

## A REVIEW OF ENVIRONMENTAL MANAGEMENT SYSTEMS IN GLOBAL DEFENCE SECTORS

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### ABSTRACT

Environmental management is a key element in ensuring positive environmental performance of an organization. The integration of environmental management into military activities has also become a growing concern for defence sectors internationally. At present, an Environmental Management System (EMS) is one of the most widely used environmental management tools throughout the world. Recent research and public concerns have been increasingly concentrated on EMS implementation and evaluation, examining how an EMS improves environmental performance. This study provides a literature review mainly on several areas: EMS related concepts, its application and evaluation methods in global defence sectors. It is found that there are no significant differences in the EMS adoption and implementation between different countries and defence sectors. Currently, there is no universal method for EMS evaluation. A case-by-case approach is preferred as long as evidence can be found to provide support for the evaluation of an EMS. Based on the review, relevant recommendations are discussed from aspects, such as environmental performance indicator, independent evaluation, data and information collection and environmental monitoring and reporting, that should help to ensure the EMS a helpful tool for sustainable environmental management. This review provides a general overview, identifies knowledge gaps and highlights aspects of the research regarding EMS implementation and evaluation; it is useful for strengthening the EMS operation, clarifying the relationship between the use of an EMS and environmental performance and producing operational guidelines for evaluating an EMS.

**Keywords:** Environmental Management System (EMS) Application, Defence Sector, Evaluation Methods, Environmental Performance, Public Concerns, Performance Indicator

### 1. INTRODUCTION

Environmental management has gained in importance around the world in recent years, with many strategies emerging as the times require (Kolk and Mauser, 2002; Ann *et al.*, 2006; Anderson *et al.*, 2007; Rashed *et al.*, 2008). The growing demand for effective and integrated environmental management has resulted from various factors, such as increasingly complex and uncertain environmental situations,

introduction of environmental legislation, growing environmental concerns and demands for better resource management and reduced environmental pollution (Chin *et al.*, 1999; Bowers and Cornish, 2000; Strachan *et al.*, 2003; Rao, 2005; Reed, 2008).

Environmental management is a complex mechanism involving many important issues, such as operations and technologies, products and services, functional strategies and management systems (Klassen and McLaughlin, 1996; Kolk and Mauser, 2002).

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Environmental management is considered as a methodology for managing the operations of an organisation to ensure they are performed in an environmentally responsible manner. It can also be seen as the sensible utilisation and management of environmental resources in a cost-effective and sustainable way (Hale, 1995).

At present, there are many environmental management tools in use, such as environmental impact assessments, environmental auditing, substance flow analysis, life-cycle assessments and environmental management systems (Emilsson and Hjelm, 2002; Ramos *et al.*, 2009). These tools provide environmental information and assist environmental management in order to make organisations more environmentally friendly (Emilsson and Hjelm, 2002). Of these tools, an Environmental Management System (EMS) is one of the most commonly used in organisations worldwide (Zutshi *et al.*, 2008; Nawrocka and Parker, 2009; Ramos *et al.*, 2009). To date, the International Organization for Standardization (ISO) 14001 is the only international standard for the development and implementation of an EMS (Sinclair and Tschirhart, 2001; NHDES, 2002).

Recent research has focused on evaluating an EMS's effectiveness and environmental performance relative to the ISO14001 standard, rather than investigating its adoption and development in an organisation (NHDES, 2002; Dawson, 2004; Hertin *et al.*, 2008; Nawrocka and Parker, 2009). Although there have been many studies on the connection between an EMS and environmental performance, quantitative evidence is lacking (Hertin *et al.*, 2008). This study reviews the EMS implementation and evaluation in global defence sectors.

The environmental management of military activities is a growing concern for defence forces worldwide (Ramos and Melo, 2005; 2006; Bioce, 2006; Anderson *et al.*, 2007; Ramos *et al.*, 2007a). As an essential part of society, the defence sector is a large, complex and important social organisation (DD, 2003) and its military activities are closely interrelated with the environment. Defence authorities all over the world recognise that sustainable environmental management is a key issue in keeping military activities effective in the long run (Ramos and Melo, 2005). As Diecidue (2008) stated, "increased environmental diligence and scrutiny can result in increased military readiness".

Defence's management of the natural environment, especially sensitive ecosystems, has been a hot and complicated research topic (Ramos and Melo, 2005);

some baseline studies related to this issue have already been conducted. Military training activities have impacts on the environment (Kreizenbeck, 2004). Many military training areas are located in environmentally sensitive regions (e.g., protected areas and water catchments) (Rao, 2005; Godschalk, 2007). As Leitmann (1998) noted, from a survey of protected areas conducted by the International Union for Conservation of Nature, military activities are one of their top ten threats. There is also increasing public concern about military training activities and their environmental impact (DD, 2003, 2009). Given that environmental challenges and demands on management are increasing, the integration of environmental management into defence sectors should be a focus in military operations. It is also important to examine how effective an EMS is as a tool for environmental management of military training activities.

## **1.1. The Environmental Management System (EMS) and its Application in Global Defence Sectors**

### **1.1.1. The EMS and its Standards**

The EMS is a management tool to help organisations identify potential environmental impacts, protect the environment and manage their daily activities in an environmentally friendly way. Environmental management actions and protection obligations can be delivered with the help of an EMS (Andrews *et al.*, 1999; Darnall *et al.*, 2000; Beeby, 2008; DSEWPaC, 2008). Various definitions of an EMS have been documented in the literature, for example: NHDES (2002); ISO (2004); Rao (2005); Arimura *et al.* (2008); Zutshi *et al.* (2008). Generally speaking, an EMS is a comprehensive and well-organised management system with systematic processes and procedures that allow an organisation to plan its environmental activities, assess and manage its environmental aspects and impacts, produce and implement its environmental policies and achieve its environmental objectives.

Since the 1990s, several standards applying to an EMS have been established, such as the British Standard 7750 (BS7750), the Eco-Management and Auditing Scheme (EMAS) and the ISO14001 (NHDES, 2002; Moore, 2004).

The BS7750 was the first standard for an EMS produced by the British Standards Institute in March 1992 (DD, 2002; North Atlantic Treaty Organization Committee on the Challenges of Modern Society (NATO-CCMS), 2000). The standard provides a

framework to implement an EMS, which includes environmental policy, targets and objectives, environmental risk management and auditing. Its limitations include a lack of detailed criteria for evaluation of environmental performance. Although replaced by the ISO14001 in March 1997, the BS7750 provided a foundation for the development of other significant EMS standards (DD, 2000; Rowland-Jones *et al.*, 2005).

The EMAS was initially published in Official Journal L168 in July 1993 and launched in the United Kingdom (UK) in April 1995. The EMAS has been widely used in European Union organisations (NATO-CCMS, 2000; Rowland-Jones *et al.*, 2005). Designed under the European Union (EU)'s Fifth Environmental Action Program, it was used in the private sector in the first instance. It then spread to a large range of EU organisations excluding the UK, mainly focusing on industrial actions. Although the EMAS was set up as a voluntary mechanism, all EU member states are now required to comply with it. Further elements were subsequently added to the EMAS, such as environmental policy, the EMS implementation, environmental commitment, monitoring and auditing, public communication, review and continual improvements (DD, 2000; NATO-CCMS, 2000). Third-party auditing is also required in the EMAS (Cheesbrough, 2006).

The ISO is a Non-Government Organisation (NGO) established in 1947 and now comprises approximately 100 national standard entities (Edwards *et al.*, 1999; Arimura *et al.*, 2008). It is the largest institution in the world involved in developing voluntary international standards (ISO, 2007). In 1991, this organisation formed a Strategic Advisory Group on the Environment (SAGE) to examine the demand for the establishment of an international environmental management standard (Strachan *et al.*, 2003; Rowland-Jones *et al.*, 2005). Following SAGE requirements, an official Technical Committee (TC-207) was formed and, with its help, a large number of standards concerning environmental management issues have been produced (Strachan *et al.*, 2003; Potoski and Prakash, 2005; Rowland-Jones *et al.*, 2005). One of their most significant outcomes was an International Standard for an EMS, the ISO14001, first called for at the 1992 Rio Summit and subsequently completed in Geneva, Switzerland in September 1996 (Rondinelli and Vastag, 2000; Rao, 2005).

The ISO14001 is the first EMS standard used internationally. It is regarded as the international benchmark for organisations in implementing and evaluating environmental management practices and has been accepted and implemented widely (Edwards *et al.*, 1999; Gallagher *et al.*, 1999; Maier and Vanstone, 2005).

A voluntary EMS standard, the ISO14001, provides a systematic and integrated management framework for an organisation to operate their environmental management activities and bring good environmental practice to the entire organisation (Morrow and Rondinelli, 2002; Welch *et al.*, 2002; Melnyk *et al.*, 2003; Ann *et al.*, 2006). The content of the ISO14001 EMS includes:

- Fulfilling environmental legislation requirements
- Setting environmental policy
- Clarifying objectives and targets for environmental performance
- Identifying environmental aspects and impacts
- Mitigating environmental pollution and harmful impacts
- Training and monitoring, checking and auditing EMS implementation
- Communicating with the public
- Evaluating environmental performance
- Documenting environmental management procedures
- Reviewing and continually improving management practices

The ISO14001 uses Plan-Do-Check-Act (PDCA) to establish the EMS process (Arimura *et al.*, 2008; Rashed *et al.*, 2008). Details are given in **Table 1**. The ISO14001 document gives detailed guidelines on how to establish, implement, evaluate and improve an EMS at every stage (ISO, 2004). There are several outstanding advantages of this standard. For example, it emphasises the significance of identifying environmental impacts and taking precautionary controlling measures at the earliest possible stage. Continual improvement of the EMS and environmental performance is a focal point at all times (Andrews *et al.*, 1999; Lundberg *et al.*, 2005).

Some countries, such as Canada, France, Ireland, Spain and South Africa, have produced their national standards (NATO-CCMS, 2000). All these standards aim to achieve effective environmental management. In view of differences between these national standards, the ISO14001 is regarded as the worldwide EMS standard for organisations to adopt, because it is the only standard widely accepted by a large number of countries (Sinclair and Tschirhart, 2001; NHDES, 2002).

The adoption and implementation of the ISO14001 EMS therefore have many advantages and benefits for an organisation (Dahlstrom *et al.*, 2003; Dawson, 2004; Rashed *et al.*, 2008; Zutshi *et al.*, 2008).

**Table 1.** Plan-Do-Check-Act methodology with the ISO14001 EMS requirements (ISO, 2004; Anderson *et al.*, 2007; Arimura *et al.*, 2008)

PDCA	Requirements of the ISO14001	EMS stages
Plan	Define an environmental policy that is compatible with the organisation's specific characteristics Include commitment to EMS framework, such as compliance with legislation, environmental protection principles and future improvement  Make it known to organisation personnel and the public Develop an Environmental Management Plan, identify environmental aspects, impacts and legal requirements and formulate objectives, targets and program of environmental management Comply with the environmental policy	Commitment and environmental policy   Planning
Do	Implement the EMS processes to achieve the commitment to environmental policy, objectives and targets  Clarify roles and responsibilities, allocate resources, conduct awareness and management training, communicate with the public, control environmental damage, respond and report environmental incidents	Implementation and operation
Check	Monitor and evaluate the environmental performance to examine whether the EMS implementation fulfils the environmental policy, achieves objectives and targets, complies with legal requirements	
Act	Conduct internal audits Review the entire EMS process, determine its feasibility and effectiveness Find ways to improve EMS performance and management	Checking and evaluation  Management review and continual improvement

Amongst these benefits, it can help to:

- Improve environmental performance and management efficiency
- Ensure compliance with stringent environmental legislation
- Promote environmental policy
- Identify and reduce environmental risks and potential environmental impacts
- Mitigate environmental pollution and protect resources and ecosystems
- Motivate effective EMS implementation
- Enhance internal and external communications and cooperation with stakeholders and the public
- Reduce environmental management costs
- Minimise environmental liability
- Strengthen public awareness and concern for the environment and its management
- Provide a mechanism to certify an organisation's leading role in environmental management; and
- Resolve problems regarding environmental goals in a timely fashion

## 1.2. Application of the ISO14001 EMS in Global Context

There is a global trend to increased usage of an EMS (Hui *et al.*, 2001; Zutshi *et al.*, 2008; Nawrocka and

Parker, 2009). More and more organisations, such as industries, companies, government agencies and other social groups, are introducing and implementing the ISO14001 EMS (Rondinelli and Vastag, 2000; Welch *et al.*, 2002; Schylander and Martinuzzi, 2007). According to the ISO Survey of Certifications 2009, there were more than 223,149 certified ISO14001 EMSs in 159 countries/economies in 2009 (Frost, 2010), approximately 18% more than in 2008.

As the EMS was initially designed for industrial sectors, it is used widely in both developed and developing countries in industries, firms and companies, such as chemical, electronics, auto manufacturing, computers, energy and wastewater management (Darnall *et al.*, 2000; NATO-CCMS, 2000; Zutshi and Sohal, 2001; Melnyk *et al.*, 2003; Ramos and Melo, 2005; Arimura *et al.*, 2008; Zutshi *et al.*, 2008). It should be noted that, to be certified, an EMS's implementation must conform to all the ISO14001 requirements (Rao, 2005; Nawrocka and Parker, 2009). The EMS is not a static management tool; it must be developed and improved continuously (DD, 2000).

## 1.3. Defence sectors and their Environmental Management Practices

The United Nations' (UN) Millennium Project, which focuses on the achievement of the Millennium Development Goals by 2015 as agreed by UN members,



highlights the importance of more-responsible environmental stewardship being exhibited by defence forces worldwide (Diecidue, 2008). Defence organisations are among the most significant institutions in society, with their primary mission to defend their nation's security and sovereignty, as well as people's interests and rights (DD, 2007; Ramos *et al.*, 2007a; 2007b). Preparedness for and achievement of these goals need to be supported by a series of elements, including sophisticated weapons and equipment, qualified military personnel, high-quality training areas with adequate facilities, satisfactory resources and environment and integrated management (Doxford and Hill, 1998; Kreizenbeck, 2004; Ramos and Melo, 2005).

Defence sectors throughout the world own large areas of land (Linkov and Ramadan, 2004; Ramos *et al.*, 2007a). Many training areas are located in environmentally sensitive regions, such as protected areas, agricultural land, water catchments and significant heritage areas (Rao, 2005; Godschalk, 2007). Conflict was the central point regarding establishment and environmental maintenance of protected areas. There have been many prominent disputes arising between military use and environmental reserves (West *et al.*, 2006), such as at the Otterburn Military Training Area and Northumberland National Park in the UK (Doxford and Savege, 1995; Doxford and Hill, 1998). In this case, rigorous area-use planning and public inquiries were required eventually to allow both uses and achieve harmonious development (Doxford and Savege, 1995).

Another example was the Dartmoor Training Area, used for military training for more than 200 years and located within a significant national park in the UK. The Ministry of Defence and the Association of National Park Authorities found that the best way to resolve the conflict was cooperation and a Declaration of Intent was signed in 2005 to ensure a close relationship. The ISO14001 EMS was adopted for use in that area in 2002 (DNPA, 2005). In 2005, an external audit of the Dartmoor Training Area EMS was conducted to ensure all impacts were identified and to recommend the future development of the EMS (RPSHSE, 2005). A similar cooperative initiative between the defence force and local communities regarding the Makalu-Barun Conservation Area in Nepal was highlighted in the study of Mehta and Kellert (1998).

An example of Australia is related to Shoalwater Bay Training Area (SWBTA), Queensland. In 1993-94, a Commission of Inquiry into the Shoalwater Bay area was established to assess the compatibility of the

multiple uses made of and activities undertaken, at SWBTA from an environmental perspective. A series of recommendations were made, one of which was that military use and conservation should have equal significance and that environmental protection and management should be promoted in future military activities at SWBTA (Woodward, 1994; DD, 2009).

In peacetime, defence forces spend most of their time on military training and operations with peaceful purposes (Godschalk, 2007). Good environmental practice should be integrated into all defence force activities, that is, "the environment should be treated as an element of military doctrine and ingrained in security considerations and not separate from them" (Diecidue, 2008).

#### 1.4. Empirical Studies on Environmental Impacts of Military Activities

Major environmental impacts of military training (e.g., traffic, bombing, live firing and vehicle manoeuvres) include: soil erosion and compaction; landscape change; water and waste pollution; noise and air pollution; disturbance of flora and fauna; ecosystem and environmental destruction; and impacts on human health and safety (Cuddy *et al.*, 1990; Ramos and Melo, 2005; Rao, 2005; Ramos *et al.*, 2007a). The impact might vary considerably from area to area, depending on the military activities conducted and the environmental features of training areas (Linkov and Ramadan, 2004).

There have been a number of studies concerning military disturbances and environmental effects on land (Wilson, 1988; Ayers, 1994; Lehman *et al.*, 1999; Hirst *et al.*, 2000; Whitecotton *et al.*, 2000; Smith *et al.*, 2002; Williams *et al.*, 2005; Leis *et al.*, 2005; 2008; Latham *et al.*, 2007; Warren *et al.*, 2007). These studies have used field experiments, observations, data monitoring and technical methods such as a Geographic Information System (GIS), computer simulation and multi-criteria analysis (Warren *et al.*, 1989; Mendoza *et al.*, 2002; Herl *et al.*, 2005; Wang *et al.*, 2008). The majority of these study areas are located in the United States of America (USA) and the UK, with both countries relatively advanced in this type of research. Understanding the environmental impacts of military activities is considered necessary so that the defence authorities can take measures to mitigate or prevent these negative impacts (Diecidue, 2008). These studies and applied technologies have helped to establish many management strategies, such as Integrated Training Area Management in the USA and the

Combined Arms Tactical Trainer and Integrated Land Management Plan in the UK (Doxford and Hill, 1998; Durant, 2007).

### 1.5. Application of the ISO14001 EMS by Defence sectors in Different Countries

An increasing number of countries are integrating environmental management into military activities using the ISO14001 EMS (Dawson, 2004; Ramos and Melo, 2005; 2006; RPSHSE, 2005). NATO set an early example, with environmental management operations in place since the 1990s (Kreizenbeck, 2004). The Committee on the Challenges of Modern Society (CCMS) of NATO led the way in EMS adoption in defence sectors by conducting a NATO-CCMS Pilot Study on Environmental Management Systems in the Military Sector in 2000. It emphasised the advantages of an EMS and recommended the implementation of this tool in military activities. The study report also summarised the ISO14001 EMS guidelines and implementation, using diverse examples gathered from defence sectors in EU countries (NATO-CCMS, 2000). The report found that environmental management of most military activities was better integrated when the ISO14001 EMS was in operation. After the release of the pilot study, several workshops were held to find ways of filling the gaps between EMS theory and practice (Sinclair and Tschirhart, 2001; Dawson, 2004). The NATO Standardization Agreement for Environmental Protection was also promulgated to support the NATO-led environmental management of military activities (Ramos and Melo, 2005; 2006; Ramos *et al.*, 2007a).

Australia has also become increasingly concerned with its environmental management practices and the ISO14001 standard has been adopted by various organisations (DD, 2003; Bioce, 2006; Beeby, 2008). Many institutions, such as the Commonwealth and State Governments and Standards Australia, are promoting the implementation of the ISO14001 EMS (Zutshi and Sohal, 2001). The Australian Government required all Commonwealth agencies and departments to have a certified EMS in place by the end of 2003 (DD, 2003; 2005). As a follow-up action, the AS/NZS (Australian/New Zealand Standard) ISO14001 (2004) was instituted specifically for Australian environmental management (SASNZ, 2000).

As one of the largest Australian Government landowners, the Australian Defence Force (ADF) also recognises its environmental management

responsibilities (Cuddy *et al.*, 1990; Scott *et al.*, 2000; DD, 2003). To comply effectively with environmental legislation and implement defence environmental strategies, in 2001 the ADF adopted an integrated EMS under the ISO14001 standard as the guiding framework for incorporating environmental performance into day-to-day military business (Beeby, 2008). Its central point is to provide an integrated and directive tool for successful environmental management by the ADF. The ADF EMS model is shown in **Fig. 1**. A set of executive guidelines and measures have been developed by the ADF in accordance with its EMS to facilitate environmental management. Extensive environmental management activities with regard to the ADF EMS modules have been discussed by Wu *et al.* (2010).

Several examples of the adoption and development of an EMS by defence forces of different countries are reviewed in **Table 2**. For these cases, an EMS is recognised as a critical tool in achieving the best possible performance and being a leader in environmental management (Kusnir, 2004; Moore, 2004). Generally speaking, around the world, defence environmental management is similar in defence missions, legal requirements, environmental management targets, frameworks, policies, plans, implementation tools, existing weaknesses and future improvements. These similarities show that benefits could be gained by information sharing between stakeholders (Linkov and Ramadan, 2004; Kreizenbeck, 2004).

### 1.6. Evaluation of EMS Effectiveness

#### 1.6.1. EMS and Environmental Performance

Empirical studies have shown various beneficial outcomes because of an EMS, such as better legal compliance and ecological improvement (Steger, 2000; Potoski and Prakash, 2005). Recently, research and public concerns have become increasingly concentrated on how an EMS is implemented, whether and how it satisfies the ISO14001, the ISO14001 and how it improves environmental performance (Arimura *et al.*, 2008; Hertin *et al.*, 2008; Nawrocka and Parker, 2009). As one of the projects' final report stated, "[it] is not simply whether an EMS is in place or has been certified, but what impacts were identified as significant, what objectives and targets were set for their improvement and what actual performance or compliance results have been achieved" (UNCCHDPP, 2003).

The leading guidance documents regarding EMS and environmental performance have been produced by

the Organisation for Economic Co-operation and Development (OECD), including Improving the environmental performance of government and Improving the environmental performance of public procurement (Ramos *et al.*, 2007a). In Indonesia, the Ministry of Environment developed a public rating system called “Proper Prokasih” in 1995, in order to strengthen EMS implementation. It has been described as “the first central government program in the world to publish a single index of environmental performance” (Edwards *et al.*, 1999).

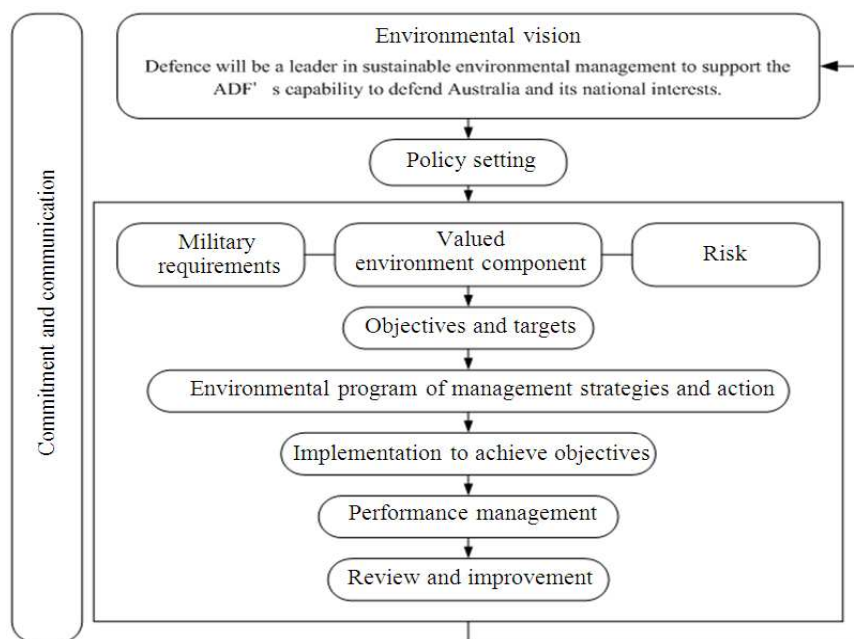
An EMS is a widely used policy and management tool. What elements contribute to the successful implementation of an EMS and to what extent can it be considered effective? Although numerous studies have been conducted to evaluate an EMS and environmental performance (NHDES, 2002; UNCCHDPP, 2003; Salmons, 2004; Cheesbrough, 2006; Ramos *et al.*, 2007b; 2009), the answer to this question is still not clear. For example, the study of Melnyk *et al.* (2003)

on American manufacturing industries showed that, as a result of ISO14001 EMS implementations, there was significant improvement in environmental performance in the areas of product quality improvement, waste reduction, efficiency of equipment utilisation and reduction of lead time. The UK Environment Agency believes there is a correlation between an EMS and environmental performance (Maier and Vanstone, 2005). The Ethical Investment Research Services conducted a worldwide survey in 2005 to explore this correlation. It found an evident and positive correlation between the quality of an EMS and the improvement in environmental performance (Maier and Vanstone, 2005).

Nawrocka and Parker (2009) reviewed 23 studies from 1996 to 2008 on the effects of implementing an EMS. They noted that the EMS resulted in improved environmental performance in some studies, but not in others. Several reasons for this were put forward. Firstly, there was not a consistent definition of “environmental performance” in the studies.

**Table 2.** Overview of the ISO14001 EMS adoption and development by defence forces of different countries Diersing *et al.* (1992); Doxford and Hill (1998); Sinclair and Tschirhart (2001); DD (2002); Dawson (2004); Linkov and Ramadan (2004); Kusnir (2004); Kreizenbeck (2004); Moore *et al.* (2004); Ramos and Melo (2005; 2006); Rao (2005); Godschalk (2007); Zutshi *et al.* (2008); Ramos *et al.* (2009); EAO/ASAIE

Country	Defence organisation	ISO14001 EMS	Environmental management status	Applied legislation	Principles/guidelines, strategies, policies, programs	Future improvement /Comments
UK	Ministry of Defence (the second largest single-ownership department following the forestry commission; holding more than 1% of the land area and 3% of the) national park regions	80% of the government estates with an EMS in place by 2006 (announced on July 24, 2002); Carried out by Army, Navy and Air Force	Formerly relatively poor record, reformed in recent years	N/A	Specific EMS team; strategic guidelines e.g. “implementing environmental management systems guidance for government departments” and “sustainable development in government”; safeguards produced by defence science and technology laboratory; significant environmental impacts identified; management principles regulated	Future improvement: environmental performance indicator development; reporting framework; data collection; public participation
Netherlands USA	N/A Department of Defense (the third largest landholder)	N/A Executive order (EO 13148) greening the government through Leadership in environmental management signed calling for the EMS adoption and implementation (April 2000); Adopted by all federal agencies (including defense) with the EPA requirements by the end of 2005; Pilot 16 selected military installations study of 16 reporting the extensive use and positive effect of the ISO14001EMS in all defence scopes	N/A No concept in military lands before the 1960s, and changed along with the serious environmental damage and protection concerns; Responsibility taken over from engineering community (1994)	The clean air act of 1970; federal water pollution control act of 1972 the endangered species act of 1973 the resource conservation and recovery act of 1976; the clean water act of 1977	Defence Environmental Policy Plan integrated natural resource management Plans (INRMPs) (1989); the army environmental policy institute (1990); US army environmental strategy into the 21st century (1991); guideline for INRMP preparation (1997); three broad programs (January 2003); environmental impacts integration of INRMPs and the ISO14001 identification EMS; military training area management (e.g. LCTA (land condition trend analysis), maintenance), TRI (training requirements integration), EA (environmental specific programs (e.g. air quality and waste management, noise reduction pollution prevention, fish and wildlife and endangered species management installation restoration and reporting system)	N/A The modern status of USA environmental management commenced with the implementation of the national environmental policy of 1969 and the establishment of the US EPA in 1970.
Canada	Department of National Defence and the Canadian Forces (DND/CF)	Adopted by Parliament (1995); complete implementation by April 2004; adopted by DND/CF	N/A	The Canadian environmental assessment the Canadian environmental protection	National strategy: the “greening government”	The first Sustainable Development Strategy (SDS) (1997) and second SDS (2000); participant in the NATO-CCMS pilot study
Portugal	Portuguese Ministry of Defence (MDN) (one of largest public sectors; holding about ¼ of the territory)	Adopted (2001); now fully implemented in all defence branches	Military policy not included for a long time; considered more recently	N/A	National plan for environmental policy instituted by the MDN (1995), relevant strategies, training and management measures followed.	Participant in the NATO-CCMS pilot study; future improvement environmental awareness training; environmental baseline survey; environmental impact identification
South Africa	South African national defence Force	Developed	Environmental responsibilities acknowledged 1977	N/A	First environmental policy (1978); sustainable training area management plan; environmental considerations in operations; environmental Implementation plan military integrated environmental Management methodology (1990s)	N/A
Slovak republic	Ministry of Defence	Developed in the armed forces (2001)	Typical military installations chosen as experimental units; Work closely with the ministry of environment	N/A	State Environmental Policy following European legislation (1993); “the conception protection” for defence (1996); pollution sources database for military Installations” project (2001)	In 2001, a “pollution sources database military installations project began to develop in the armed forces, as an outcome of a nationwide program of 1999
India	N/A	Application required	Military sector incorporated the environmental protection framework (1993)	N/A	Environmental strategies, policies and management plans formulated, well-controlled and publicly available	N/A



**Fig. 1.** The ADF EMS model (adapted from <http://www.defence.gov.au/environment/>).

The ISO14001 defines it as “measurable results of an organization’s management of its environmental aspects”. Under the framework of an EMS, environmental outcomes can be measured in light of the organisation’s “environmental policy, environmental objectives, environmental targets and other environmental performance requirements” (ISO, 2004). In other studies, environmental performance is measured by the extent to which there is compliance with legal requirements, reduction of environmental impacts and improvement in environmental efficiency (Rao, 2005; Ramos *et al.*, 2009). However, whether an EMS results in improved environmental performance is still not clear (Lundberg *et al.*, 2005).

The ISO14001 EMS allows an organisation to “evaluate environmental performance against policy, objectives and performance targets, while seeking performance improvements where appropriate” (Melnik *et al.*, 2003).

However, it merely presents the requirements and operational processes that an EMS-certified organisation should carry out, rather than providing definitive criteria for measuring improvement in environmental performance and EMS effectiveness (Edwards *et al.*, 1999; Rondinelli and Vastag, 2000; Melnik *et al.*, 2003; Nawrocka and Parker, 2009). This was highlighted by Andrews *et al.* (1999): “ISO14001 does not prescribe substantive environmental performance standards, nor does it direct which of many possible environmental

goals should be given priority. It does not prescribe the introduction of specific pollution-prevention or sustainability-related practices. It does not mandate how fast or how far ‘continuous improvement’ must proceed, nor even how quickly an organization must actually achieve compliance with environmental regulations”. Thus the adoption of the ISO14001 will not guarantee optimal environmental performance: this depends on how effectively the EMS is implemented (Rondinelli and Vastage, 2000; Anton *et al.*, 2004). Another concern is that the choice of study tools and research methods (quantitative, qualitative or a combination of the two) might lead to different processes and results in the evaluation of environmental performance (Nawrocka and Parker, 2009).

According to the findings of Nawrocka and Parker (2009), a successful EMS can be attributed to many internal and external factors in an organisation, such as its characteristics, management attitude, culture, policies and stakeholder participation. Various necessary features of an effective EMS have also been discussed (Chin *et al.*, 1999; Gallagher *et al.*, 1999; McDonach and Yaneske, 2002; Dawson, 2004; Lundberg *et al.*, 2005); these are summarised as follows:

- Environmental commitment
- Covering all environmental matters
- Vigorous environmental management plans and strategies



- Objectives and targets
- Identification of environmental impacts
- Incident response and technical support
- Documenting processes
- Environmental reporting, communication and transparency
- Follow-up measures (e.g., environmental monitoring and evaluation)
- Acceptance by all levels of the organisation and integrated into everyday management business

The above features are consistent with the ISO14001 standard. These can be used as references when assessing an EMS of an organisation.

### 1.6.2. Methods of Evaluating an EMS

Numerous studies using various assessment methodologies have been conducted to examine the motivations in and benefits of adopting the ISO14001 EMS, as well as to evaluate the effects of an EMS on an organisation's environmental performance (Andrews *et al.*, 1999; Edwards *et al.*, 1999; Maier and Vanstone, 2005; Potoski and Prakash, 2005). These studies cover organisations ranging from individual authorities to large clusters of facilities in various sectors, in both developed and developing countries.

One of the most significant studies was the pilot study Environmental Management Systems: Do They Improve Performance?, which aimed to clarify the EMS implementation processes and examine its effectiveness on a facility's environmental performance (Edwards *et al.*, 2002; UNCCHDPP, 2003). Sponsored by the USA Environmental Protection Agency (EPA), the study involved 91 facilities across 17 States. These facilities were in both public and private sectors such as major manufacturing, electronics, multinational companies, food processing, chemicals, military sectors and wastewater treatment facilities (Andrews *et al.*, 1999; UNCCHDPP, 2003). A Multi-State Working Group on the EMS was established by this study in 1996, responsible for monitoring and recording performance changes related to EMS implementation. In order to efficiently manage data and facilitate EMS evaluation, a database was developed in 1997, the National Database on Environmental Management Systems (NDEMS) (UNCCHDPP, 2003).

The research found that most participating facilities received considerable benefits from EMS adoption and implementation, including a decrease in environmental impacts, enhancement of employee environmental awareness and stakeholder relationships, promotion of documenting procedures and better evaluation of internal

operations (Darnall *et al.*, 2000; Freimann and Schwedes, 2000). This gives some indication of the effectiveness of an EMS.

The New Hampshire Department of Environmental Services (NHDES) joined this project in 1997. Five firms were involved in their study, with one being from the defence sector. This study mainly discussed EMS implementation regarding regulatory compliance (e.g., DES Compliance Assurance Response Policy), environmental audits in accordance with the EPA's Audit Policy, incentives for good environmental performance and cooperation with the National Performance Track Program and the DES Pollution Prevention Program (NHDES, 2002).

Another research team from the University of California conducted a study using extensive surveys and interviews to evaluate the effectiveness of an ISO14001 EMS in USA firms with a certified EMS, government sectors, NGOs and environmental auditors. Research issues were analysed mainly in terms of four implications: environmental; stakeholder; organisational; and legal. The companies investigated considered the EMS relatively beneficial, whereas most NGOs were suspicious about EMS effectiveness in promoting environmental performance, as also noted by Steger (2000).

Subsequently, several practical tools were developed for managers to facilitate EMS evaluation, such as the ISO Gap Analysis matrix (an ISO14001 Roadmap) and an environmental checklist (Edwards *et al.*, 1999). The gap-analysis approach was also adopted by Rashed *et al.* (2008), using the Egyptian Minerals and Salts Company as a case study. Two kinds of tables were produced, a "checklist table" and a "questioner table", to compare the requirements of the ISO standard with the company's actual environmental performance. McDonach and Yaneske (2002) proposed a sustainability model to evaluate ISO14001 EMS implementation. Different kinds of conceptual methods applied to evaluate an organisation's sustainability were reviewed by Andrews *et al.* (1999). A number of relevant studies are listed together with their aims, methods and findings in **Table 3**.

Because of the difficulties inherent in developing a universal environmental performance evaluation framework, the majority of methods applied are investigative, such as interviews, questionnaire surveys, participating observations and case studies. Self-evaluation and conceptual measures are also common, with both qualitative and quantitative methods used (Rondinelli and Vastage, 2000; Sroufe, 2003; Anton *et al.*, 2004; Rowland-Jones *et al.*, 2005). Statistical tools are used for data analysis in some studies (Chin *et al.*, 1999; Hui *et al.*, 2001; Dahlstrom *et al.*, 2003; Melnyk *et al.*, 2003; Anton *et al.*, 2004; Potoski and Prakash, 2005; Ann *et al.*, 2006; Arimura *et al.*, 2008; Hertin *et al.*, 2008; Nawrocka and Parker, 2009).

**Table 3.** A summary of studies on EMS evaluation

Author(s) and time	Aim(s) of study	Study group	Method(s)	Conclusion and comments
Chin <i>et al.</i> (1999)	Evaluate successful factors and necessity of the EMS implementation	Hong kong manufacturing facilities	The Analytic Hierarchy Process (AHP) methodology; Elements of the EMS implementation divided into several hierarchy levels, six evaluators chosen to compare elements of each level in pairs using nine-point scales; Data were collected through expert interviews; Normalized priority weights of each element decided through pair-wise comparisons with help of "Expert Choice"; The geometric mean method was applied to combine each evaluator's judgment of pair-wise comparisons to obtain relative importance of successful elements in the EMS implementation	The ISO14001 EMS should be implemented and kept effective
Rondinelli and Vastag (2000)	Assess the impacts of the ISO14001 EMS standard	An aluminium plant in South Carolina	In-depth case study; Four major aspects examined: employee awareness (environmental awareness training); operational efficiency (goals and benefits); managerial awareness (the EMS implementation; and improved management practices) ); and operational effectiveness (waste reduction and recycling); Data collected from program evaluation literature, archival material plant site visits, interviews of key environmental managers, concept mapping exercise involving 15 environmental management team members; A structured conceptualization" methodology applied: a sequence of concrete operationally defined steps that yields a conceptual representation of an evaluation result or idea domain through "concept mapping"	The ISO14001 EMS was neither a panacea for solving all environmental problems nor merely a label. Rather, it could provide a "common sense guideline for environmental management; Although the EMS might not guarantee environmental performance improvements, it could bring managerial and behavioural impacts to promote environmental practices
Steger (2000)	Assess the EMS's Impacts on companies' business and natural environment	Some small-scale EMS investigations and two comprehensive studies for Germany and Austrian environmental ministries	Literature review of empirical studies	Many companies reduced their pollution, promoted legal compliance; the EMS was considered as a powerful tool in environmental management; Enhance environmental goal setting, ecological priority consideration, integration other management systems and third-party auditing
Zackrisson and Enroth (2000)	Examine environmental effectiveness of the ISO14001 EMS	Approximately 170 ISO14001 certified firms in Sweden	Conducted jointly by Sweden's five industrial research institutes and the Industrial Research Institutes in Sweden Eco-efficiency group; Questionnaire survey and follow-up interviews with 19firms; Statistical methods and regression analysis for data processing	Waste reduction and management was considered to be the most significant improvement; Recommendations including clarifying environmental aspect identification, integrating with other management systems, increasing EMS-related knowledge and reinforcing follow-up management activities
Hui <i>et al.</i> (2001)	Identify motivations of the EMS adoption; Examine the EMS implementation, benefits and achievements; evaluate the EMS effectiveness	11 medium-sized firms with the ISO14001 EMS organized by the weightings Hong Kong productivity council in 1995	29 questionnaire surveys based on AHP methods using nine-point scale; collected data transformed into normalized using "Expert Choice" software	Benefits could be achieved through the EMS implementation the EMS had positive effects their management
Zutshi and Sohail (2001)	Detect environmental auditors thoughts about the EMS Implementation	12 auditors contacted by the Australian EPAs	Case study; Telephone and face-to-face interviews	The ISO14001 EMS had beneficial effects on regulatory compliance managers' involvement, relationship with the public, environmental training market competitive strength, environmental monitoring and reporting
Emilsson and Hjelm (2002)	Examine motivation of EMS adoption, the EMS implementation, anticipated and actual outcomes	289 Swedish local authorities	Nationwide survey; Posted questionnaires including both quantitative and qualitative questions	Most reported positive experiences from the EMS implementation some had no environmental changes; the EMS had the potential to become a useful tool in environmental performance improvements
Morrow and Rondinelli (2002)	Examine motivation and impacts of the EMS adoption	Small energy and gas companies in Germany	Literature review and few previous empirical studies; Five in-depth case studies	Beneficial broadly, but hard to quantify; Not all expectations were met The majority of environmental performance improvements were not related to the EMS
Welch <i>et al.</i> (2002)	Examine the ISO14001 EMS adoption drivers; Find adoption differences between first-stage, second-stage and non-adopters	Four of Japan private sectors (chemical, electronics electric machinery and electric power)	Questionnaire survey; A model established containing regulatory, competitiveness, social responsibility and organization theory; Hypothesis testing and regression analysis	The ISO14001 EMS adoption did not have clear causal relation with green activities, but was related to environmental action
Dahlstrom <i>et al.</i> (2003)	Assess the relationship between the EMS, operator performance and enforcement action; assess whether the EMS could be applied to expand "risk-based regulation"	More than 800 production sites in England and Wales within the UK's Integrated Pollution Control regime	Survey; interviews with iso14001 certified sites, environment agency enforcement officers and the united kingdom accreditation service mostly subjective assessments Based on Operator Performance and Risk Appraisal (OPRA) database and the Environment Agency's enforcement database; Analyses of statistical variance (ANOVA tests)	The EMS achieved certain procedural aspects of environment management No evident relation between the EMS enforcement action and operator performance on non-compliance issues
Melnik <i>et al.</i> (2003)	Assess the EMS's impact on corporate environmental Performance	North American manufacturing industries	Self-reported measures; A multi-method research perspective incorporating case studies; pilot tests; interviews; questionnaire surveys; and regression analysis using STATA statistical tool; 11-point scale for respondents to those who not assess environmental variables.	Firms with an ISO14001 certified EMS usually had a better environmental performance than

Table 3. Continue

Sroufe (2003)	Examine direct and indirect effects of the EMS on firms' environmental management and operation	USA manufacturing companies	Field study; Survey (the largest survey conducted in manufacturing field in USA) Conceptual model established including EMS, environmental design, recycling and waste practices and operation performance; structural equation modelling elliptical reweighted least squares; confirmatory factor analysis	Positive relationship between the EMS, environmental performance and operation management; A list of measurement indicators corresponding to the conceptual model was developed
Strachan <i>et al.</i> (2003)	Examine the ISO14001. EMS adoption motivation, implementation barriers and benefits	Eight UK oil and gas companies in the United Kingdom Continental Shelf	Review EMS-related literature; Structured interviews with senior managers	The majority considered improved environmental performance and environmental awareness was achieved; the EMS was a useful deserved broader adoption in oil and gas industry; reinforcement of social responsibility and environmental management.
Anton <i>et al.</i> (2004)	Examine the EMS adoption motivation; Explore the relation between the EMS quality and toxic Release intensity	USA Standard and poor SandP) 500 firms under the Corporate Environmental Profile Directories	Survey conducted by the investor research responsibility centre; Establishment of conceptual and empirical framework, including 13 environmental management practices as evaluation indicators; Count data from the Toxics Release Inventory (TRI); quantile regression analysis (e.g., poison and negative binomial models, instrumental variables methods and Generalized Methods of Moments)	The EMS reduced toxic emission, particularly in higher pollution intensity plants, reduced on-site releases and off-site transfers
Remas project	Explore the relationship between the EMS, operator performance and environmental	Business and industry companies around EU Member States; A three-year project from 2002 to 2005	Questionnaire survey; emission standards were in accordance with "best available techniques" under the EU's integrated pollution prevention and Control directive; quality-control audits (e.g., site visits, cross reference to regulatory inspectors, data website);	No direct relation between influenced factors of the EMS quality and toxic release intensity
Salmons (2004)				Significant positive relation between the ISO14001 EMS adoption and operator performance; No strong evidence about improved operator performance and better environmental outcomes
Cheesbrough (2006)	Outcomes		Mathematical model, hypothesis testing, regression analysis; Operator performance was measured by a facility's EMA; scores for environmental outcome, EP scores	
Hughey <i>et al.</i> (2005)	ISO14001 driving forces, benefits evaluation	15 wine companies in New Zealand	Qualitative survey; Questionnaire is consistent with triple bottom Line reporting sustainability guidelines, including environmental aspects and quality, EMS implementation, management influences; Interview-based questions, face-to-face and telephone interviews	Calling for integrated environmental management and sustainable developments
Lundberg <i>et al.</i> (2005)	Detect rail operation, environmental activities, environmental aspects and impacts and current follow-up actions; examine the EMS and EPE application	Swedish National Rail Administration; Railway departments of different countries	Participant observations; questionnaire surveys; unstructured interviews	EMS was broadly used; EPE and environmental performance indicators were relatively new issues and should be developed; Demand of integrated environmental management
Maier and Vanstone (2005)	Explore the relationship between the EMS and environmental performance over a three-year period	More than 800 high-environmental-impact companies in the FTSE all world developed index (including global medium- and large- size companies)	Worldwide survey and publicly available data; Assess the EMS's quality using the basic EMS elements as indicators; UK Environment Agency treated the EMS using risk-based approach through the OPRA scheme. Companies with the EMS could get additional awards in the OPRA scoring system Five categories for environmental performance improvement given according to individual weighted scores	The majority had the EMS in place; Some environmental performance improvements were reported; A positive correlation between the EMS quality and environmental performance improvements;
Potoski and Prakash (2005)	Investigate whether the ISO14001 EMS could improve environmental performance	More than 3000 facilities considered as 'major sources' under the USA clean air act	Indicators (Risk-Screening Environmental Indicators) from the EPA(CHHI/RSEI) weighting approaches; model, STATA software to do data analysis	Demand of greater environmental reporting and quantitative data disclosure
Ann <i>et al.</i> (2006)	Investigate the EMS impacts on firm environmental performance and customers' satisfaction	ISO14001 certified firms in the Federation of Malaysian Manufacturers	Mail survey; Hypothesis testing and Pearson product-moment correlation	Firms with the ISO14001 certified EMS reduced pollution emissions; Demands of efficient monitoring and sanctions, third-party auditing and information disclosure
Schylander and Martinuzzi (2007)	Examine driving forces, expectation and actuality of the EMS implementation, environmental impacts and effects, integration with other management systems	More than 500 organizations with the ISO14001 certified EMS in Austria	Questionnaire survey; Face-to-face interview	Positive impacts reported and enhanced corporate image" was considered to be the strongest impact; Cooperation between firms, government and communities
Arimura <i>et al.</i> (2008)	Evaluate the ISO14001 EMS implementation and environmental performance changes	Japan manufacturing facilities	Questionnaire survey; Japanese facility-level data obtained from the OECD survey; Application of econometric model; Establishment of statistical connection between different parameters to examine environmental performance	The ISO14001 EMS could reduce environmental impacts, especially in waste field; The ISO14001 EMS would be one of the most effective methods to improve environmental performance
Hertin <i>et al.</i> (2008)	Evaluate the EMS's impacts on companies eco-efficiency	European companies in five industrial sectors	Review of key studies on connection between the EMS and environmental performance; Large dataset from the Measuring Environmental Industry (MEPI) program, which incorporated 15000 environmental performance data points from 274 companies of six manufacturing sectors in six EU countries; Three independent instruments statistical tools (simple regression, Jaggi-Freedman indices, "trend differences" approach)	Environmental regulation was related to the ISO14001 EMS effectiveness
~				No obvious evidence about the EMS's positive impacts on facilities environmental performance; Implication of social and soft policy

The majority of qualitative data is obtained from surveys, interviews (structured, semi-structured and open-ended) and in-depth case studies. Questionnaires and interviews usually use a ranking or Likert scale. Quantitative methods have also been used in numerous long-term research projects (e.g., the NDEMS program and Remas project). A combination of qualitative and quantitative methods has been adopted by some researchers (Dahlstrom *et al.*, 2003; Melnyk *et al.*, 2003; Sroufe, 2003; Anton *et al.*, 2004).

These studies reveal that presently there is no widely agreed methodology for evaluating EMS effectiveness (Hertin *et al.*, 2008). A case-by-case approach is considered to be acceptable as long as evidence can be found to provide support for the evaluation of the relevant EMS. The majority of the findings conclude that there is a positive correlation between an EMS and improved environmental performance (Edwards *et al.*, 1999; Ann *et al.*, 2006; Rashed *et al.*, 2008), although some studies find no clear relationship (Hughey *et al.*, 2005; Rowland-Jones *et al.*, 2005; Hertin *et al.*, 2008; Nawrocka and Parker, 2009).

In defence sectors, work is beginning on the evaluation of military EMSs with the aim of greening military strategies. Examples include the NATO-CCMS and Dartmoor Training Area cases have already been described. These examples provide useful background information for conducting the evaluation of a military-related EMS in future, examining connections between the effects of an EMS and the environmental performance of military activities.

In order to evaluate EMS effectiveness, the use of a supplementary instrument, an indicator framework comprising a set of complementary and objective indicators, has been suggested (Bowers and Cornish, 2000; Freimann and Schwedes, 2000; Kolk and Mauser, 2002; Dahlstrom *et al.*, 2003; Lundberg *et al.*, 2005). Dahlstrom *et al.* (2003) also noted that objective indicators for environmental performance measurement should be developed.

Many studies reviewed in this study have proposed various environmental indicator sets to assist in EMS evaluation (Edwards *et al.*, 1999; Sroufe, 2003; UNCCHDPP, 2003). Ramos *et al.* (2007a) provided a comprehensive review of environmental indicator initiatives relevant to defence sectors, citing initial work on estimating EMS effectiveness (Dawson, 2004; Viegas, 2005; Ramos *et al.*, 2007a). Indicator related issues are not the scope of this review, which have been discussed by Wu and Wang (2011) and Wu (2012).

## 2. CONCLUSION

The environmental management, especially in military activities, has been widely recognised as important by a large number of researchers and practitioners. Due to the complexity of defence operations, environment-related issues “need to be addressed in a systematic way” (Diecidue, 2008), for example, with the help of the ISO14001 EMS, one of the internationally best-known environmental management tools. As discussed in this study, there are no significant differences in the EMS adoption, structure and implementation between different countries and defence sectors. In any case, the key point is to examine how effective an EMS is in environmental management, rather than whether there is an EMS or not (Bowers and Cornish, 2000; Dawson, 2004). Based on a literature review, this study has contributed to an understanding of EMS implementation and evaluation in global defence sectors.

There is a wide range of application of an EMS all over the world. As illustrated in this review, there is no “one-size-fits-all” method (NOAACSC, 2007) for evaluation and analysis of an EMS (Rowland-Jones *et al.*, 2005). An EMS is a complicated system, requiring a number of criteria to evaluate its success that depend on different specific factors (e.g., organisational features, environment and management objectives). However, there is an absence of absolute environmental performance requirements specified in the ISO14001 standard (Andrews *et al.*, 1999; Rondinelli and Vastag, 2000; Lundberg *et al.*, 2005; Nawrocka and Parker, 2009). Therefore, it is difficult to accurately assess an EMS in a quantitative way (e.g., by calculating a final score), especially for the environmental management of military activities.

There have been many different methods used in previous studies to assess the EMS effectiveness, both quantitative and qualitative. Nawrocka and Parker (2009) noted that one significant difficulty of quantitative approach was obtaining high-quality quantitative data. Furthermore, measuring environmental performance, especially quantitatively, is a widely recognised challenge in the field of environmental management and EMS implementation (Rowland-Jones *et al.*, 2005; Hertin *et al.*, 2008). Both quantitative and qualitative methods have advantages and disadvantages. It is important to choose methods cautiously and appropriately, because each organisation has its own characteristics. Case-by-case analyses are required, considering such issues as the context (e.g., political,



environmental and economic), features of the study area, objectives and methods and management capabilities (Edwards *et al.*, 1997; NOAAACSC, 2007; Arimura *et al.*, 2008; Broderick, 2008; Zutshi *et al.*, 2008; Lennox *et al.*, 2011).

As can be seen from this review, although relevant studies have been conducted, they still do not provide sufficient understanding of an EMS's effect on policy formulation, environmental performance and social influence, especially in defence sectors. Knowledge gaps between the EMS efforts and improved environmental performance need to be identified; further research on how to evaluate EMS effectiveness is therefore needed (Gallagher *et al.*, 1999; Freimann and Schwedes, 2000; Lundberg *et al.*, 2005; Rashed *et al.*, 2008). For example, it is necessary to establish Environmental Performance Indicators (EPIs) and make them publicly available, in order to clarify the relationship between EMS implementation and environmental performance (Steger, 2000; Strachan *et al.*, 2003; Rowland-Jones *et al.*, 2005; Cheesbrough, 2006; Schylander and Martinuzzi, 2007).

Rather than self-assessment by managers (Ramos and Melo 2005; 2006; Ramos *et al.*, 2007a; 2007b; Rowland-Jones *et al.*, 2005), an independent evaluation through the collection of various data and information from different viewpoints has also been suggested, in order to obtain an integrated analysis (Greenwood, 2001; Beger *et al.*, 2005; Burger *et al.*, 2005). The internal assessment method is considered not comprehensive and objective enough; internal evaluations tend to give positive assessments (Rowland-Jones *et al.*, 2005; Hertin *et al.*, 2008; Nawrocka and Parker, 2009). Therefore, a "third-party evaluation" approach is important; it could "prevent bias, omission of important or 'bad news' events and improve credibility" (Greenwood, 2001). Additionally, it is important to collect various scientific data and high-quality information (e.g., reliable, verifiable, complete and comparable), improve environmental impact assessment, promote continuous environmental monitoring and reporting, in order to facilitate implementation and evaluation of an EMS (SASNZ, 2000; Burger *et al.*, 2005).

This study has furthered the knowledge of EMS application and evaluation practices and provided a reference for policy making and environmental management of an organisation. Environmental management is a changing process; the EMS implementation demonstrates an organisation's ability to respond to changes, leading to continuous improvement (Perron *et al.*, 2006). As shown in this review, it is difficult to define a single way to evaluate an EMS; it

should be revised and updated to respond to the changing situation (West *et al.*, 2006). Regular reviews will ensure effective interaction between the EMS modules. In a word, organisations need to find out the best way to use an EMS effectively and to gather convincing evidence to evaluate an EMS.

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