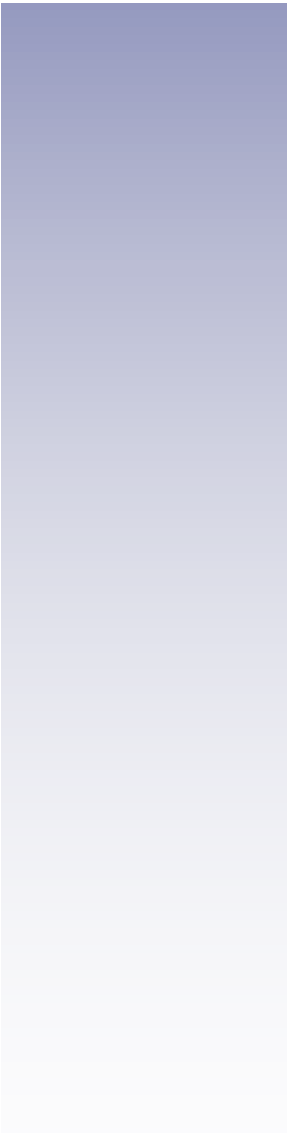




**ROYAL ROADS
UNIVERSITY**



**MAKING ADVANCES IN CHINA ON
REDUCTIONS IN THE USE OF THE
PERSISTENT ORGANIC POLLUTANTS
CHLORDANE AND MIREX FOR TERMITE
CONTROL:
A PILOT STUDY**

**PRELIMINARY REPORT ON THE
DEVELOPMENT OF A TOOLBOX FOR
INTEGRATED PEST MANAGEMENT (IPM)
STRATEGY**

**Report to FECO/SEPA by
Royal Roads University, Victoria, British Columbia, Canada**

**Royal Roads University
2005 Sooke Road
Victoria, British Columbia, Canada
V9B 5Y2**

October 2004

Report Contributors

Dr. Bill Dushenko Professor RRU

Tel. 250-391-2580; e-mail bill.dushenko@royalroads.ca

Dr. Matt Dodd, Research Professor RRU

Tel. 250-391-2583; e-mail matt.dodd@royalroads.ca

Dr. Steve Grundy

Associate Vice-President, Academic and Information Services, RRU

Tel. 250-391-2579; e-mail steve.grundy@royalroads.ca

TABLE OF CONTENTS

1	INTRODUCTION.....	1
1.1	BACKGROUND AND OBJECTIVES	1
1.2	INTEGRATED PEST MANAGEMENT (IPM).....	1
2	ELEMENTS OF AN IPM STRATEGY	3
2.1	STEPS IN IPM IMPLEMENTATION	3
2.2	GENERAL PRELIMINARY FRAMEWORK FOR IPM STRATEGY DEVELOPMENT.....	3
3	IPM TOOLBOX	6
3.1	ELEMENTS OF THE IPM TOOLBOX	6
3.2	IPM TOOLBOX DEVELOPMENT	7
3.3	INTEGRATION OF IPM TOOLBOX ELEMENTS IN THE GENERAL FRAMEWORK.....	7
3.3.1	<i>Policy Tool Integration.....</i>	<i>9</i>
3.3.2	<i>Monitoring Tool Integration.....</i>	<i>9</i>
3.3.3	<i>Prevention Tool Integration</i>	<i>10</i>
3.3.4	<i>Control Tool Integration.....</i>	<i>10</i>
3.3.5	<i>Utilization of Toolbox Alternatives in IPM Strategy Decision Making</i>	<i>11</i>
4	INVENTORY OF IPM TOOLBOX ELEMENTS IN CHINA.....	12
4.1	POLICY TOOL INVENTORY	12
4.2	MONITORING TOOL INVENTORY	15
4.2.1	<i>Bait Monitoring.....</i>	<i>16</i>
4.3	PREVENTION TOOL INVENTORY	16
4.3.1	<i>Building Design</i>	<i>17</i>
4.3.2	<i>Site Management.....</i>	<i>17</i>
4.3.3	<i>Chemical Barriers.....</i>	<i>18</i>
4.3.4	<i>Physical Barriers</i>	<i>21</i>
4.3.5	<i>IPM Example for Prevention - Green City Residential Development Demo Project</i>	<i>22</i>
4.4	CONTROL TOOL INVENTORY.....	23
4.4.1	<i>Chemical Control.....</i>	<i>24</i>
4.4.2	<i>Bait Control</i>	<i>26</i>
4.4.3	<i>Physical Control</i>	<i>26</i>
4.4.4	<i>Biological Control</i>	<i>27</i>
5	CONCLUSIONS AND RECOMMENDATIONS.....	29
6	REFERENCES.....	30

1 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

The overall objectives of the Sino-Canadian project are to assist China in identifying technically and environmentally sound alternatives to chlordane and mirex use. These two organochlorine pesticides are two of 12 persistent organic pollutants (POPs) currently designated as priority pollutants under the [Stockholm Convention on Persistent Organic Pollutants](#)¹. The Convention, which came into force on May 17, 2004, is intended to phase out and eventually eliminate the so-called 'dirty dozen' POPs including six that have been used to control termites in the past (aldrin, chlordane, dieldrin, endrin, heptachlor, and mirex). Of the 150 signatory nations, a number of countries, including China, requested specific exemptions during the negotiations of the convention, to continue with the use of chlordane, heptachlor and mirex for termite control with the intention of finding alternatives in the next few years. As one of the signatory nations, China has been directed to develop a National Implementation Plan (NIP)² coordinated by the State Environmental Protection Administration (SEPA) through its Central Implementation Office (CIO). The phase-out of chlordane and mirex, along with PCBs, by China is anticipated to be completed by 2014.

The primary goal of this project is to assist China in developing an Integrated Pest Management (IPM) Strategy for termite prevention and control that will assist the country in phasing out chlordane, mirex and potentially other harmful POPs. This strategy is being developed in conjunction with a Demonstration Project for termite prevention and control, in a selected demonstration province (using pilot sites), that will be used as a model for scaling up IPM activities to other areas in China. This overall FECO/SEPA project is a pilot project of limited geographic, monetary, and temporal scale, wherein lessons learned can be captured toward future projects that achieve virtual elimination of chlordane and mirex. The purpose of this report is to document the development of an IPM toolbox specific to the demo area that can be used within a general framework to assist in formulating an IPM strategy. It is expected that the project outputs will be of further value not just for the elimination of chlordane or mirex production and use in China, but also for encouraging elimination of all Annex A POPs in various regions throughout the world.

1.2 INTEGRATED PEST MANAGEMENT (IPM)

IPM may be best defined as a philosophy whereby pest and environmental information (assessing the pest situation and evaluating the merits of pest management options) is used in conjunction with complementary management options to mitigate pest damage while protecting human and environmental health, and economic viability. An IPM strategy should have the following characteristics:

¹ http://www.pops.int/documents/convtext/convtext_en.pdf

² Under Article 9 of the Convention.

- Be dynamic and adaptable to diverse management approaches - the more flexible the IPM program, the greater the chances of finding an effective solution that will provide long lasting benefits);
- It must prevent unacceptable levels of pest damage by the most economical means;
- Decisions are predicated on the three important considerations of economics, environment, and human health;
- Decisions can be made by the individual producer, business entity or government agency but are influenced by the diversity of public and private values;
- Pesticides (posing the least possible hazard) are used only after careful monitoring indicates they are needed according to pre-established guidelines and treatment thresholds.

(Minnesota Department of Agriculture³, EPA Pesticide Glossary⁴, California Health Schools Act, 2000⁵)

The roots of Integrated Pest Management (IPM) can be traced to the late nineteenth century when "ecology" was identified as the foundation of scientific plant protection (Radcliffe's IPM World Textbook, 2003). Farmers used the concept long before scientists came up with the term IPM, by employing sound practices based on an understanding of the ecology of plants, animals and pests, and minimizing the use of chemicals. These practices included enhancing natural enemies, planting pest resistant crops, adapting cultural management and using chemicals judiciously as a last resort. IPM is the preferred strategy for pest management under Agenda 21 of the United Nations Conference on Environment and Development.

Integrated pest management, which combines biological control, host plant resistance and appropriate farming practices and minimizes the use of pesticides, is the best option for the future, as it guarantees yields, reduces costs, is environmentally friendly and contributes to the sustainability of agriculture (UN DESA, 2003).

IPM in China goes beyond simply replacing one chemical alternative for another. The ultimate goal of an IPM strategy is the reduction of the use of chlordane and other pesticides using a variety of practical alternative methods in an integrated manner, in support of the NIP for the phase-out of POPs.

³ <http://www.mda.state.mn.us/ipm/Definition.htm>

⁴ <http://environment.about.com/cs/pesticides/g/IPM.htm?terms=integration+issues>

⁵ www.schoolipm.info/overview/definition_ipm.cfm

2 ELEMENTS OF AN IPM STRATEGY

2.1 STEPS IN IPM IMPLEMENTATION

In applying IPM to termite control, the focus is placed on the ecology of the termite as the basis for the prevention of problems, more so than the use of toxic chemicals. As mentioned earlier, the IPM approach involves a philosophy rather than a specific control measure (Su and Scheffrain, 1998) and relies on a series of steps. These include:

1. Identify the pest problem and gather information on the biology of the organism, the behaviour, enemies, and its life history.
2. Monitor, scout and model populations, which will allow for the timing of treatment as well as its necessity.
3. Establish the tolerable injury level, including economic injury thresholds, tolerance thresholds and action levels.
4. Develop prevention and treatment strategies, which may include a combination of biological, physical, mechanical or limited chemical control methods.
5. Evaluate the integrated pest management program to determine the success and benefits and modify where necessary.

2.2 GENERAL PRELIMINARY FRAMEWORK FOR IPM STRATEGY DEVELOPMENT

The above steps and some of the characteristics of IPM mentioned above can be integrated into a general decision-making framework which allows for a systematic implementation and assessment of IPM for termite management (Figure 2.1). This is partially based on components advocated by the Minnesota Department of Agriculture⁶, which emphasizes that “*integrated pest management is an information based learning process...*”. The information gained during the implementation of different management options is then used to inform the overall program planning process and allow for refinements of the IPM strategy. The key elements of the framework include the following:

- *Planning* - using a “big-picture” (institutional) approach where objectives are clear, problems are anticipated and well-informed decisions can be made using current and historical information on a given site and pests. Institutional arrangements and effective policies are also important here. This allows for the full consideration of all management options; identifies areas where additional education, training or advice is needed; and allows for both short and long-term strategy development.
- *On-going Monitoring and Detection* – allowing for early detection and assessment of a situation for potential emerging problems, including site and environmental factors. This

⁶ <http://www.mda.state.mn.us/ipm/Definition.htm>

includes assessing pest populations and distribution patterns to map out problem areas and comprehend their extent to allow for the initiation of timely pest management decisions.

- *Proper Identification* – correct identification of the pest as part of monitoring to avoid wasted management efforts on ineffective control. This includes an understanding of the termite's biology and ecology to expose areas of vulnerability in the pest's life cycle that might be exploited as part of management actions.
- *Setting Action Thresholds* – determining when intervention will occur based on a balance of values (personal and social), priorities, economics (assessing pest damage vs. management costs), human health issues, and environmental impacts. A realistic trigger is key to avoid both unacceptable damage; and un-necessary management efforts that can waste time, energy, money, and result in human- and/or environmental health consequences. Management actions may also be triggered by both qualitative and quantitative information, including on-site monitoring, site history, climate, and computer models.
- *Action/Implementation of Alternatives* – involves complex decision-making and is contingent on the nature of the pest problem, knowledge of the site, and available management options for the situation. The range of available options for termite management and their use in various countries have been discussed in an earlier report⁷. As all options have both good and bad aspects, management decisions attempt to minimize adverse risks (particularly human- and environment health risks) and maximize benefits. Using a favourable combination of cost-effective management options is key in implementing any IPM strategy.
- *Evaluation of Results* – careful assessment of the outcomes in relation to the original goals of the program is important for providing opportunities for improvement and adaptive management of an IPM strategy. This includes determining whether the management options implemented were effective or if some modification or change is needed, as well as any unanticipated problems that will be met by modification of the IPM program. This includes surveys to assess significant changes in public and stakeholder awareness and practices, and termite infestation using spatial models and analysis. Documentation is key here. The information gained is fed into the planning component of the IPM strategy.

⁷ Royal Roads University, 2004. Preliminary Status Report No. 1: Use of Alternatives And IPM Practices. Report to FECO/SEPA. October 2004.

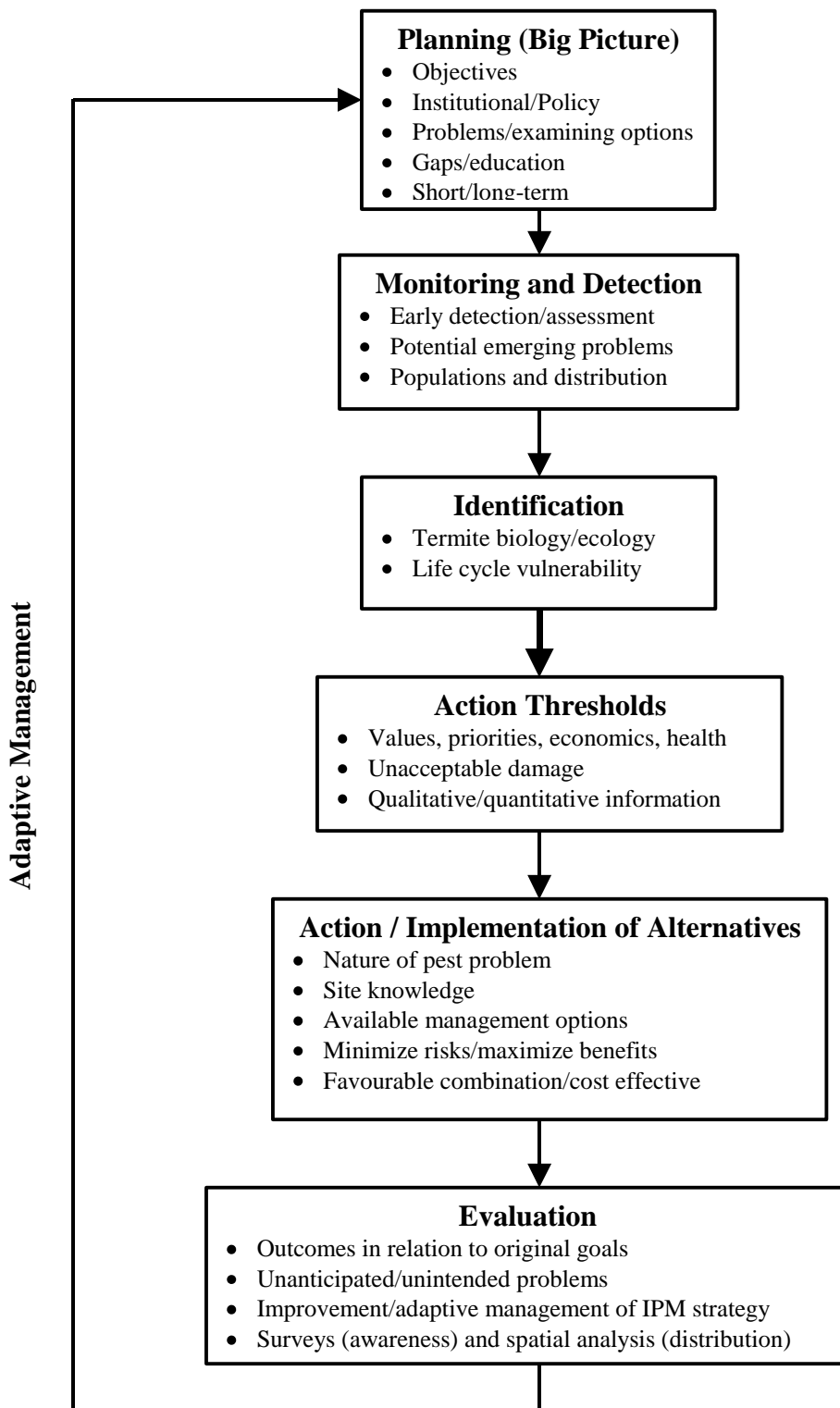


Figure 2.1 Preliminary IPM Framework for Decision-Making

3 IPM TOOLBOX

One of the central features of a given IPM strategy is the “IPM Toolbox”. This consists of a supporting conceptual framework that documents and provides the range of technologies and instruments⁸ for effective termite management and implementation of alternatives. Implicit in the conceptual framework is that a true IPM strategy goes beyond simply replacing one chemical alternative for another, but that a range of options and supporting components need to be considered. The toolbox is specific to the given (demo) area and used within a general framework, discussed above, to formulate an adaptive IPM strategy. The elements of the toolbox are discussed below.

3.1 ELEMENTS OF THE IPM TOOLBOX

Considerable discussion on the Sino-Canadian project with China termite authorities and the World Bank occurred in regard to the development of the IPM toolbox in June 2004⁹. Based on these deliberations, it was determined that the “toolbox” to be developed for termite management in the demo province(s) will need to consist of the following basic elements:

- *Policies* – including institutional arrangements among stakeholders (government, private and public) at different levels, and mandates that support and encourage the adoption of a range of alternatives (e.g., construction codes, chemical registration, pricing, warranty and training) (Schillhorn van Veen et al., 1997);
- *Monitoring* – systems in place to assess the nature and progress of termite infestation, direct the selection of management actions, and evaluate their efficacy (e.g., biology/ecology, bait boxes, computer based monitoring, inspection and visual monitoring, locating nests, education and training);
- *Prevention* – proactive alternative approaches that minimize or mitigate the risk of potential termite infestations (e.g., structural design, treatment of wood, physical barriers, chemical barriers, cultural control, and education and training); and
- *(Damage or Remedial) Control* –prescriptive alternative measures designed to mitigate existing termite infestations in structures [e.g., chemical treatment, biological control (research and development), physical measures (e.g., nest digging), and education and training].

All of these basic elements provide guidance at various points in the general decision-making framework for IPM strategy development as discussed further below.

⁸ Including policy, legislation, research, education and training

⁹ Royal Roads University, 2004. Mission Report for June Field Visit (10 –20 June 2004). Report to Foreign Economic Cooperation Office and State Environmental Protection Administration. June, 2004.

3.2 IPM TOOLBOX DEVELOPMENT

The toolbox is specific to the demo area and used within the general framework to formulate an IPM strategy. Specificity of elements in the toolbox to a given area is determined by a number of criteria including the following:

- *Existing public policy framework* – does a policy framework around legislation instruments (i.e., building/ construction codes, orders, standards for pest management), education/training, and institutional arrangements currently exist for the area that would support the adoption of a specific alternative or alternatives for termite management, or is this something that needs to be developed? If policies and education/training for the implementation of certain building codes, for example, does not exist, then this will affect the ability of this management alternative to be implemented effectively.
- *Environmental setting* – the setting (urban, rural, forest, agricultural, parkland/heritage) will also dictate the range of management alternatives available. Some management alternatives that are suitable for a low density rural setting, for example, may not be practical for a high-density urban environment.
- *Type of structure(s)* – the type of structure (residential, commercial, cultural, utility) will also determine the suitability of various alternatives for termite management. Management options for residential buildings, such as above-ground bait boxes, for example, might not be practical for utilities structures such as telecommunications poles where they might be exposed to damage or tampering.
- *Availability of management alternative(s) and efficacy* in the given setting – do the materials/resources required for the implementation of a management alternative exist, and has the effectiveness of the termite management technology been demonstrated and documented for the area? Where a potential technology is unproven in a given area, scientific and social research (ascertaining public awareness and perception by surveys) and documentation may be required to verify its efficacy.
- *Cost effectiveness* of management alternative(s) – is the management alternative cost-effective in terms of set-up, long-term human and environmental health risks, supporting infrastructure required, and existing management practices? Often the total cost of existing technologies such as pesticides (including health, environmental, and disposal costs) are not adequately taken into account when comparing these to (lower-risk cost) management alternatives, providing an inflated view of the existing technology's cost-effectiveness.

3.3 INTEGRATION OF IPM TOOLBOX ELEMENTS IN THE GENERAL FRAMEWORK

All of these basic elements in the toolbox provide guidance at various points in the general decision-making framework for IPM strategy development as discussed further below. The conceptual framework of the toolbox and its integration with the general framework for decision-making is provided in Figure 3.1.

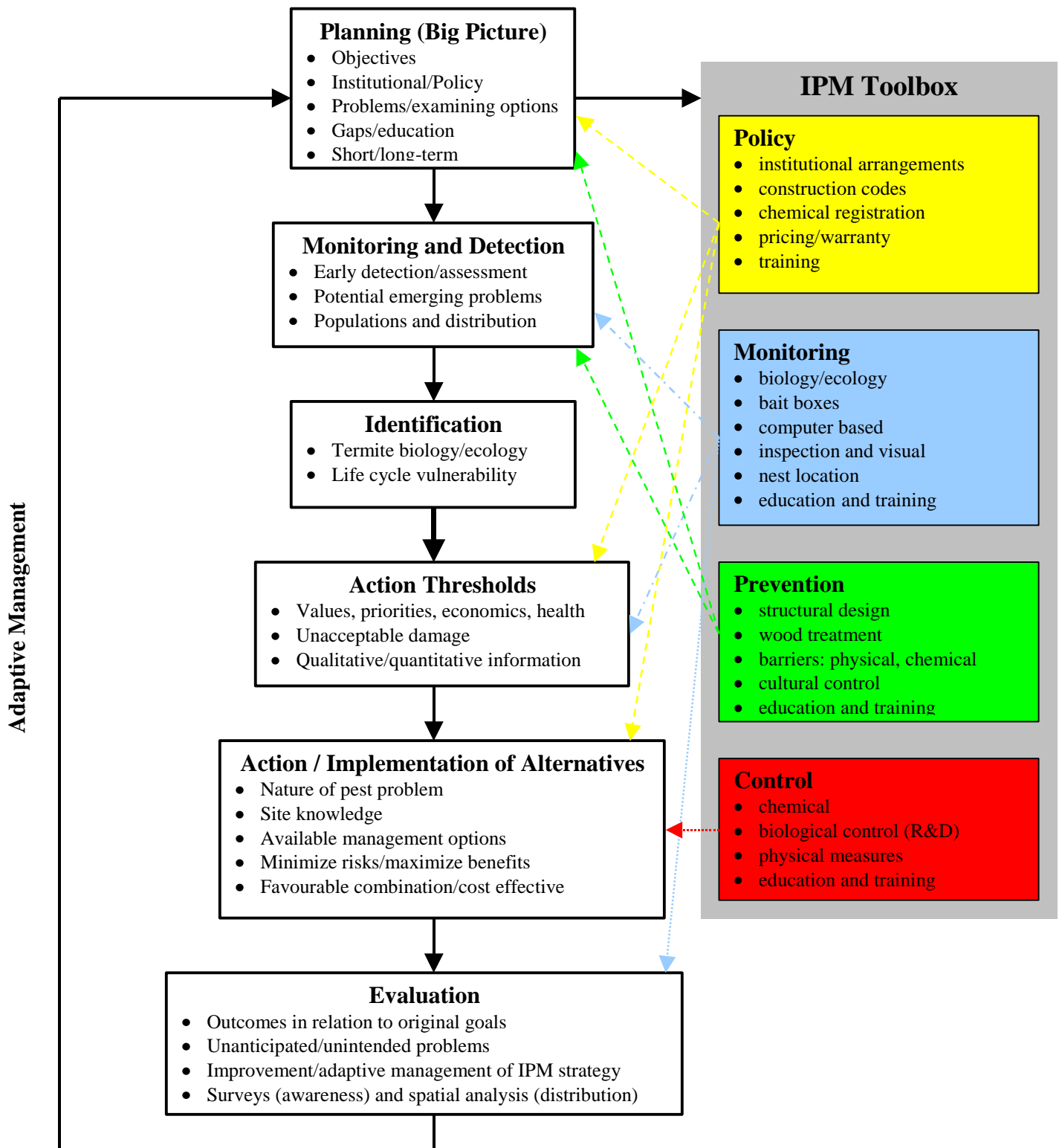


Figure 3.1 Integration of Toolbox in IPM Framework for Decision-Making

It should be noted that not only does the IPM toolbox provide guidance to the larger IPM framework for decision-making, but the information gained in the process of implementation, evaluation of results and adaptive management also informs and allows for improvements to the IPM toolbox which continues to evolve as part of the larger IPM strategy for the given area. Training and education are two important underlying enabling themes that occur throughout the toolbox and the general framework for decision-making

3.3.1 Policy Tool Integration

The policy tools of the IPM toolbox are key for providing guidance on the stakeholders required in the *planning process* through institutional arrangements (Figure 3.1). Objectives can be more widely determined, and clearly articulated and understood by all parties involved. Policy tools such as construction codes, chemical registration, pricing and warranty issues around alternatives also assist in allowing for the full range of management options to be considered in the planning process. This may be accompanied by economic and legal disincentives (e.g., “polluter pays” principle), and/or economic incentives (e.g., grants, tax-breaks, research and extension). Where gaps or uncertainty in information occur, expert advice can be sought or additional research can be planned. Appropriate policy infrastructure to support training and public education (awareness) is important for developing effective IPM strategies that allow the effective implementation of possible alternatives. These can be supported through new or existing research, extension and training programs ((Schillhorn van Veen et al., 1997).

Policy tools also play a role in providing guidance for the setting of *action thresholds* in the general framework (Figure 3.1). This can be done by establishing criteria to determine when implementation of a given (alternative) management is warranted based on prevailing values, economics, and human and environmental health impacts. Training and education is an important element for effectively using these policies to determine appropriate thresholds, as well as the underlying science, social science and economics that inform policy.

Management actions and the implementation of alternatives in the general framework are also guided by policy tools that can provide criteria for determining which alternatives might be used under appropriate circumstances (Figure 3.1). These criteria take into consideration the nature of the pest problem, site characteristics, required training and education, range of management options available, risks and benefits, and cost-effectiveness.

3.3.2 Monitoring Tool Integration

The monitoring tools of the IPM toolbox have a clear link in guiding the *monitoring and detection* component of the general framework (Figure 3.1). A variety of tools in the monitoring category are available; however, not all of these are applicable in all circumstances and are subject to a variety of criteria (see Section 3.2 above) that dictate whether they are appropriate candidates to be used in a toolbox for a given area. Employing the correct combination of monitoring tools at the appropriate time will inform on emerging infestation problems, pest population and

distribution patterns, and problem areas.

Monitoring tools also play a role in guiding the determination of *action thresholds* under the general framework (Figure 3.1). Monitoring tools can be employed to estimate the level of damage and pest population size for guiding triggers for timely management actions.

The evaluation component of the general framework is informed by monitoring tools that provide both qualitative and quantitative information to assist in determining whether the implemented management options have been effective in relation to the goals of the strategy (Figure 3.1). These tools also allow for both a qualitative and quantitative assessment of areas for improvement as part of adaptive management of the IPM strategy. Education and training elements of the monitoring tools also provide the opportunity for surveying public awareness of management alternatives and their implementation, and analysis of termite distributions.

3.3.3 Prevention Tool Integration

Prevention tools play a key role informing the *planning component* of the general framework (Figure 3.1). The main goal is to prevent termite infestations before they start. A range of management options focusing on reducing favourable environments (primarily food and habitat availability) for termites may be used to guide the planning process, depending on the characteristics of the area in question. Public education and training are particularly important for employing cultural controls, building codes and practices, and termite-resistant materials in building construction where possible.

Monitoring and detection in the general framework may be guided in part by prevention tools that assist in the monitoring and early detection of termite activity in the area (Figure 3.1). This may include, for example, barriers that force termites out into the open (e.g., antcaps) or detection of shelter tubes on physical barrier surfaces (e.g., foundation wall caps and metal shielding).

3.3.4 Control Tool Integration

Control tools guide the *management actions and the implementation of alternatives* component of the general framework in circumstances where structural infestation and damage is already occurring (Figure 3.1). A range of management alternatives for control are potentially available, dictated by the specificity criteria discussed in Section 3.2. Chemical controls are the most commonly used; however, others including biological control agents, and physical measures are also showing some promise. Some of the more involved controls, such as bait box technology are labour and knowledge intensive, and require an education and training component to support their implementation.

3.3.5 Utilization of Toolbox Alternatives in IPM Strategy Decision Making

Management decisions on which combination of alternatives from the toolbox are used for a given area, are based on a number of site-specific factors including the following:

- *Site conditions* – the climate, soil and general environment (urban, rural, urban, rural, forest, agricultural, parkland/heritage) will partly dictate the appropriate management alternatives to be used;
- *Nature of Structure* - the type¹⁰, construction phase (preconstruction, construction or post-construction e) and construction materials (i.e., wood, brick, concrete, steel or combinations thereof) will set the stage for the nature or potential for infestation and the combination of management alternatives available for consideration;
- *Termite species* - including its biology, ecology, life cycle and habitats will be a factor in the selection of management options and timing of implementation;
- *Status of infestation* – depending on whether the infestation is non-existent, on-going (early/advanced), or historical will determine whether termite management calls for prevention and/or control measures as well as the appropriate tools contained within each; and
- *Policy Infrastructure* – the existing policies, resources, support, education and training available will determine the capacity for implementing a given management alternative.

Many of the toolbox elements for the implementation of an IPM strategy for termite management in China exist, but have not been adequately inventoried in the supporting conceptual framework of the toolbox to guide decision-making in IPM strategy development. An overview of the IPM tools available in China, based on available baseline data, is discussed below, as well as information and data gaps that might be addressed to implement an IPM strategy for a given area more effectively.

¹⁰ Residential, commercial, cultural, or utility (e.g., dam or utility poles).

4 INVENTORY OF IPM TOOLBOX ELEMENTS IN CHINA

The importance of collecting accurate baseline information on the Sino-Canadian project has been emphasized. This has been problematic in the past given the range of different activities and agencies involved in termite management. The following sub-sections provide an inventory of the IPM toolbox elements for termite management currently existing in China, as well as information gaps and areas of uncertainty for further investigation or development.

4.1 POLICY TOOL INVENTORY

The current government strategy in China is for research and management to protect the environment and ensure human health, and achieve all related targets for termite management. This includes regulation for safe control of pesticides and other hazardous chemicals; import/export controls; and reducing stockpiles, wastes and polluted sites¹¹.

In terms of institutional arrangements, the National Termite Control Centre in China indicates that a local Project Implementation Unit for the demonstration project consisting of members from the local construction and Environmental Protection Bureaus, National Termite Control Centre, and Provincial Termite Control Association is to be organized. Other institutional arrangements include the following:

- Start-up meeting with stakeholders from the government, associations and control institutions;
- Preparation and finalization of the training manual (including IPM technology, new policies and regulations) for personnel in the demo area;
- Training implementation (workshops and training of technicians, managers, government personnel; and
- Building an information exchange platform (using ministry and prevention industry websites) for POPS/IPM background, project development and management, termite classification and distribution, expert strategies and IPM strategy application; and
- Strengthening the infrastructure of the National Termite Control Centre and the ability of Provincial Termite Control Association¹¹.

A number of policies and regulations for termite control have been put into force by the Ministry of Construction since 1987, including the following:

- *Technical Criterion for Termite Control in New Homes and Buildings* by the Department of Construction of Zhejiang Province in 1986 – designed to strengthen the management of termite control. These have been followed by the issue of a number of technical criterion and standards for termite control in China;

¹¹ Royal Roads University, 2004. Mission Report for June Field Visit (10 –20 June 2004). Report to Foreign Economic Cooperation Office and State Environmental Protection Administration. June, 2004.

- Notice No. 28 *Performing the Prevention of Termites in New House and Buildings* in 1987– ordering local departments of construction to extend the control work being done in Zhejiang Province to other jurisdictions as soon as possible;
- Notice No. 166 *Further Promote Termite Prevention Work in New House and Buildings* in 1993 – ordering all termite control units to do termite control according to *Rules for the Construction of Termite Prevention Engineering in House and Buildings*;
- Regulation No. 72 *Rules for the Management of Termite Control in House and Buildings in City Area* in 1999 – requiring the treatment of all new and re-furbished buildings with preventive termiticides, setting jurisdictional authorities, qualification of termite control units, control guarantee of 15 years, encouraging research work on new alternatives, chemical registration, and proper storage and management.

A number of technical criteria and standards have been issued for termite control in cities (13), dams and dykes (4), and for the study of termiticides (4) over the past decade. In addition to Regulation No. 72, discussed above, regulations have also been established for reducing environmental pollution and protecting human health¹², pesticide management¹³ and import and export rules for toxic chemicals (1994), and the safe management of dangerous chemicals¹⁴ (Liu, 2004).

Information available for construction in Zhejiang province between 1997 and 2002 indicates that while the building area for prevention and control has increased (10 million m²/yr), chlordane use has gone down. The market scale has also increased with greater attention to termite control. Treatment costs vary across the province ranging from 4 RMB/m² (for concrete) to 9 RMB/m² (for wood), and are set and approved by the government. There are currently 88 control stations/units in Zhejiang province and five production plants – the Hangzhou Termite Control Station has approximately 100 staff. If current policies on termite control change and the enforcement of alternatives are put into place, it is anticipated that the termite control market will be decreased. The current 15-year guarantee provided to the developer by the termite control service or agent (based on chlordane) may also be problematic using alternatives¹¹.

Preliminary incremental cost comparisons for alternatives have also been conducted by Zhejiang University examining two components: A) a one-time chemical barrier with a monitoring/control system, and B) physical barrier with a monitoring control system. Three

¹² Regulation No. 6 in 1999 – Requiring lagging chemical producers to set out their plans and techniques for the phaseout of harmful annexed chemicals with a stated time limit.

¹³ Regulation for Pesticide Management in 1997 – to strengthen the monitoring and management of the production, distribution, and use of pesticides, ensure the quality of pesticides, enhance the production of agriculture and forest and ecological environment, and to protect human and animal health.

¹⁴ Established in 1987 and revised in 2002 - strengthening the safe management of dangerous chemicals including regulation on the production, storage, use, transport, and registration, and the jurisdictional responsibilities.

different cases have been considered employing different ratios of each component ranging from 95%A + 5%B to 80%A + 20%B. The calculations were based on proportional estimates of different building structure types including wood, brick/ wood, brick/concrete, and steel/concrete. Incremental costs have been found to be higher in cases where a greater proportion of physical barriers were utilized. There are some uncertainties about some of the assumptions made in the incremental cost calculations and the reliability of the estimates, as well as the absence of any environmental costing (i.e., human and environmental health risks). These will need to be examined more closely. Another extreme might also be introduced in the exercise as a fourth case, i.e., 20%A + 80%B, to provide a more balanced perspective of physical barriers in the analysis. There are also concerns that the full range of IPM alternatives (including cultural controls) are not being considered in formulating a strategy and associated incremental costs¹⁵.

Zhejiang University have proposed a training component for the demonstration project that would consist of a one-week training period with the National Termite Control Centre, Professional Association, and all termite control stations in the province and units in the municipality. Anticipated topics would range from the POPs convention, to management policy, to using an IPM strategy. This would be managed through the Centre and include advisory (experts) and executive committees. The Centre and Professional Association would also set up training and communications to promote public awareness, develop the draft of the application manual and solicit input through liaisons from individual termite control units. Study tours on IPM strategies to other countries will also be conducted.

Policy evaluation and strengthening will need to be addressed in terms of the local demonstration area(s) including revising the following to satisfy the demands of the IPM strategy: termite management methods and technical regulations for controls, quality management methods for termite control and construction projects, fee collection standards, and a price manual of construction projects. Similar strengthening needs to occur at the national level including the following:

- Firming up institutional arrangements between CIO and the project team players (e.g., National Termite Control Centre, Provincial associations and other provincial entities. Local governments (finance, construction, real estate, environment) also need to be more involved in promoting alternatives and reducing production of these chemicals. This includes clearly identifying members, and team leaders (e.g., organizational chart)
- Clearly defined objectives and plans for an integrated framework in which to develop an IPM strategy that could be both tailored to a specific province (demo area) and scaled up to other areas in China;
- Review, assessment and revision (where necessary) of all policies and provincial/national regulations dealing with termite management;

¹⁵ Royal Roads University, 2004. Mission Report for June Field Visit (10 –20 June 2004). Report to Foreign Economic Cooperation Office and State Environmental Protection Administration. June, 2004.

- A management information system (MIS) that integrates information on all POPs, including chlordane and mirex, for information sharing between CIO and the provinces (possibly contracted through a professional company);
- Regulations controlling the production, transport and application of chlordane and mirex;
- Revising the 72nd Order from the Ministry of Construction¹⁶ relating to termite control as a compulsory management regulation of the State Department of China, including economic incentives;
- Standard(s) and guidelines/procedures for cleaning up chlordane (level of clean-up);
- Public education including movies, magazine articles, websites, expert workshops, IPM training, picture books and manuals, and demonstration activities to increase awareness¹². Liu (2004) discusses this component in more detail.

4.2 MONITORING TOOL INVENTORY

Much information already exists on termite species, population, life history, biology and ecology based on the studies by various Chinese scientists and termite control centres and institutes. Over 500 species have been documented in China belonging to the Hodotermitidae, Kalotermitidae, Rhinotermitidae and Termitidae families respectively; distributed mainly in the provinces in the southern portion of Yangtse River. Approximately 67 species are structural or wood pests, and belong to four families and 13 genera including the following:

- Homes and buildings - *Cryptotermes declivis*, *C. domesticus*, *Coptotermes formosanus*, *Reticulitermes dabieshanensis*, *R. chinensis*, *R. flaviceps*, *R. speratus*, *Odontotermes formosanus*, *Macrotermes barneyi*.
- Dykes and dams - *Odontotermes formosanus*, *O. fontanellus*, *O. hainanensis*, and *Macrotermes barneyi*;
- Utilities including cable and electric wire - *Coptotermes* and *Reticulitermes*; and
- Trees (over 300 species) – families include *Odontotermes*, *Coptotermes*, *Macrotermes*, *Olyptotermes*, *Neotermes*, *Stylotermes*, *Hodotermopsis*, *Reticulitermes*, and *Cryptotermes* (Liu, 2004).

The economic injury level has also been documented. It has been estimated that termite damage in China results in approximately 1.8 billion RMB annually (equivalent to \$217 million US) in economic loss per year in the absence of chlordane and mirex use (Zhejiang University, 2001). Liu (2004) notes that there were more than 2000 accidents of reservoir collapse and countless cases of dyke collapse. In 1993 alone there were more than 1000 dykes which collapsed from termite damage in Guangdong province and it is estimated that more than half of dams and dykes are being damaged by termites in southern China including *Odontotermes formosanus* Shiraki, *O. fontanellus* Kemner, *O. hainanensis* (Light) and *Macrotermes barneyi* Light.

¹⁶ Entitled *Management Regulation for Termite Control in House and Building in City* issued in October, 1999.

It is clear that termites threaten critical infrastructure, including housing, communications, dams, dykes, forestry and food production - control and prevention is needed. A diminished ability to control pests, therefore, is not a viable option due to the expected direct impacts on economic well-being and human health that exceed tolerance thresholds.

Zhejiang University has proposed the development of a termite control monitoring system using GIS applications that would also be operated during the demonstration period to provide a database for inputting information from the project elements, tracking termite control activities and distribution, and disseminating this information to other organizations. Feasibility would be determined on a trial system, evaluating its reliability and the information contained within it, and identifying those termite control organizations that would employ the system. The system would also be used to make evaluations on the successful implementation of IPM in other provinces. This would be supported by a workshop on the technical aspects of the system. An accompanying website and database would be made available to control staff and policy makers and include information on termite distribution, consultative experts, IPM strategy and practices¹⁷.

Liu (2004) notes that the investigation and prediction of termite damage is an important component of IPM in China. Since termite damage tends to concentrate in different part of the year, when the economic threshold is determined, a variety of factors need to be considered including the costs of different control measures, economic loss, species, degree and location of damage (and its implications). This information, however, can only be acquired through investigations and prediction to determine economic thresholds prior to the establishment of an IPM strategy for termite control.

4.2.1 Bait Monitoring

The routine deployment of bait boxes filled with a source of cellulose fibre can be used to make observations about the presence or absence, and densities of termites in an area. Such monitoring bait boxes are typically small, inexpensive boxes fitted with side access holes for termites, and buried flush with the ground, except for an inspection lid at the ground surface. The routine monitoring of important areas allows pest control managers to know when a new termite colony is being established in an area, and provides an estimate of trends in population densities (Su and Scheffrain, 1998).

4.3 PREVENTION TOOL INVENTORY

Many or even all of the approaches may be applied in a complimentary way. The measures

¹⁷ Royal Roads University, 2004. Mission Report for June Field Visit (10 –20 June 2004). Report to Foreign Economic Cooperation Office and State Environmental Protection Administration. June, 2004.

required in any individual situation depend on the ecology of the termites present in the area and the threat they represent to a given structure. Physical barriers and informed construction techniques represent an excellent alternative for prevention of termite infestation when creating new structures, and can sometimes be used effectively to retrofit structures after de-infestation, through judicious applications of chemical pesticides using bait box technology. Zhejiang Province has taken the lead in developing termite prevention work in the construction of new houses and buildings since 1986.

4.3.1 Building Design

Measures can be incorporated through building design to prevent termite infestation. These include the use of concrete slabs and keeping all wood at least 0.3 m above the soil beneath the building. Any wood that comes in contact with soil is commercially pressure-treated with a wood preservative such as borate and is not attached to the house. Where available, the use of termite resistant lumbers such as cedars are encouraged. Site grading drains water away from the building to discourage moisture near the foundations and favourable conditions for termites. These requirements are often incorporated into local building codes (CWC, 2001).

For China, Liu (2004) notes that the potential termite infestation should be considered in the building design. This includes choosing anti-termite materials first in architectural designs; allowing good ventilation and lighting in buildings to prevent termite colony establishment; and paying particular attention to specific locations such as kitchens and washrooms by introducing measures for reducing the water leakage and inhibiting termite invasion in these areas.

In urban areas of China, termites forage great distances through soil tunneling to find scarce food sources. Constructing buildings according to codes for effective termite management will reduce the risk of termite invasion. This includes removing waste wood and other fibre materials in the backfill materials of the building foundation (see also sub-section 4.3.2 below). Wooded constructed doors and windows should also be kept separate from rainwater to reduce the potential for termite colonization (Liu, 2004).

4.3.2 Site Management

This involves careful site preparation and cleanup to discourage the colonization of new or existing building sites by termites. These often also fall under the category of “cultural controls”, whereby conditions are created to discourage favourable habitat for termites. Some of these activities include:

- Removal of all stumps, roots, wood, survey pegs, grade stakes and other cellulose materials and construction debris from the building site and disposed of properly, rather than past practices of burying or encasing waste materials in the concrete foundations.

- Placing landscape plants and irrigation systems at least two feet away from foundation walls.
- Ensuring any wood that contacts the soil, such as fence posts, poles and general foundation structures, is commercially pressure treated
- Fence post and other wooden materials should not be directly attached to the house and wooden materials do not rest against walls of the structure.
- Correcting leaky plumbing, air conditioning condensate, and any portion of the building that may collect excessive amounts of moisture¹⁸.

It is also recognized in China that termites use deadwood, wood detritus, and plant residues as a food source and play an important ecological role in the cycling of materials and energy flows. The importance of establishing greenbelts or spaces in city layouts and neighbourhood planning using species of plants and trees in accordance with natural ecosystems in the area is recognized. Careful planting of herbaceous plants and trees will provide alternative food sources for termites, reducing termite damage to buildings (Liu, 2004).

4.3.3 Chemical Barriers

In jurisdictions that have already eliminated chlordane use, there was an initial switch to other organochlorine pesticides such as aldrin, heptachlor, lindane. Most, if not all of these alternatives are also covered under the Stockholm POPs convention, which necessitated a switch to organophosphate use. The organophosphates (e.g. chlorpyrifos) and carbamates, unlike the organochlorines, have a relatively short half-life in the environment, act as broad-spectrum pesticides and are also highly toxic to non-target organisms.

The organophosphates were followed by pyrethroids, which are synthetic analogues of pyrethrins. These include bifenthrin, cypermethrin, fenvalerate and permethrin. These synthetic pyrethroids vary in their toxicity and are easily degraded in the environment into non-toxic products. Other novel insecticides have since been developed. These include hexaflumuron (a benzophenyl urea used in bait technology), imidacloprid (a chloropyridinal compound) and fipronil (a phenyl pyrazole). These are characterized by low-use application rates and are generally very selective. Some of the novel pesticides that have become available outside of China in recent years (imidacloprid and fipronil, for example) have limited mammalian toxicity relative to older generation insecticides, but are still highly toxic to insects (Ware and Whitcare, 2004).

Since the ban of chlordane in 1999, some pesticide factories and termite control stations have

¹⁸ Royal Roads University, 2004. Mission Report for June Field Visit (10 –20 June 2004). Report to Foreign Economic Cooperation Office and State Environmental Protection Administration. June, 2004.

started studying chemical alternatives in order to meet the demand for chemicals for termite control (i.e., soil and wood treatment). Some have been introduced into market on a trial basis for termite control. Foreign chemical companies have also applied for the registration of their termiticides and several alternatives have been awarded permits for their use in China (Liu, 2004). Two groups of chemicals exist namely non-toxic repellents (e.g., chlordane, chlorpyrifos, and most pyrethroids) and toxic termiticides (e.g., ivermectin, imidacloprid, fipronil, chlorfenapyr, and acetamiprid). Liu (2004) provides a listing of the two dozen alternative chemicals currently registered with the Ministry of Agriculture of China and its manufacturers. Only a small number of these – sulfuramid, phoxim, fenvalerate, permethrin, and chlorpyrifos – are undergoing active trials. An assessment of the efficacy of six alternatives are also provided in the report as follows:

- *20% Tianying Termite-killing (fenvalerate) EC*¹⁹ - a low toxicity product, but with demonstrated eye light skin irritation on skin, low mobility in soils (strong adsorption) and groundwater, potentially used as a soil treatment or wood treatment for termite control. Bioassays indicated a strong acute toxicology for *Reticulitermes flaviceps*, the LC₅₀ (lethal concentration for 50 % of individuals) value was 40.16 ppm in 96 hours after treatment, and a strong repellent activity was exhibited on termites. Fenvalerate concentrations in soil beyond 125 ppm and 62.5 ppm prevented soil tunnelling by *Coptotermes formosanus* and *Reticulitermes flaviceps* respectively. Wood treated with a 62.5 ppm fenvalerate solution, was free from termite damage.
- *8% Juningdan EC (sulfuramid and fenvalerate)* - low toxicology alternative chemical, exhibiting slight skin irritation on exposure. Bioassay results indicated that 8% Juningdan EC had rapid and strong lethal action on the *Coptotermes formosanus* and *Reticulitermes aculabialis*. Treatment of soil using a solution of 400 ppm of Juningdan solution was found to retard the tunnel of *Coptotermes formosanus* in soil.
- *25% Le'anju EC (permethrin and phoxim)* – moderate mammalian toxicity. In field experiments soil treated with 2500 ppm resulting in mortality to 85.7 percent of *Reticulitermes flaviceps* individuals. The wood treated at the same concentration retarded the feeding of *Reticulitermes flaviceps*, *Reticulitermes chinensis* and *Coptotermes formosanus*. Phoxim is subject to photolysis and, if not covered by soil after application, control effects are difficult to ensure.
- *40% chlorpyrifos EC* - organophosphate with moderate mammalian toxicity (nerve system damage, and the liver metabolism effects in children) and still currently used for termite control in China. Field experiments indicate good control effects lasting between 3 to 8 years.
- *25% deltamethrin SC* - a low toxicology alternative for preventative soil treatment. Field experiments showed both good preventive and remedial effects on termites.
- *5% Pisagao (esfenvalerate) SC* – low toxicity alternative showing effective termiticidal properties at a concentration of 3000 ppm in southern China. The soil treated with 312.5

¹⁹ Developed by the Zhejiang Institute of Termite Control, the Hangzhou Qingfeng Agro-chem. Co., Ltd. and the Yuhang Termite Control Station of Hangzhou City

ppm of Pisagao solution resulted in 100 % mortality of termite individuals within two years in Zhejiang, with a strong repellent action. Soil concentrations of 62.5 ppm, can prevent *Reticulitermes flaviceps* and *Coptotermes formosanus* from passing through a 5 cm soil pillar length (Liu, 2004).

Currently, more than 70 percent of termite control organizations, distributed mainly in 14 provinces, have attempted to use alternatives for termite control in China. In terms of termite prevention, the total amount of alternative termiticides tested for use by termite control organizations was about 100 tons in China in 2001. This included 50 tons of 20% fenvalerate EC, approximately 50 tons for 40% chlorpyrifos EC, and roughly 10 tons for 10% permethrin EC (Liu, 2004).

Liu (2004) notes that 15 provinces have at the present developed termite prevention for new homes and buildings in China including Zhejiang, Jiangsu, Anhui, Guangdong, Guangxi, Fujian, Jiangxi, Hunan, Hubei, Sichuan, Chongqing, Yunnan, Shanxi, Shandong, and Liaoning. The total treatment area of new house and buildings by the preventive termiticides in 15 provinces amounted to approximately 220 million m² in 2002 equivalent to a chlordane (original oil) useage of 1000 tons. Liu (2004) estimates that substituting this with chemical alternatives for prevention in 2002 would result in termiticides useage exceeding 2000 tons, with an addition 100 tons used for the prevention of termite damage in utility structures such as dam and dykes, and electrical wire and cable. As city areas continue to grow along with termite control in China, the demand for alternative termiticides is anticipated to rise rapidly in the near future (Liu, 2004).

Liu (2004) identifies three key challenges for the implementation of chemical termiticide alternatives as follows:

1. Shorter persistence time of alternative termiticides relative to organochlorine pesticides (e.g., chlordane) and consequent need to be applied two or three times within the 15-year guarantee period;
2. The perceived²⁰ higher cost of alternative termiticides relative to chlordane and extra expenditure required; and
3. Odours associated with alternative termiticides making termite control unit personnel unwilling to use them.

Counter measures for resolving the above challenges in adopting chemical alternatives are also provided by Liu (2004) as follows:

- More scientific study on improving product formulation to increase persistence and period of efficacy, and decrease associated odours;

²⁰ As noted elsewhere, these costs do not generally consider environmental costs (health risks) to present a full cost-accounting of the alternative relative to organochlorine pesticides such as chlordane.

- Revise the quality standard for the prevention treatment of termites by shortening the guarantee term for prevention to 10 years.
- Increase the internal capacity for the production of alternatives by increasing technical and financial input, thereby decreasing the cost of production and product cost
- Policies enhancing the standard charge standard for termite control, and decreasing operation risks to the termite control units.
- Increase propaganda, education, and work training to increase awareness on the benefits of using alternatives relative to organochlorines (e.g., reduced health risks and environmental), and garner support in amending the relevant standards and establishing of relevant policies.
- Strengthening the management of termiticide use in the control industry, to penalize those in the industry illegally using organochlorine pesticides (chlordane and mirex).
- Full use of the administrative functions of the National Termite Control Center for the training and the harmonization of work between termite control units. This will facilitate extension activities and the dissemination of the use of alternative chemicals in termite control industry in China.

4.3.4 Physical Barriers

Physical barriers such as uniformly sized sand, granite chips, stainless steel or synthetic polymers can be used for termite control. Sand barriers consist of a layer of uniformly sized sand or crushed stone placed underneath buildings and around the walls of foundations. The sand particles must be too heavy for the termites to move and the spacing between them must be too small for the termites to squeeze through. Thus the type of sand used depends on the size and nature of the termites. Stainless steel mesh and synthetic polymers have also been used to cover the complete sub-floor in concrete slabs or service openings and wall cavities.

Barrier type technologies, either physical or chemical are effective only to the extent that there are no gaps in the barrier. Also, the efficacy of repellent barriers to intrusion may decrease as the densities of termites in the surrounding environment increases. Barrier-type protection of isolated structures, therefore, is vulnerable to possible build-up of termite populations in the region.

Research has been conducted on physical barriers by the Urban Entomology Research Center of Zhejiang University using four main types including the following:

- *Termite barrier sands* - Research by the Urban Entomology Program has shown that coarse sand is an effective barrier when at least 50% of the particles are between 1.4 and 2.8mm and no more than 25% of the mixtures are smaller than 1.4mm. The Guangdong Institute of Entomology has also tested the effects of physical barrier materials on dams in 1979-80 using coarse coal cinder and sand paved on the surface of the Zhiman reservoir dam in Guangdong, which effectively prevented invasion and colonization by *Odontotermes formosanus*. South China Agriculture University has

examined the effects of sands in preventing the tunnelling of *Coptotermes formosanus* under laboratory conditions in 1997. Sand barrier particles of 2.0mm-3.0mm diameter were effective in preventing the tunnelling of this termite species.

- *Stainless steel mesh* – in other countries such as Australia and USA; however, no studies have been reported currently on the use of this technology in China.
- *Termite shields* - in use in other countries such as parts of Canada; however, no studies are reported currently on the use of this technology in China.
- *Waterproof membrane barriers* - in use in other countries such as parts of Canada; however, no studies are reported currently on the use of this technology in China.
- *Other physical barriers* - Alumite Collar, Cavi Guard (Termite barrier and cavity drainage system) and Termite-Tite System available in Australia - no studies are reported currently on the use of this technology in China.

Based on the above observations, it is clear that mesh shields and other physical barriers have not been studied to any great detail in China and may merit closer investigation.

4.3.5 IPM Example for Prevention - Green City Residential Development Demo Project

The Green City Residential Development is located in a new section of Hangzhou City near the Qiantang River. This development was started in 2001 and will be completed in 2004. It stands on the former site of an old wood processing factory, which suggests that termite colonies may be present in the area based on historical evidence. Homeowners, developers, the National Termite Control Centre and the Real Estate Association have worked collaboratively on this demo project in creating a building development protected from termites by both chemical and physical means. Chemical measures have included the use of chemical barriers (permethrin/phoxin mixture) prior to construction using regulations prescribed by Zhejiang Province and the Ministry of Construction. The building construction of steel and concrete contains virtually no structural wood, aside from wood used for interior finishing in the luxury apartment condos, and pressure-treated wood used for landscape design (e.g., pergolas).

A monitoring program using pine-baited boxes will also be conducted starting in October 2004 and will be examined monthly for the termite populations by the National Termite Control Centre. If termites are detected, the nest will be located and destroyed. In cases where the nest cannot be located, they will be eliminated indirectly by treating the bait with the pesticide, Termitor® (fipronil). This demo project provides a good starting example of IPM use in China. A mist irrigation system and landscaping plants occur in close proximity to the buildings, which may possibly keep the humidity and moisture level high creating a favourable habitat for termites. This suggests more might be done in the IPM strategy from the perspective of cultural control and reduced use of chemical pesticide barriers. Proper evaluation and feedback through an adaptive management framework, such as the general framework for decision making proposed in Section 2.2, will assist in the development and continued improvement of the IPM strategy.

4.4 CONTROL TOOL INVENTORY

China's efforts to find alternative methods for termite control are paralleled by international efforts. The United Nations Environment Programme maintains a searchable database on many of the available alternatives to chlordane and mirex for pest control, and strategies to limit economic losses and human health risks ([United Nations Environment Programme POPs Database on Alternatives](#))²¹. The Food and Agriculture Organization of the United Nations, United Nations Environment Programme (UNEP) also organized a workshop on Termite Biology and Management with a number of termite experts from all continents of the world to aid in identifying alternatives to POPs pesticides.

Over a dozen Chinese academies and institutes have conducted research work primarily focussed on control technology, termite taxonomy and biology over the past few decades. Research into alternatives and spraying instruments for termite control in recent years has also been conducted by professional termite control units, including Hangzhou Institute of Termite Control in Zhejiang, Zhuji Institute of Termite Control in Zhejiang, and Deqing Institute of Termite Control in Zhejiang (Liu, 2004).

Control in Hangzhou City and Zhejiang province has been primarily concerned with homes, dams and dykes (in affiliation with the Water Resources Department), hotels, cultural relics and tree plantations (aesthetics, as well as safety and commercial loss)²².

Termite control in homes and buildings prior to 1949 consisted primarily of nest-digging, originating in Dongyang City and Yiwu City in Zhejiang province and Shashi City and Jianglin City in Hubei province. Arsenic trioxide, originating in Australia, was also used to control termites in Hong-Kong, Guangzhou, and Shanghai (Liu, 2004).

According to the Wuxi City Termite Central Control Unit in Jiangsu Province, techniques under the technical components of the plan are seen as chemical barriers and monitoring systems, whereas supplemental control techniques include construction design and nest digging. Biological controls are not as well developed as chemical technologies and are, therefore, not deemed to be feasible. There are concerns over the perception of IPM by the Chinese authorities as substituting one chemical alternative for another without giving full consideration to the range of possible control measures in a more integrated fashion. The availability of a "toolbox" exploring the wider range of alternatives for termite prevention and control is needed for formulating a more comprehensive IPM framework.

IPM strategies in other countries focus on a combination of building design (codes), cultural controls (i.e., preventing conditions favourable for termites), physical barrier systems, biological

²¹ <http://dbserver.irptc.unep.ch:8887/irptc/owa/ini.init>

²² Royal Roads University, 2004. Mission Report for June Field Visit (10 –20 June 2004). Report to Foreign Economic Cooperation Office and State Environmental Protection Administration. June, 2004.

control (or biocontrol) agents, and chemical alternatives. Some of the best opportunities for IPM strategies in China may include employing a combination of the following:

- Understanding the ecology of the pest (and employing cultural controls);
- Design and construction, including physical barriers;
- Bait trap monitoring of colony establishment for prevention of infestation;
- Bait trap plus chemical toxicant, for early control;
- Targeted growth regulator chemicals; and
- Limited use of other chemicals to handle heavy infestations.

Some of the components of the general decision-making framework for IPM strategy development, nevertheless, have been recognized by the Wuxi Termite Control Unit. The Unit has identified six components to assist in IPM strategy development: IPM technologies, promotion, an application manual, study tours to see IPM in other countries, cost variations in implementation, and functioning of the demo project. The main components of the IPM strategy in the demo project area(s) are seen as the following:

- Investigations of natural conditions in the area(s);
- Recognizing the project objectives;
- Technical components of the plan in counties and smaller cities;
- Practical implementation of all technologies used; and
- Evaluating results and making improvements²³.

Liu (2004) reports that mirex baits and chlordane grouting are being used to successfully control termite to dams and dikes in southern China combined with other measures such as damage inspection, nest digging, and aluminium phosphide fumigation. In forest and orchard operations, the termite control industry have used mainly chemical treatment (fogging, mirex baits and spraying the roots of trees) agricultural and forestry measures (plant ash in planting holes, nest digging nest, trapping alates with lights, careful selection of forestry sites and mixed plantings, soil preparation, adjustment of planting time, resistant seedlings, management of dead trees, protection of wildlife, and the establishment of trapping pits) to control the infestation of termites in forest and orchards in China (Liu, 2004). Some of the challenges will be finding and investigating suitable alternatives for chlordane and mirex as part of these management activities.

4.4.1 Chemical Control

These chemicals have slow action, non-repellent properties, and must be transferred to the whole colony population via termite forage workers. A number of institutes In China have tested the efficacy of a variety of termiticides (including plant extracts). Zhejiang University has also developed experimental methods for evaluating chemical alternatives in IPM strategies, in

²³ Royal Roads University, 2004. Mission Report for June Field Visit (10 –20 June 2004). Report to Foreign Economic Cooperation Office and State Environmental Protection Administration. June, 2004.

addition to training the researchers from the termite control stations in Zhejiang province on how to test termiticides under laboratory and field conditions (Liu, 2004).

Based on accumulated information on testing from Chinese institutes and other organizations, chemicals determined to be viable alternatives for chlordane and arsenic formulations include fenvalerate, permethrin, cypermethrin, chlorpyrifos, fipronil, imidacloprid, ivermectin, spinosad, and inorganic compounds (e.g., aluminium phosphide). Ivermectin, spinosad, and inorganic compounds can potentially be used for termite control in building interiors due to their high safety properties. The Deqing Institute of Termite Control have developed a termiticide for both prevention and control in building interiors using ivermectin as the active ingredient. Similar formulations have been produced using inorganic compounds as active ingredients for termite control in building interiors by the Urban Entomology Research Center of Zhejiang University, Hangzhou Qingfeng Agro-chemical Co., Ltd., and Zhuji Shuguang Institute of Science and Technology of Zhejiang province (Liu, 2004).

The application modes of remedial chemicals to control Chinese termite infestations in buildings include the following:

- *Spraying or injection* – fenvalerate, permethrin, cypermethrin, bifenthrin, deltamethrin, cyfluthrin for general spraying, and fipronil, imidacloprid, acetamiprid, ivermectin, and spinosad for injection.
- *Fogging* – mainly insecticides from plants or mixtures with synthetic termiticides for control of *Coptotermes formosanus* and *Odontotermes formosanus*.
- *Fumigation* – mainly Vikane and methylbromide used broadly for termite control in wood, and treatment of the imported lumber and wood products.
- *Spraying powder* - mirex and arsenic trioxide were traditionally used but are being phased out, other active ingredients including ivermectin, indoxcarb, and powdered diatomite (from Germany) are currently being investigated by various Chinese termite control agencies and require further evaluation in practice.
- *Bait technology* – using chemicals such as hexflumurom, diflubenzuron, N-butyl perfluorooctane sulfonamide, ivermectin, chlorfenapyr, indoxcarb, and borate acid (Liu, 2004). This technology is further discussed below in Sub-section 4.4.2.

Liu (2004) notes that the Nanjing Institute of Termite Control paved PVC pipe in the soil around homes and buildings during the period of 2000 to 2002 to facilitate repeated applications of alternative termiticides having a short persistence. This technology was not found to be feasible under current economic conditions due to the difficulty of paving PVC pipe around house or buildings where this was not considered in the original design, the high level of skill and technology needed for installation, and the high cost of this method compared with chlordane application.

4.4.2 Bait Control

Manufactured bait systems have also been developed in the United States that contains toxicants (e.g., hexaflumuron, sold commercially as Sentricon™, and sulfuramid, sold commercially as FirstLine™). Normally, the populations in an area are monitored using bait boxes containing untreated cellulose materials. Where an increase in termites is detected in a critical area, the cellulose bait is replaced with bait containing hexaflumuron, borate or sulfuramid. These formulations are not intended to be acutely toxic to termites, but rather exhibit chronic toxicity. In this way, a termite feeding at a bait station can carry the insecticide back to the establishing colony. Provided that a sufficient number of worker termites do so, levels in the colony reach a critical toxicity threshold for the queen (and the colony in general), and the colony dies out.

Liu (2004) notes that although this system has been used broadly in the US, the potential for the application of this system in China needs to be further evaluated. Zhejiang Institute of Termite Control has used the active ingredient, idoxacarb to develop a new bait toxicant for termite control. Sulfluramid and chlorfenapyr have also been used as active ingredients in a luring tube, which is a patent product for termite control by the Zhuji Institute of Termite Control and Zhuji Shuguang Institute of Science and Technology. Good results have been achieved in the field. Insect growth inhibitors are also being to develop new baits for termite control by the Guangdong Institute of Entomology. Such bait-administered termiticides are an obvious alternative to the use of mirex; however, research and experimentation is still ongoing to develop the most effective bait and delivery systems (Liu, 2004).

4.4.3 Physical Control

Liu (2004) notes that a number of Chinese scientists have investigated the biology and ecology of termites allowing for the development of the termite control industry in China. These include artificial digging nest, heating treatment, liquid nitrogen freezing, microwave treatment, and electric current treatment. Nest digging still plays an important role in termite control in some areas. One of the disadvantages of this method in urban environments is the destruction of ground plant cover and aesthetics – an undesirable outcome (Liu, 2004). Others including heating, liquid nitrogen, microwave treatment may also have undesirable side effects on building structure and aesthetics; most are also primarily effective only as spot treatments.

4.4.4 Biological Control

Laboratory studies have consistently indicated that biological agents such as fungi, nematodes, and mites can act as pathogens to termites. Field trials using these biological agents have generally been unsuccessful (Su and Scheffrain, 1998); however, research in this area is still relatively recent and on-going. Other green control methods have been used for prevention, but are not usually as effective as other more conventional controls. Liu (2004) notes, however, that some biological control products will eventually enter the termite control market in the near future.

Research and development into alternatives and biological controls has been identified by Zhejiang University as another important component of the IPM, including the following aspects:

- Testing and promotion of botanical and microbial alternatives to synthetic pesticides (e.g., neem extracts, *Metarhizium* sp., nematodes);
- Testing and promotion of treatment and release technologies using biological products;
- Testing and promotion of block-wide termite control technologies in heavily infested and high risk areas;
- Testing and promotion of chemical and physical barriers for termite prevention;
- Excavation and treatment of termite nests; and
- Sensitizing the general public on IPM issues and activities through informal educational channels and public awareness campaigns (extension activities)²⁴.

Researchers in the Urban Entomology Research Center of Zhejiang University are investigating technologies for using one termite species to control another. Both intra-specific and inter-specific termites have been found to fight among each other during encounters under field conditions. Clues on the mechanism of antagonism between different species or colonies may reveal opportunities for the development of new control technologies in this regard. Phytophagous ants show similar potential for control of *Odontotermes formosanus* and *Macrotermes barneyi*. Red foreign fire ants have also been found to be predators of *Reticulitermes* in forest environments. The degree of resistance is governed by the ratio of soldier termites in the colony. *Coptotermes* termites tend to have larger ratio of soldiers than that of *Reticulitermes* (Liu, 2004).

Liu (2004) notes that more than 20 species of fungus are parasitic to termites, but their application potential is unclear. Most of research has concentrated on fungi, *Beauveria bassiana* Vuill. and *Metarhizium anisopliae*, which both show good control effects under field conditions; some research also showed that *Metarhizium anisopliae* had repellent effects on termites. Fungus now has been used as the component of baits for termite control in Australia

²⁴ Royal Roads University, 2004. Mission Report for June Field Visit (10 –20 June 2004). Report to Foreign Economic Cooperation Office and State Environmental Protection Administration. June, 2004.

and it shows bright prospect of application. Other fungi including *Aspergillus*, *Beauveria*, and *Metarhizium* have also exhibited high toxicity effects on termites. Other microorganisms (e.g., bacteria, viruses, protozoans and nematodes) also demonstrate the potential for termite control, but currently lack efficacy in the field. It is anticipated that many of these may become more viable alternatives once application technologies are worked out in the future. Liu (2004) provides a more detailed review of these biological alternatives.

5 CONCLUSIONS AND RECOMMENDATIONS

The challenges in developing and implementing a toolbox to support an IPM strategy for the demo project under the Sino-Canadian project include the following:

- The establishment of institutional arrangements for the management and implementation of the demo project;
- CIO reaching a final decision on the province(s) to be used for the project;
- Collecting sufficient and accurate baseline information on the demo area(s) from SEPA (State Environmental Protection Administration) and Chinese termite experts that can be used to develop an effective general framework (and decision matrix) for guiding IPM, this includes regulations and building codes concerning termite management;
- Identifying a series of viable chemical and non-chemical alternatives particular to the demo area(s) or “toolbox” that can be used to implement a strategy under the general framework; and
- Accurately determining incremental costs (over existing chlordane approaches) for implementing an IPM strategy.

Given the known problems with chlordane and mirex, any ‘viable’ alternative for termite control would be widely accepted and would contribute to the National Implementation Plan towards a curtailment of chlordane and mirex production and use. The Chinese government, however, requires that a period of efficacy of termiticides applied for prevention must be over 15 years, while pyrethroid insecticides, imidacloprid, and chlorpyrifos tend to have a more limited environmental persistence that limits their effectiveness in termite control to less than ten years following applications at rates that are typically used. In addition, the monetary costs of chemical alternatives to chlordane are very high in comparison. This is in the absence of full cost accounting that also takes into consideration environmental costs (e.g., human and environmental health) when comparing more environmentally-friendly alternatives. The physical and chemical characteristics of soil in China are also different from western countries, where alternative termiticides have been used. Chinese operators, therefore, do not know if they are suitable or not for termite control in China (Zhejiang University, 2001). The need for continued research into alternatives to support the development of a toolbox for a given area and continued improvement of the IPM strategy through adaptive management cannot be over-emphasized.

Any possibility of eliminating chlordane and mirex from production and use in China will require not just a consideration of technological alternatives available in a given toolbox, but also issues associated with education and training, public awareness of risks, regulatory/management regimes, pesticide production and distribution infrastructure, and building practices and design.

6 REFERENCES

Canada Wood Council (CWC) 2001. Termite Control and Wood-Frame Buildings. Building Performance Series No. 3. URL: http://www.cwc.ca/pdfs/BP_3-termitecontrol-e.pdf

Liu, J., 2004. General Status Report on Termites, Use of Mirex and Chlordane, the Alternatives and IPM Practice for Termite Control in China. Prepared for Central Implementation Office, State Environmental Protection Administration by Peking University, Beijing.

Lu, F. C. A review of the acceptable daily intakes of pesticides assessed by the World Health Organization. Regul. Toxicol. Pharmacol. 21: 351-364, 1995.5-39

Radcliffe's IPM World Textbook, 2003. Integrated Pest Management. Radcliffe and W. D. Hutchison [eds.], URL: <http://ipmworld.umn.edu>, University of Minnesota, St. Paul, MN.

Schillhorn van Veen, T.W., D.A. Forno, S. Joffe, D.L. Umali-Deiningner and S. Cooke. 1997. Integrated Pest Management: Strategies and Policies for Effective Implementation. Environmentally Sustainable Development Studies and Monographs Series No. 13. The International Bank for Reconstruction and Development, The World Bank, Washington DC. May 1997.

Su Nan-Yao and R.H. Scheffrain, 1998. A review of subterranean termite control practices and prospects for integrated pest management programs. Integrated Pest Management Reviews 3:1-13.

United Nations Department of Economic and Social Affairs (UN DESA) 2003. Integrated pest management and control in agriculture. Division of Sustainable Development, Agenda 21, Chapter 14, Section I. URL: <http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21chapter14.htm>

Zhejiang University, 2001. Current Status of Insecticides for Termite Control and Strategy in China. POPs Workshop Presentation, March 19-21, 2001. Beijing