations are not always taken into account or given the weight of consideration that they should, because procurement decisions are taken by senior managers or administrators without full consultation with laboratory staff or assessment of the servicing/repair arrangements. Additionally, some donor organizations tend to offer well-meaning gifts of items of equipment without fully considering the issues of service and maintenance and the impact of these gifts on routine service and maintenance funds. This can mean that funds may be diverted to support the maintenance of new, sophisticated equipment at the expense of other, more “routine” items.

Accreditation
The increasing international demand that residue data come from accredited laboratories has had a major effect on many laboratories. The introduction of accreditation was an initiative to generate greater confidence in the data generated by laboratories, to ensure broader acceptance of that data. Although a general requirement for data produced for regulatory purposes, many other organizations (e.g. major importers and retailers) submitting samples for routine analysis have also chosen solely to use accredited laboratories. In the developed world, this is not a problem. A choice of high-quality, accredited analytical facilities is available. In the developing world, the options are much more limited, with relatively few accredited pesticide residue laboratories. Exporters dealing with the European market will frequently send their samples to European laboratories instead of local, unaccredited laboratories. Similarly, the lack of accreditation limits the use of such laboratories in data development for European pesticide registration purposes.

Although accreditation appears to have met its objectives, the trend has been such that data from non-accredited laboratories has been viewed as rather “second-class.” Given a choice between an accredited and a non-accredited laboratory, many clients routinely will opt for the former. Generally there is a cost difference, with the accredited laboratory charging a higher price for a given analysis compared with the non-accredited laboratory. However, clients will generally be prepared to pay the higher price.

This puts an extreme pressure on non-accredited laboratories, which may be very diligent and produce data of comparable quality to that of accredited laboratories, but whose circumstances are such that they have not been able to submit for accreditation. Although this affects laboratories in the developed world, the impact is far more significant on developing country labs. It restricts their attractiveness to bigger clients and precludes the use of their data, for instance for European Union MRL development.

The Way Forward

The success and sustainability of laboratories in the developed world, politics apart, depends primarily upon their financial basis and their status. The problems that they face are well understood, although the solutions may not always be attainable for individual laboratories. In the developing world, however, many of the solutions require external understanding and support which is presently lacking. Issues such as management, staff motivation and remuneration are internal issues which can be resolved if given the appropriate care and attention. The other key issues are largely financial or relating to status or recognition. For these, there is a major role for developed country partners.

The experience of donor organizations has shown that many laboratories established with aid funds have deteriorated since the full transfer of ownership (and costs) to the host country government. Clearly, the process has not been as successful as we would have liked. Should we now say, “well we have tried and it does not work?” Or should we use that experience and learn from it? Why didn’t it work, what could have been done better? This latter approach would be more productive. A major problem, however, is that donor policies and funding themes are constantly changing emphasis. Although food safety is always recognized as a key developmental issue, there seems less funding nowadays for laboratory establishment, re-equipment or technical support.

Many potential clients argue strongly that they would rather deal with a privately-owned laboratory than one in the public sector: there is less bureaucracy, a greater awareness of the commercial issues, and generally a more responsive service. Some governments also recognize this and have moved their laboratories into separate, more streamlined agencies, still under governmental control but with less emphasis on strict civil service procedures. The future path may be for donor agencies to work much more closely with the private sector, and particularly with laboratories managed by or supporting produce marketing organizations. The UK's Department for International Development is using such principles in support of its Rural Livelihood Program.

The concept of aid or other public funds going to a private, profit-making organization could raise objections, but with a properly structured agreement, such activities should be acceptable, particularly where they support agricultural production, a major employer in the developing world. Initial intervention whilst the laboratory establishes itself or support to an area like laboratory accreditation projects or the short-term provision of technical expertise could have a marked effect on laboratory viability. This could contribute to the development of a national or regional network of high-quality pesticide residue laboratories across the developing world. Such a network would underpin major food safety and horticultural export programs, allowing increased regional development and retention of important foreign exchange earnings.

The development of an internationally-recognized system for evaluating non-accredited laboratories and listing national and regional laboratories operating according to recognized performance standards would also be a major step forward. This would ensure a minimum laboratory standard and encourage the use of such laboratories by a wider client base. It would also provide a professional boost to the staff and management of those laboratories. Such a program should be linked to a commitment that the evaluated and "listed" laboratories actively work towards full accredited status within a reasonable period of time. Progress should be monitored, and those not fulfilling that commitment without good reason should be removed from the list.

For this to be successful, substantial international good-will and understanding will be needed. The appointment of regional evaluators would help to reduce travel requirements and facilitate continuous dialogue with the laboratories within that region. There would be a cost implication for the initial laboratory inspection and subsequent follow-up visits, but on balance this would be a small price to pay if it helped encourage laboratory development and sustainability. If funded internationally by a consortium of donors, the cost to each would be small, yet the benefits on a national or regional basis could be substantial.

Conclusions

The access to competent pesticide residue laboratories is essential, given that routine analysis underpins food safety programs and helps retain consumer confidence in the food that we eat. For consumers in the developed world, we take such access for granted; laboratories exist and government, wholesalers and retailers regularly check both locally-produced and imported foodstuffs. A professional analytical service exists, but at a cost. Unfortunately, in the developing world the situation is not so clear. Some of the more advanced countries have developed high-quality analytical laboratories underpinning national food safety initiatives or thriving horticultural export programs. In other places, residue laboratories either do not exist or are limited by resource constraints or essential services such as electricity. Some of the problems they face need to be addressed at the national level. Others require external support and intervention, and if we are to be serious about food safety then developed country agencies must, in a coordinated, structured manner, look to see what needs to be done and what can be done. It is to be hoped that this paper will help to draw attention to some of the issues.

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