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Review

A comprehensive review of the development of zero waste management: lessons learned and guidelines

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ABSTRACT

Zero waste is a visionary concept for confronting waste problems in our society. The idea is being developed and implemented in various sectors including waste management and treatment, mining, manufacturing, and urban development. The zero waste concept has been embraced by policymakers because it stimulates sustainable production and consumption, optimum recycling and resource recovery. Professionals in waste management systems, however, perceive and apply it in different ways. This study aims to conceptualize zero waste development based on a critical review of available academic journal publications. Very few studies have been found in the domains of zero waste design, assessment and evaluation that have examined production, and sustainable consumption. This study reveals that the scope of the zero waste studies is diverse, and a zero waste concept is constantly developing through various programmes, plans, policies and strategies. The findings of this review study suggest that the zero waste programmes are applied in many countries without any holistic *zero waste strategy*. The study emphasizes that countries might be able to achieve zero waste goals by developing a national zero waste strategy and by integrating and promoting zero waste initiatives (in communities and industry) through waste management policy. This article presents a critical review of the major studies conducted by researchers on zero waste in the last decades. Based on the review findings the study concludes that zero waste concept has been applied widely in different phases of production and waste management systems. The findings of the study assist to identify priority areas of zero waste strategy and to develop national zero waste guidelines. Thus, this study can be useful to policy and decision makers in developing the evidence-based zero waste guidelines.

1. Introduction

In the industrial age, resource extraction and production of goods has constantly expanded to satisfy the ever-growing consumption culture (Lopez, 1994). A broad range of consumer products, such as cloth, white goods and electronic products, once treated as luxury items are now used as everyday goods (Crocker, 2013). Production processes have transformed into a complex system that mainly use composite and hazardous materials. As a result, the waste we produce today is from mixed sources, environmentally damaging and expensive to manage sustainably. The multiplicity of various waste streams leaves decision makers no other option but to choose inefficient and environmentally polluting waste management solutions such as landfill. The shortage of landfill sites in urban areas forces waste authorities to look for an alternative waste management systems (Wen et al., 2009).

Zero waste (ZW), a visionary waste management system, has been presented as an alternative solution for waste problems in recent decades (Connett, 2013a). Zero waste has become an aspirational goal for tackling waste problems. Many cities such as Adelaide, San Francisco and Vancouver have adopted zero waste goals as a part of their waste management strategies (Connett, 2006; SF-Environment, 2013). The ZW concept has been embraced by policymakers because it stimulates sustainable production and consumption, optimum recycling and resource recovery, and restricts mass incineration and landfilling. However, professionals in waste management systems perceive and apply the zero waste concept in different ways by. For instance, a number of studies have claimed to achieve ZW goals while using waste-to-energy technology, such as incineration, as a part of waste

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treatment (Abbasi et al., 2012; Björk, 2012; Premalatha et al., 2013), even though zero waste concepts prohibit incineration and landfills (ZWIA, 2009).

The aim of this study is to present the ZW development over time based on a critical review of available academic journal publications. Using the Scopus and Google Scholar databases, I have identified 96 peer-reviewed zero waste studies published between 1995 and 2014 and analysed them through a scoping study. In order to analyse ZW through a comprehensive perspective of global waste management systems, I considered various waste types including liquid waste, solid waste, and hazardous waste in my examination. The study may add to our knowledge based on available evidence for developing coherent and enhanced ZW strategies. Therefore, this review would be useful to public administrators who develop strategies and improve policies on zero waste.

2. The zero waste development

Waste management systems in place today were conceived long before the development of our modern civilization. Over time, innovations such as landfill, composting, recycling and advanced treatment methods have been implemented. The ZW is the most holistic innovation of the twenty-first century for achieving a true sense of sustainable waste management systems (Zaman and Lehmann, 2011a). Palmer (2004) first used the term "zero waste" in 1973 for recovering resources from chemicals. However, the concept has attracted much public attention since the late 1990s. A number of organisations worldwide have adopted the concept of zero waste, setting a target of zero waste disposals to landfill. The process of community consultation in Canberra, Australia originated the radical idea. Municipalities proposed the first 'no waste' bill, *No Waste by 2010*, in 1995 and Canberra became the first city in the world to adopt an official zero waste target (Connett, 2013b, p. 303; Snow and Dickinson, 2003, p. 5).

The establishment of the Zero Waste New Zealand Trust in 1997 supporting waste minimization initiated the zero waste movement in New Zealand. The Trust voiced a goal of creating "*a closed loop materials economy; one where products are made to be reused, repaired and recycled, an economy that minimises and ultimately eliminates waste*" (Tennant-Wood, 2003). In 2000, Del Norte County, California took on the first comprehensive zero waste plan in the United States and in 2001, the California Integrated Waste Management Board adopted zero waste goals as strategic waste management plans (Connett, 2013b, p. 307). Key milestones and events pertaining to zero waste development are given in Table 1.

In 2002, the Zero Waste New Zealand Trust defined zero waste as:

> "*… a new goal that seeks to redesign the way that resources and materials flow through society taking a 'whole system' approach. It is both an 'end of pipe' solution that maximises recycling and waste minimisation and a design principle which ensures that products are made to be reused, repaired or recycled back into nature or the marketplace. Zero Waste envisions the complete redesign of the industrial system so that we no longer view nature as an endless supply of materials*" (Tennant-Wood, 2003).

The Zero Waste International Alliance gave the first working definition of zero waste in 2004, which developed further in a peer-reviewed panel in 2009. According to the Zero Waste International Alliance, zero waste is defined as:

> "*… a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. ZW means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them*" (ZWIA, 2009).

Table 1
Key milestones and events on the zero waste development.

Year	Country	Milestones/events
1970s	USA	The term 'Zero Waste' was coined by Paul Palmer.
1986	USA	The National Coalition against Mass Burn Incineration was formed.
1988	USA	Seattle introduced the Pay-As-You-Throw (PAYT) system.
1989	USA	The California Integrated Waste Management Act was passed to achieve 25% waste diversion from landfill by 1995 and 50% by 2000.
1990	Sweden	Thomas Lindhqvist introduced 'Extended Producer Responsibility.'
1995	Australia	Canberra passed the 'No Waste by 2010' bill.
1997	New Zealand, USA	• The Zero Waste New Zealand Trust was established. • The California Resource Recovery Association (CRRA) organized conference on zero waste.
1998	USA	Zero waste was included as guiding principles in North Carolina, Seattle, Washington, and Washington, DC.
1999	USA	The CRAA organised zero waste conferences in San Francisco.
2000	USA	The Global Alliance for Incinerator Alternatives was formed.
2001	USA	GrassRoots Recycling Network published 'A Citizen's Agenda for Zero Waste.'
2002	New Zealand, USA	• The book *Cradle-to-Cradle* was published. • Zero Waste International Alliance was established. • The First ZW Summit was held in New Zealand.
2004	Australia, USA	• ZWIA gives a working definition of zero waste. • GRRN adopts ZW business principles. • Zero Waste SA was established in South Australia.
2008	USA	The Sierra Club adopted a zero waste producer responsibility policy.
2012	USA	• The documentary film *Trashed* premiered at the Cannes Film Festival. • The Zero Waste Business Council was established in the USA.

(Adapted from Connett (2013b).)

Others who wish to achieve holistic ZW goals have adapted and utilized the working definition. The Department of the Environment in San Francisco defines zero waste as "*sending nothing to landfill or incineration.*" (SF Environment 2011). Zero waste in England is defined as "*a simple way of encapsulating the aim to go as far as possible in* reducing the environmental impact of waste. It is a visionary goal which seeks to prevent waste occurring, conserves resources and recovers all value from materials." (Phillips et al., 2011).

3. Methods

Various research methodologies such as quantitative, qualitative and a combination of both methods (mixed method) can be applied based on the scope of a study (Bryman, 2006; Creswell, 2003). In this paper, a qualitative research method was used to analyse previous studies on zero waste. This study applied the three-tiered methodological approach similar to a recent review study conducted by Laurent et al. (2014): Identification, Classification, and Evaluation. The study carefully defined the scope (zero waste literature) and used reliable sources for the identification of relevant academic literature. The study classified available literature and then critically evaluated the zero waste study based on their relevance and significance. In addition, the study has analysed various ZW perceptions to better understand the ZW concept used by professionals. Several definitions of waste exist (Christensen, 2011), and in this review study both solid and liquid waste were considered.

3.1. Identification of the zero waste study

The study applied a two-step screening procedure to identify relevant studies in scientific journals. In the first step, study used Scopus database as a search engine which has indexed over 15,000 peer-reviewed journals (Scopus, 2014). The study systematically screened the ZW studies using 'zero waste' and 'zero-waste' as keywords. After careful evaluation, study fixed the timeframe of the ZW research from 1995 to July 2014 and considered ZW themed articles published during this period for review. In the second step, study cross-checked all cited literature using Google Scholar search engine. After compiling all findings from both steps, author identified a total of 96 peer-reviewed journal publications to classify and evaluate.

3.2. Classification and evaluation of the studies

The study identified the following six criteria to classify the chosen studies: (1) time of publication, (2) types of publication, (3) geographical location of the study, (4) types of waste considered, (5) key research aspects, and (6) extent of the study with respect to the ZW concept. Table 2 shows key criteria considered in the review study.

A holistic ZW life cycle broadly includes seven phases: (1) resource extraction and processing, (2) product design, (3) manufacturing, (4) consumption and waste generation, (5) waste management, (6) waste treatment, and (7) waste disposal. The study considered all ZW life phases and evaluated each study to identify the extent, relevance and scope of the ZW studies. Detailed classification and evaluation of the studies are presented in Appendix A. The study judged the relevance and scope of the ZW studies based on (1) usage of zero waste terminology, (2) usage of 'zero waste' with no further explanation, (3) usage of 'zero waste' with a partial explanation, and (4) extensive usage of 'zero waste' with a considerable amount of discussion.

Table 2
A brief scoping of the classification and evaluation criteria.

Classification criteria	Brief scoping
Time of publication	Year in which the study was published.
Types of publication	• A – article • RA – review article • R – report • CP – conference proceedings • E – editorial • N – note
Geographical location	Country where the case study was performed.
Types of waste	• Municipal solid waste (including household waste, organic waste, construction and demolition waste) • Industrial waste (including industrial waste-water treatment) • Mining waste (including mining production and treatment) Hazardous waste (including radioactive and electronic waste)
Key research aspects	Analysis of the main focus and aim of the study.
Relevance and scope of the ZW study	Four symbols indicate the extent of the study: ○ – Zero waste term is used without any further supportive argument Δ – Zero waste concepts are used with a limited or short argument □ – Zero waste concepts are used with a considerable amount of discussion ⌂ – Zero waste concepts are used within a holistic *zero waste management* system

4. Results and discussion

The study has presented findings of the zero waste studies according to the publication date, types of publications, major publisher, types of waste studied and the relevance and scope of the study. The following sections present major findings of the review study.

4.1. Zero waste studies over the time

The study categorised the types of published articles as a journal article, conference paper, review article, note or technical note, or others types of publication. A significant proportion (about 79%) of publications was published as journal articles (see Fig. 1). Conference papers accounted for 7% of publications followed by review papers (4%) and technical notes (4%). The percentage distribution of the publications is illustrated in Fig. 1. Studies of ZW have increased over time, and the categorical percentage distribution of the publications has also expanded. The ZW movement attracted people's attention when the ZW concept was used to describe a 'zero waste community.' In 2002, the city of San Francisco established a goal of 75% diversion by 2010 and ZW by 2020 (SF-Environment, 2014) that also elevated a widespread ZW practices. In 2004, the Zero Waste International Alliance adopted the first peer-reviewed, internationally accepted definition of zero waste (ZWIA, 2004), which helped to understand and define a practical use of the holistic ZW concept.

Fig. 2 shows the number of publications each year and the distribution of the papers among journals. It is evident from the table that research on zero waste has been conducted widely in the last decade, and the number of ZW studies has increased since 2003. A substantial number of articles (17 articles equivalent to 18%) were published in 2007. Interestingly, ZW studies have been published in a wide range of journal publications including Journal of Waste Management (6 studies), Journal of Cleaner Production (6 studies), Journal of Material Cycles and Waste Management (5 studies), Resources, Conservation and Recycling (5 studies), Waste Management & Research (5 studies), Environmental Development and Sustainability (5 studies). Other journals accounted for 57 articles in the sample timeframe.

4.2. The contextual settings

Waste professionals have conducted ZW studies from every continent on earth. Fig. 3 shows the geographical distribution.

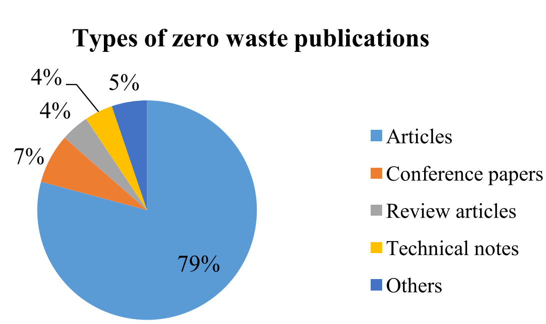

Fig. 1. Types of zero waste publications.

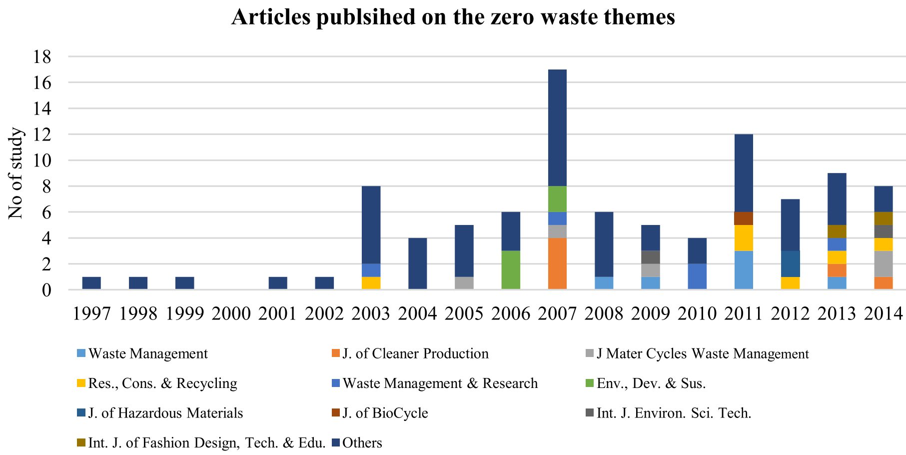

Fig. 2. ZW studies published between 1997 and 2014.

Eight-one studies covered 28 countries. Australia and the USA each reported 12 case studies. The next greatest number of case studies came from South Africa (7), England (5), Taiwan (5) India (5), Sweden (4), China (3), Japan (3), Thailand (3) and Brazil (3). American and European countries contributed the same proportion (16%) of ZW studies, whereas Asia contributed the most (24%). Oceania countries contributed around 11% and African countries contributed around 5%. The rest (26%) were holistic and generic. It is evident from the figure that the zero waste programmes and studies have not yet been documented in a large number of countries around the globe. The experiences of all jurisdictions that implement zero waste programmes are important and necessary to consider when developing zero waste strategies in a new place.

4.3. Waste typology

Zero waste studies cover a broad range of waste types from municipal solid waste to radioactive waste. Fig. 4 shows 45 ZW studies (47%) conducted on municipal solid waste, 38 studies (40%) concerned industrial waste (including industrial waste-water treatment), 6 studies (6%) were on hazardous waste (including radioactive waste and electronic waste), 5 studies (5%) were on mining waste and 2 studies (2%) were on holistic and generic waste types. It is evident that the zero waste studies covered a broad range of waste types. Surprisingly, no one documented construction and demolition (C&D) waste for a zero waste study. This does not necessarily mean that C&D waste management does not aim to achieve zero waste goals, but my search criteria did not uncover studies of zero waste management systems.

4.4. Relevance and scope

Zero waste is a holistic approach which considers the whole life cycle of a product from the extraction of resources to the final disposal. Fig. 5 shows a schematic life cycle diagram of the ZW management system. Natural resources such as gas, coal, oil, and minerals are mined in the extraction phase. Products are designed and manufactured and then distributed through retailers to consumers. After consumptions and utilization of products, waste is generated. A small proportion of waste is recovered using reuse and recycling techniques and waste treatment technologies, and the large proportion of waste is disposed of to landfill. The ZW approach encourages zero landfills and a 100% resource recovery from waste.

The scope of ZW study covers every ZW life phase from extraction of resources to the final disposal of waste. Researchers conducted a significant number of studies (approximately 58) on regulatory policy (19%). The greatest number of studies (67) were conducted on waste management (22%) followed by ZW extraction processes (32 studies) and ZW treatment (31 studies). Fig. 6 shows the scope of the ZW studies. It is evident from the figure that zero waste studies focused on a number of life cycle phases

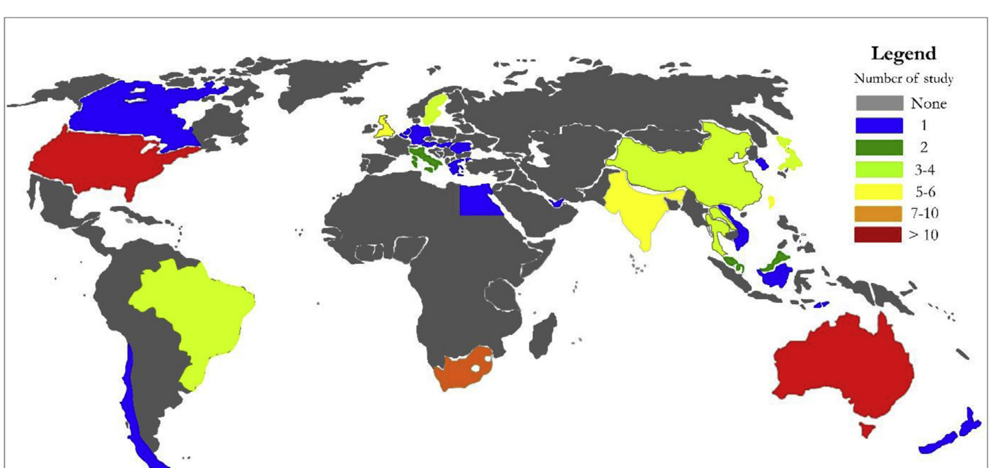

Fig. 3. Geographical distribution of the ZW study (not to scale).

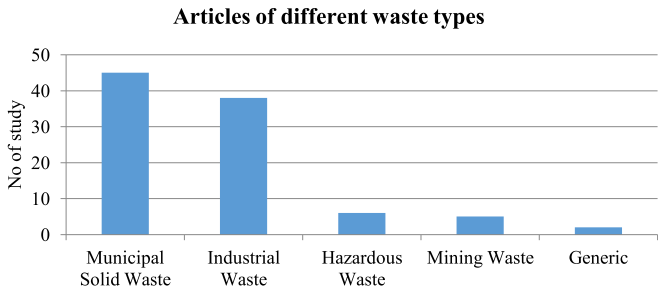

Fig. 4. Types of waste included in the ZW research.

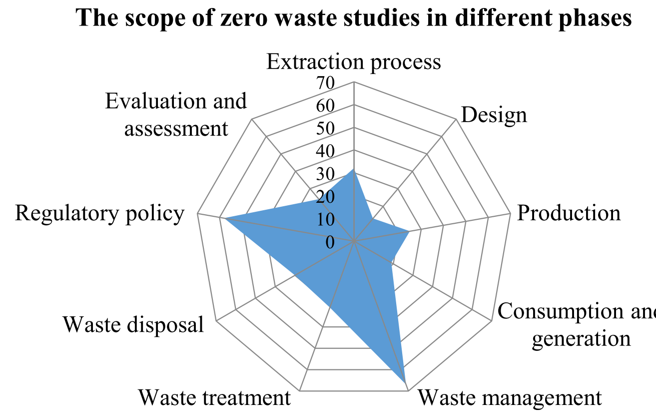

Fig. 6. The scope of the ZW studies.

including: extraction of resources, design, production, consumption and waste generation, waste management, treatment, regulatory framework and evaluation of waste management performance. However, the scope of the studies was not equally distributed. For instance, very few studies were conducted on product design and zero waste evaluations. It is important to acknowledge that we need to study, practice and implement zero waste practices in every phase of the zero waste life cycle to achieve zero waste goals. Zero waste research should focus on zero waste design and production. If products are designed and manufactured by applying cradle-to-cradle principle, it would be easier to recover all resources from waste and thus the zero waste design would ensure effective resource utilization optimum recycling programmes.

The study analysed the extent, significance and relevance of studies using nine scoping criteria (see Appendix A). Fig. 7 shows the overall extent of the studies. Around 24% of the studies used the term 'zero waste' with no further supportive information, around 18% of the studies used the ZW concept with a limited or short argument, 16% of the studies used the ZW concept with a considerable amount of argument and discussion and 43% of the studies used the ZW concepts within a holistic ZW management systems. The study determined the relevance of the documented zero waste studies conceptually, using zero waste terminologies. It is not surprising to see the lack of relevance as zero waste is still an emerging concept. This study asserts that the zero waste studies that aligned with the core principles of zero waste philosophy are important and more will be required frequently in the future.

4.5. Lessons learned from zero waste studies

Professionals from multidisciplinary research areas practice zero waste in mining, process technology, industrial design and production, waste treatment and management, and, sustainable consumption. Hence, the focus and application of the core ZW philosophy is different in different areas. The ZW concepts are further expanded and conceptualized in various studies as holistic approaches of zero waste society (Bartl, 2011; Whitlock et al., 2007), zero waste community (Dileep, 2007), zero waste city (Lehmann, 2012; Premalatha et al., 2013; Zaman and Lehmann, 2011b), zero waste living (Khan et al., 2007), zero waste campus (Mason et al., 2003), zero waste places (Phillips et al., 2011), zero waste practices, programmes and strategies (Cole et al., 2014; Connett and Sheehan, 2001; Johnston, 2014). The material flow in an urban system is better understood in holistic zero waste approaches (Kumar et al., 2005; Zaman and Lehmann, 2011b). The close-cycle material flow based on nature's no waste principles is applied in the zero waste system which also promotes a circular economy (Greyson, 2007; Zaman, 2012). However, a number of studies claim to achieve a zero emission and zero waste system while using waste-to-energy technology, which is contradictory to the zero waste philosophy (Premalatha et al., 2013). It is important to understand and maintain zero waste principles while claiming

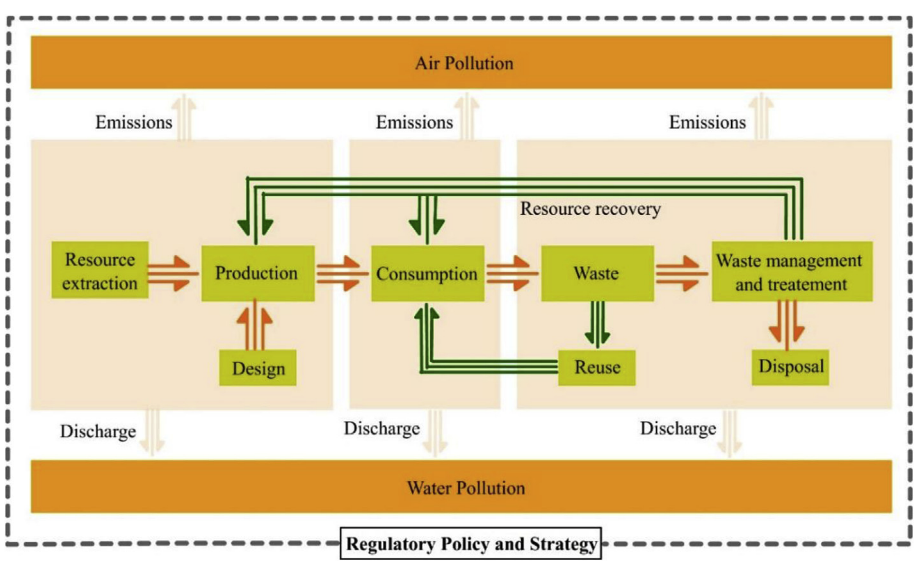

Fig. 5. The life cycle of zero waste management systems.

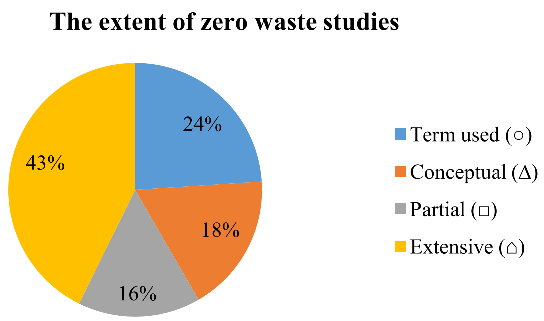

Fig. 7. The extent of the zero waste studies.

zero waste achievements. The following sections present the key lessons learned from the zero waste studies.

4.5.1. Zero waste extraction and process

Zero waste is used in mining and resource extraction industries as an innovative technique to eliminate waste by applying advanced technologies, such as ZW polymer technology and ZW metal processing (Antrekowitsch and Steinlechner, 2011; Bochek, 2008), and using by-products for other useful purposes (Ahmed et al., 2014; Chiang et al., 2014; Krajnc et al., 2007). However, most of the ZW studies in the mining and resource extraction industries use the term 'zero waste' at conceptual levels without explaining the scope of the study and the overall benefits of the ZW goals.

We assume extraction and use of a natural resource will affect the environment adversely (Noel, 1978). If we continue to extract global, non-renewable resources at today's rate, we predict we will likely experience permanent global shortfall of 23 non-renewable resources, such as cadmium, gold, mercury, tellurium and tungsten, by 2030 (Clugston, 2010). There are limited numbers of zero waste studies which addressed these problems. Instead of traditional sources for resource extraction and mining, an alternative source is essential, for instance, urban mining that is resource extraction from waste.

4.5.2. Zero waste design and production

The holistic ZW concept is used in design and manufacturing phases. However, very few studies were available that addressed ZW design. The ZW design has been mainly implemented and tested in fashion industries (Carrico and Kim, 2014; Martins et al., 2013; Niinimäki, 2013). Zero waste design is one of the fundamental aspects of achieving ZW goals because it eliminates unnecessary waste creation at the first phase of production through green engineering and production principles (Anastas and Zimmerman, 2003). The design professionals mainly perceive ZW production as integration of 'lean' production processes, industrial ecology and cradle-to-cradle design principles that eliminate waste at the production phase (Black and Phillips, 2010; Braungart et al., 2007; Paez et al., 2004). The waste by-products that industry produces during manufacturing are further used through industrial symbiosis (Lin, 2012; Termsinvanich et al., 2013).

Cradle-to-cradle design, which is an important part of zero waste design philosophy, is primarily based on *eco-effectiveness* to celebrate the creative and extravagant application of materials; it allows for short product lifespans under the condition that all materials retain their status as productive resources (Braungart et al., 2007). From the holistic point of view, ZW and eco-effectiveness strategies are not contradictory to each other; instead, they can be supportive and promote holistic sustainable development. The zero waste product design and manufacture is a key factor in achieving zero waste goals, because zero waste product design and manufacture not only ensures up-cycling by avoiding and eliminating waste at the place of production, it also promotes optimum recycling and recovery of resources from waste.

4.5.3. Sustainable consumption and waste generation

Sustainable resource consumption is one of the preconditions for moving towards ZW goals. Sustainable consumption is not about consuming less but consuming efficiently to improve the quality of life while minimizing waste and environmental damage (Jackson, 2005; UNEP, 1999). Surprisingly, a scarce number of studies adequately addressed the problems and challenges associated with over-consumption and waste problems. The ambitious 'zero consumption' concept considers materials that become useful without losing their capacity to feed the system again after being used. Thus, the concept of 'consumption' itself is replaced by one of 'use' when resources are inserted into closed loops systems (Orecchini, 2007). A limited number of studies (Bartl, 2011; Lehmann, 2011; Zaman and Lehmann, 2011a) addressed existing over-consumption trends, barriers, and the needs for sustainable behaviour to achieve ZW goals.

Many studies suggest that over-consumption leads to generate excessive waste (Clapp, 2002; Gutberlet, 2003; Wahab and Lawal, 2011). Sustainable consumption practices promote responsible consumption behaviour which ensures zero production of unwanted waste. It is possible to avoid and prevent waste creation of unwanted and excessive waste through sustainable consumption. In addition to the sustainable consumption, a systematic transformation of existing inefficient manufacturing systems is also required for eliminating waste creation.

4.5.4. Zero waste management and treatment

Most of the ZW studies addressed holistic ZW management systems by integrating avoidance, recycling, and advanced waste treatment technologies. In traditional waste management systems, waste is considered an 'end-of-life' product, produced in the last phase of product-consumption. Hence, the management techniques are mainly based on 'end-of-pipe' solutions. Zero waste challenges the traditional definition of waste by recognising that waste is a transformation of resources that happens in the intermediate phase of resource consumption. Resources that are transformed into waste as a result of our consumption activities should, therefore, be redirected into production through holistic ZW management systems (Zaman, 2014a). Thus, ZW management is a combination of integrated design and waste management philosophies.

Currently, most cities have developed zero waste goals by targeting zero waste landfills (Connett and Sheehan, 2001). For instance, San Francisco's zero waste target is to achieve zero waste landfill by 2020 through diverting waste from landfills. Undoubtedly, achieving a 100% diversion rate is not possible in the current forms of production, consumption and waste management systems in our society. It requires a universal transformation of existing extraction, production, marketing, consumption, management and treatment systems.

4.5.5. Zero waste regulatory policies and assessment

A considerable number of studies (58) address zero waste plans, regulatory policy and implementation strategies. Zero waste studies on regulatory strategy focus on a range of problems from very specific waste problems, such as a zero waste processing and treatment (Brady, 2004; González et al., 2005), to holistic ZW implementation policies (Yoo and Yi, 2014; Zotos et al., 2009). Many cities around the globe have adopted zero waste strategies, policies and plans to achieve zero waste goals. Local communities, government institutes, research institutes and business organizations are taking part in the zero waste movement. Zero waste regulatory policies are important to guide and promote the zero waste practices within all sectors of society.

Researchers examine zero waste performance through a number of evaluation tools, such as the ISB (infrastructure, service, and behaviour) model and the ZW index tool. The ISB model can be used by waste practitioners when planning interventions that maximize recycling better to understand the situation and context for behaviour (Timlett and Williams, 2011). The ZW index is a tool to measure the potentiality of virgin materials offset by ZW management systems. The ZW index forecasts resource recovery and environmental benefits from waste management systems by measuring the reverse resource flow (Zaman and Lehmann, 2013b).

4.6. Overarching guidelines for strategic ZW development

Despite that fact that zero waste has been introduced and is in practice for the last few decades, the concept is yet in development. This review study revealed that the concept is used and practised in the various resource extraction, production and waste management fields. The overarching guidelines for strategic ZW development can be broadly implemented in the following four phases (see Fig. 8):

The first phase integrates and applies various methods and techniques of resource extraction, industrial ecology, cradle-to-cradle, and green engineering principles to promote industrial symbiosis and up-cycling processes. The zero waste extraction strategies should ensure utilization of existing resources in society instead of extracting virgin materials and non-renewables resources. The industrial ecology, cradle-to-cradle, and green engineering principles apply integrally to ensure minimum environmental degradation and optimum resource utilization through eco-effectiveness. It is often recommended that producers should not manufacture products which are not easy to disassemble, recycle and recover resources from the end-of-life product (Ziout et al., 2014). Avoidance, prevention, and reduction of waste are possible in these segments through sustainable design, production, consumption and motivations (Tseng, 2013; Vallero, 2011).

The second phase ensures citizens' responsibility in regards to resource consumption and behaviour. Sustainable consumption practices are very important for local and global communities. Current over-consumption practices generate an enormous amount of waste, and a significant proportion of waste can be minimised and avoided through responsible behaviour and sustainable consumption practices. Sustainable consumption practices empower individual attitudes and decision making during consumption activities. Previous studies showed that sustainable consumption and behaviour patterns which lead to waste reduction are seldom socially oriented and exposed to peer pressure, and is thus dependent on individual attitudes (Cecere et al., 2014).

Zero waste management and treatment are the third phase of implementing ZW strategies, which are based on 'down-cycling.' In this phase, waste sorting, collection, recycling, resource recovery and treatment should follow strict ZW guidelines to optimum resource recovery with minimal environmental degradation. Zero waste management should promote economic activities by creating job opportunities and a circular economic society (Lee et al., 2014). Producers play key roles along with waste management service providers in the ZW

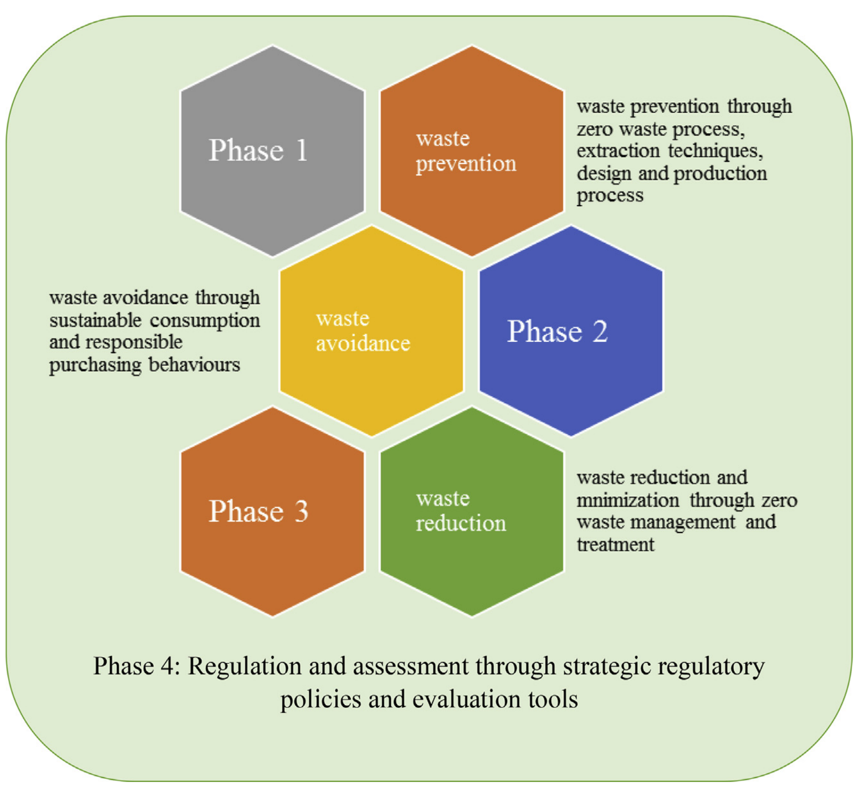

Fig. 8. Phases in implementing zero waste guidelines.

management system. Extended producer responsibility is one of the vital tools to ensure product stewardship and protect the environment.

In the final phase of ZW strategies, regulatory policy can play its role to guide ZW development by promoting ZW programmes, plans and activities and by putting restrictions on mass burning and landfill technologies. Zero waste policies and strategies should promote recycling activities by creating waste recycling jobs and hence contribute to circular economic growth. The ZW assessment and evaluation tools are important to evaluate ZW systems in regards to socio-economic and environmental performances. Therefore, holistic ZW strategies and guiding principles should consider all seven segments of ZW life cycle.

5. Conclusions

Zero waste is a holistic approach to tackling waste problems in the twenty-first century. Based on the review of the literature, this study concludes that zero waste is still in development. Professionals have proposed various ideas, plans, policies, and strategies and have implemented them in cities to achieve zero waste goals. However, we need to redevelop the holistic ZW strategy in regards to its implementation practices and practicality. At this moment, ZW strategy is targeted toward zero landfills through diverting waste from landfills. However, the study acknowledges that achieving a 100% diversion rate is not currently possible in production, consumption and waste management systems in our society. We require a universal transformation of existing extraction, production, marketing, consumption, management and treatment systems. Therefore, studies on how to transform existing systems into ZW systems are important for moving towards ZW goals.

This review study attempted to incorporate all relevant research conducted on zero waste in the last decades. The study identified the scope and relevance of previous studies in regards to the implication of the zero waste philosophy. The findings of this study are important for policymakers who develop zero waste policies, as the study identified the key gaps and trends in current zero waste studies. Based on the available evidence, the study has presented overarching and guiding principles as recommendations for zero waste development.

This review study revealed that different professionals are practising and applying zero waste in several areas, even though the scale and scope zero waste are diverse. A scarce number of studies addressed ZW design, production, sustainable consumption, and ZW assessment and evaluation domains. Countries may be able to achieve zero waste goals by developing a national zero waste strategy and by integrating and promoting zero waste initiatives (in communities and industry) in waste management policy. This article has presented a critical review of the major research conducted on zero waste. Based on the review findings, this study concludes that zero waste concept has been applied widely in different phases of production and waste management systems. The findings of the study assist to identify priority areas of zero waste strategy and to develop national zero waste guidelines. Therefore, this article can be useful for decision and policymakers who develop evidence-based zero waste guidelines.

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Appendix A. Classification and analysis of zero waste studies

Reference	Article types[a]	Geographical location	Waste types	Study focus	Zero waste life-phases addressed in the studies (√)									Scope of study[b]
					Extraction process	Design	Production	Consumption/ generation	Management	Treatment	Disposal	Reg. policy	Evaluation	
Ahmad et al. (2012)	RA	Asia	Industrial waste	Zero waste water treatment process	√									○
Amaral Filho et al. (2010)	CP	Brazil	Mining waste	Zero waste coal mining	√									○
Anastas and Zimmerman (2003)	A	Generic	Industrial waste	Green engineering design and production		√	√							Δ
Antrekowitsch and Steinlechner (2011)	A	Generic	Industrial waste	Zero waste process for metal industries	√									○
Ball et al. (2009)	A	Generic	Industrial waste	Zero waste production and supply chain management.			√	√	√	√				⌂
Bartl (2011)	E	Generic	MSW	Barriers in creating a zero waste society					√			√		Δ
Bochek (2008)	A	Generic	Industrial waste	Zero waste process technology for polymer industries	√									○
Brady et al. (2008)	A	USA	Industrial waste	Zero waste through biodiesel from organic waste	√				√	√				□
Braungart et al. (2007)	A	Generic	Generic	Eco-effectiveness and cradle-to-cradle design		√	√		√			√		⌂
Braungart (2007)	A	Generic	Generic	Cradle-to-cradle design principles		√	√		√			√		⌂
Carrico and Kim (2014)	A	Generic	Industrial waste	Zero waste apparel design		√	√							Δ

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Reference	Article types[a]	Geographical location	Waste types	Study focus	Zero waste life-phases addressed in the studies (√)									Scope of study[b]
					Extraction process	Design	Production	Consumption/ generation	Management	Treatment	Disposal	Reg. policy	Evaluation	
Carvill (2012)	RA	USA	MSW	Kerbside waste collection to zero waste movement					√			√		Δ
Chavalparit et al. (2013)	A	Thailand	Industrial waste	Nature of the industrial ecosystems	√		√		√		√	√		⌂
Chen and Houng (2004)	CP	Taiwan	MSW	Community based collection and market creation					√			√		Δ
Chiang et al. (2014)	A	Generic	Industrial waste	Zero waste sequestration	√		√							Δ
Chung and Lo (2004)	A	China	MSW	Waste education and avoidance preferences					√		√		√	□
Ciampichetti et al. (2002)	A	Generic	Hazardous waste	Zero waste options for radioactive waste						√				○
Clay et al. (2007)	N	Australia	MSW	Recycling and cleaner production programmes			√		√			√		□
Cole et al. (2014)	RA	England	MSW	Zero waste strategy and programmes				√	√		√	√	√	⌂
Colon and Fawcett (2006)	A	India	MSW	Community initiatives to promote zero waste					√	√	√	√	√	⌂
Connett (2007)	R	Australia, Canada, USA, Italy	MSW	Zero waste as an agenda for sustainable society				√	√	√	√	√		⌂
Connett and Sheehan (2001)	R	USA	MSW	Zero waste movement			√		√	√	√	√	√	⌂
Curran and Williams (2012)	A	Europe	Industrial waste	Zero waste system, industrial networks, symbiosis		√	√		√	√		√	√	⌂
David and Kopac (2012)	A	Romania	Hazardous waste	Zero waste industrial chemical process	√		√					√		□
Dey and Bhattacharyya (2007)	A	India	Mining waste	Multi-product zero waste application of coal mines	√									○
Dieu (2006)	A	Vietnam	Industrial waste	Zero waste industrial ecosystem	√	√	√		√					⌂
Dileep (2007)	A	India	MSW	Waste management in tourism industry					√	√	√	√		⌂
Dusseault (2011)	A	Generic	Mining waste	Zero waste discharge in petroleum industry	√									○
Fehr (2012)	A	Brazil	MSW	Reverse logistics for waste management system					√		√	√		□
Fujita and Hill (2007)	A	Japan	MSW	Zero waste city through industrial ecology		√	√		√		√	√		⌂
Gentil et al. (2011)	A	England	MSW	Environmental consequences of waste prevention			√		√				√	□
Gjetley and Pierre (2003)	CP	USA	MSW	Green purchasing and zero landfills				√	√		√	√		⌂
González et al. (2005)	A	Chile	Mining waste	Zero waste process	√									○
Gravitis et al. (2010)	A	Generic	Industrial waste	Zero-waste emission technologies	√						√			Δ
Greyson (2007)	A	Generic	MSW	Economic instrument for circular economy					√			√		□
Grishina et al. (2007)	A	Generic	Industrial waste	Zero waste process and production	√									○
Haslenda and Jamaludin (2011)	A	Malaysia	Industrial waste	Zero waste process and industrial symbiosis	√				√	√				□
Hiranandani (2014)	A	USA, Netherlands, Australia, South Africa	Industrial waste	Sustainable policies and practices								√		○
Hu et al. (2004)	A	Generic	Industrial waste	Zero waste emission	√									○
Huang and Shih (2009)	A	Taiwan	Industrial waste	Environmental performance and knowledge management	√				√			√		□

Interpol (2009)	N	USA, England	Hazardous waste	Informal e-waste recycling and crime					√			√		○
Jewell et al. (2004)	A	South Africa	Industrial waste	Zero waste treatment technology					√	√				Δ
Karani and Jewasikiewitz (2007)	A	South Africa	MSW	Waste management strategy	√				√	√				□
Kathiravale and Muhd Yunus (2008)	A	Malaysia	MSW	Advance waste treatment technologies					√	√	√			□
Khan et al. (2007)	A	Generic	Industrial waste	Process technology for zero waste living	√				√	√	√	√		⌂
Klee (1999)	A	Fiji	MSW	Integrated bio-system					√	√				Δ
Krajnc et al. (2007)	A	Generic	Industrial waste	Sustainable production and assessment indicators	√		√		√			√	√	⌂
Krajnc et al. (2007)	A	Slovenia	Industrial waste	Zero waste production and environmental performance	√		√		√			√	√	⌂
Kumar et al. (2005)	CP	India and china	MSW	Multi-use Zero waste recycling					√	√	√	√		⌂
Lang (2005)	A	Singapore	MSW	Zero landfill and zero waste through the greening of industry					√	√	√	√		⌂
Lehmann (2011)	A	Australia, Denmark, Egypt, India, Brazil	MSW	Sustainable consumption and zero waste economy			√		√	√	√	√		⌂
Lin and Lin (2005)	A	Taiwan	MSW	Waste legislation and recycling activities					√			√		Δ
Lindorfer et al. (2008)	A	Austria	Industrial waste	Zero waste process for metal industry	√									○
Liu et al. (2012)	A	Generic	Mining waste	Zero waste recovery process	√									○
Maedgen and Hunt (1998)	A	Generic	Industrial waste	Zero waste steel production	√									○
Mason et al. (2003)	A	New Zealand	MSW	Zero waste practices and programmes				√	√		√	√		⌂
Matete and Trois (2008)	A	South Africa	MSW	Zero waste models and strategy				√	√		√	√		⌂
Montoneri et al. (2014)	A	Italy	Industrial waste	Zero waste bio-surfactants process	√									○
Morioka et al. (2003)	A	Japan	Industrial waste	Industrial ecology and zero waste factory		√			√		√	√		⌂
Murphy and Pincetl (2013)	A	USA	MSW	Regulatory framework and zero waste planning process				√	√	√	√	√		⌂
Nicol and Thompson (2007)	A	EU and North America	Hazardous waste	Extended producer responsibility and product stewardship					√		√	√		□
Niinimäki (2013)	A	USA	Industrial waste	Zero waste fashion design practices		√	√		√					□
Oosterveer et al. (2006)	A	Thailand, Vietnam	Industrial waste	Environmental performance of industries			√		√			√		○
Orecchini (2007)	A	Generic	Industrial waste	Zero consumption through closed-cycles of energy resources	√		√		√			√		⌂
Phillips et al. (2011)	A	England	MSW	Zero waste strategy and places				√	√			√	√	⌂
Premalatha et al. (2013)	A	China, Abu Dhabi	MSW	Zero waste and zero-emission city		√			√			√	√	⌂
Randall et al. (2011)	A	South Africa	Industrial waste	Zero waste water treatment process	√									○
Shao et al. (2011)	A	Generic	Industrial waste	Zero waste gas emission	√									○
Snyman and Vorster (2010)	A	South Africa	MSW	Zero waste model and treatment technologies					√	√	√	√	√	⌂
Stave (2008)	CP	USA	MSW	Zero waste system dynamic			√	√	√	√	√	√	√	⌂
Sullivan (2001)	A	USA	MSW						√			√		Δ

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Reference	Article types[a]	Geographical location	Waste types	Study focus	Zero waste life-phases addressed in the studies (√)									Scope of study[b]
					Extraction process	Design	Production	Consumption/ generation	Management	Treatment	Disposal	Reg. policy	Evaluation	
				Zero waste policy, strategy and programmes										
Tennant-Wood (2003)	A	Australia	MSW	Zero waste events and programmes					√			√		Δ
Timlett and Williams (2011)	A	England	MSW	Recycling behaviour and evaluation tool		√		√	√			√	√	⌂
Townsend and Mills (2013)	A	Generic	Industrial waste	Zero waste fashion design		√	√							Δ
Usapein and Chavalparit (2014)	N	Thailand	Industrial waste	Zero landfill waste					√				√	Δ
Uskoković (2007)	A	Generic	Industrial waste	Zero waste nano-technologies		√						√		Δ
Vadapalli et al. (2012)	A	South Africa	Industrial waste	Zero waste process	√									○
van Kempen (2003)	CP	Generic	Industrial waste	RE-Cycle Concept					√	√				Δ
Wang et al. (2003)	A	Generic	Industrial waste	Pulverised coal combustion as a zero waste process	√									○
Weng et al. (2009)	A	Taiwan	MSW	Consumer behaviour and econometric modelling				√	√			√	√	⌂
Whitlock et al. (2007)	CP	Generic	Industrial waste	Waste-water management in a zero waste society						√		√	√	□
Wrona and Julien (1997)	A	Generic	Industrial waste	Zero waste plant and production					√	√		√		□
Yoo and Yi (2014)	A	South Korea	MSW	Zero waste optimization planning and strategy					√	√	√	√	√	⌂
Yoshida et al. (2012)	A	Japan	MSW	Material-cycle society					√			√		Δ
Young et al. (2010)	A	Taiwan	MSW	Zero waste environment					√	√	√	√	√	⌂
Zaman and Lehmann (2011a)	A	Australia, USA, Sweden	MSW	Challenges and barriers in zero waste				√	√	√		√		⌂
Zaman and Lehmann (2011b)	A	Australia, Sweden	MSW	Material flow in a zero waste city				√	√	√		√		⌂
Zaman (2012)	A	Australia	MSW	Social business mode for a circular economy				√	√			√		□
Zaman and Lehmann (2013b)	A	Australia, Sweden	MSW	Zero waste index as a performance evaluation tool			√	√	√	√	√	√	√	⌂
Zaman and Lehmann (2013a)	A	Australia, Sweden	MSW	Resource forecasting from waste			√	√	√	√	√	√	√	⌂
Zaman (2014b)	A	Australia	MSW	Performance assessment using the zero waste index			√	√	√	√	√	√	√	⌂
Zaman (2014a)	A	Australia	MSW	Zero waste indicators				√	√	√	√	√	√	⌂
Zorpas and Lasaridi (2013)	RA	Generic	MSW	Zero waste evaluation				√	√			√	√	⌂
Zotos et al. (2009)	A	Greece	MSW	Holistic waste strategy and framework					√		√	√	√	⌂
Zucchetti (2005)	N	Generic	Hazardous waste	Zero waste options for radioactive waste	√									○
Zucchetti and Sugiyama (2006)	A	Generic	Hazardous waste	Zero waste options for radioactive waste	√									○

[a] Types of article: A – article, RA – review article, R – report, CP – conference proceedings, E – editorial, N – note.

[b] Extent and scope of the Zero waste study: Zero waste term is used without any further supportive argument: symbol used – ○; Zero waste concepts is used with a limited or short argument: symbol used – Δ; Zero waste concepts is used with a considerable level of discussion: symbol used – □; Zero waste concepts is used within a holistic Zero waste management systems: symbol used – ⌂.

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