# Industrial Hazardous Waste Management: Avenues for Collaborations

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## Abstract

*As nations industrialized people benefited greatly from the advances in technology but with negative effects of pollution and production of hazardous waste. On the other hand, with growing demand for raw materials for industrial production the non-renewable resources are declining gradually. Disposing of any kind of waste including industrial hazardous wastes is a loss of resource as disposed wastes contain a lot of reusable substance of high value as one industry's hazardous waste could be resource to another industry. This paper aims to present a framework to manage industrial hazardous waste through a collaborative strategy in Sri Lanka. The study was conducted through survey approach and semi structured interviews were carried out to elicit relevant opinions from industry professionals and waste management experts. Content analysis was used to arrive findings of the research. Findings revealed that few collaborative strategies for industrial hazardous waste management are exist while more to implement.*

***Keywords***: *Industrial Waste, Hazardous waste management, Collaborative approach, Sri Lanka*

## 1.0 Introduction

Globalization, rapid population growth and industrial development have led to the huge quantity of industrial waste during last few decades (Rai and Rao, 2005). The term industrial waste refers to all waste arising from industrial operations or derived from manufacturing processes (Jasem, Alhumoud, Fatima and Kandari, 2008). Industrial waste is broadly divided into hazardous and non-hazardous waste.

An industrial waste can be considered hazardous if its extract concentration exceeds maximum concentration of contaminants according to the toxicity characteristic leaching procedure (Tsai, 2010). Therefore, when hazardous waste dumped indiscriminately in any environmental media it readily contaminates surface and ground water and finds its way into food chains creating both short and long-term effects on both human and ecological systems (Misra and Pandey, 2004; Nelson, 1998). The need for a long-term management of industrial hazardous waste is obvious in terms of the impact upon the environment, and consequences for human health (Collier, 2003). Lal and Reddy (2005) stated that scientists and industrialists have made efforts to solve the challenging problem faced due to industrial hazardous waste including introduction of certain alternatives for disposing of the same waste.

Merely disposing of any kind of waste including industrial hazardous wastes is a loss of resource as disposed wastes contain a lot of reusable substance of high value. Launfenberg (1996) further added that these residual products could be transferred into commercial products either as raw materials for secondary processes or as ingredients for novel products. For examples, chemicals and chemical products manufacture industries sell their outdated products as secondary raw material in Turkey and Eckert (Salihoglu, 2009) and the substitution of hazardous waste-derived fuel for conventional fossil fuels in cement and aggregate kilns (Guo, 1998). There are short and

long-term benefits from utilization and recycling of Industrial Hazardous Waste (Haq and Chakrabarti, 1998). Alternatively, collaborative industrial hazardous waste management approaches can serve as an effective way of disposing such waste without causing ill effects. Thus, this paper intends to identify what are the potential avenues for collaborative industrial hazardous waste management in Sri Lanka.

## 2.0 Industrial hazardous waste and it's impacts

Industrial hazardous wastes are special wastes that, being toxic, infectious, irritant, explosive, flammable, or having carcinogenic, teratogenic or mutagenic effects, are or may be harmful to human health or the environment (Vasillis, 2011). Cheremisinoff (2013) defined industrial hazardous waste as all non-product or product hazardous outputs from an industrial operation into all environmental media, even though they may be within the permitted limits. Therefore, industrial hazardous waste could define as an unwanted product aroused out of an industrial activity as a by-product or discarded material which has a potential of damaging to the environment and/or living beings.

The increased use of chemicals in the industrializing world has resulted in many residual hazardous substances. Waste produced due to increasing trend of consumption has reached to threatening levels in terms of quantity and hazardous content. In Lebanon an estimated 347 000 tons of solid waste 16 000 tons of hazardous waste are generated annually from 41 industrial zones (El-Fadel , Zeinati, El-Jis and Jamali, 2001). In China, the reported generation of industrial hazardous waste was 11.62 million tons in 2005, which accounted for 1.1% of industrial solid waste volume (Duan, Huang, Wan, Zhou, and Li, 2008). This emphasizes amongst industrial waste a considerable volume is hazardous.

According to the studies carried out by the Metropolitan Environmental Improvement Programme in collaboration with the Central Environmental Authority of Sri Lanka in 2003, it was revealed that, about 50,000 metric ton of hazardous waste is annually generated in Sri Lanka quantity wise (Weerasundara, 2013). Moreover, Weerasundara stated that the information is currently not available to readily figure the amount of hazardous waste being generated in Sri Lanka but only a rough estimate of 80,000 metric tons of hazardous per annum. Among this quantity, 65% are from various industries. According to the Central Environmental Authority of Sri Lanka (2013), the major hazardous waste generating industries in Sri Lanka are,

- Agro chemicals repackaging
- Waste oil handling and processing
- E –waste processing
- Tyre manufacturing
- Pharmaceuticals
- Insulated cable and wire manufacturing

Therefore, hazardous waste management in particular has become a crucial issue for individual industries and for the industry and other sectors in Sri Lanka. Conversely, the volume is high or low, the Industrial Hazardous waste cannot be neglected because of its properties or characteristics (Wang, Hung, Lo &Yapijakis, 2004).

The hazards related to the industrial hazardous wastes may stem from various factors, including their ignitability, corrosivity, reactivity or toxicity (Huitema, 2002). According to the Resources Conservation and Recovery Act, these are the characteristics of industrial hazardous waste and if a waste indicates any of these characteristics should be treated as a hazardous waste (Texas Commission on Environmental Quality, 2011). Into the bargain, materials can turn out to be hazardous waste status if they are mixed with, or contaminated with, or are derived from, other wastes that are themselves hazardous.

Industry has become an essential part of modern society, and waste production is an inevitable outcome of the developmental activities. According to Haq and Chakrabarti (1999) the impacts from the industrial hazardous waste include but not limited to, degradation of lands, air pollution, ground water and surface water contamination, unpredicted risks to human health and loss of valuable resources. This was further assured by German advisory council on global change (2001), disclosing that industrial hazardous waste contribute substantially to air pollution, to localized impairment of the water quality of the oceans and to the conversion of coastal eco systems.

Humans, plants, and animals can be exposed to hazardous substances through inhalation, ingestion, or dermal exposure. Breast cancer, prostate cancer and childhood brain disorders are increasing at an alarming rate and the increasing rates of contamination and pollution have only furthered these health problems. Moreover, hazardous waste is a motive behind the rise in certain maladies like autism and learning disabilities (Dutt, 2007).

In addition, the cost linked with industrial hazardous waste has caused an impact upon the organisations. Philips ( as cited in Gracia, Pongracz and Keiski, 2004) reported that the true cost of waste includes disposal costs, purchase cost of materials, handling/processing costs, management time and monitoring costs, lost revenue, any potential liabilities and post-disposal segregation. Thus, it is important to manage the industrial hazardous waste in a proper way to mitigate the impacts declared above.

### 3.0 Industrial hazardous waste management: Collaborative approach

To safeguard both individuals and ecosystems, specific waste treatment and waste minimization techniques should be systematically implemented throughout the waste management cycle: generation, separation, collection and recovery (Amador, 2010).

In determining on the superlative method for managing any waste there is a hierarchy for decision making which addresses issues for instance sustainability, cleaner production, health, safety, and environmental protection (Lee, 2013). As illustrate in Figure 3.1 current thinking on the best methods to deal with waste is centered on a broadly accepted hierarchy of waste management which gives a priority listing the waste management options available (Datta, 1999).

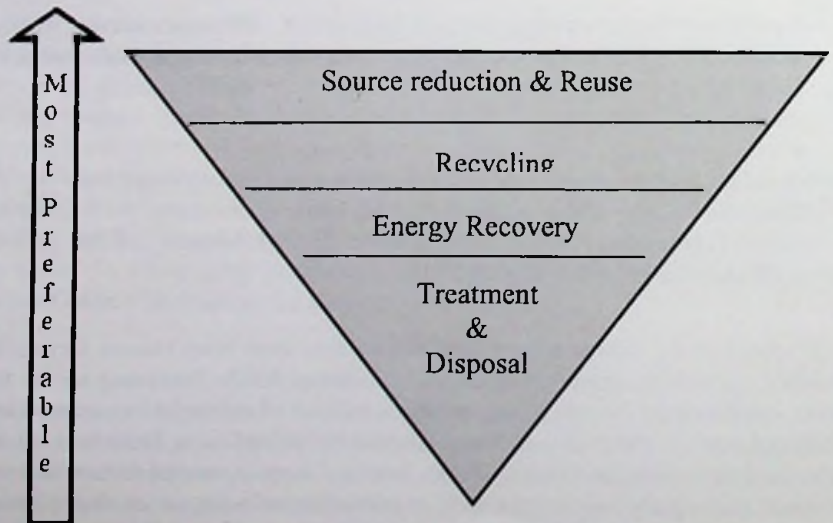


**Figure 3.1: Waste management hierarchy**
*Source*: Lee, 2013

The hierarchy directs the industrialists to develop their industrial hazardous waste management plans by first seeking to prevent the production of solid waste. When further elimination is not feasible, the industrialists would envisage actions that promote reuse. Subsequently, recycling options should be considered. The next action should be to energy recovery while treatment and disposal being the final. According to Muthukudaarachchi (2013), existing Industrial Hazardous Waste management performs in Sri Lanka are, dispose along with the Municipal waste, market the scrap containers, burning and thermal destruction.Moreover, Muthukudaarachchi argued that even thought, there are some acceptable ways to manage the hazardous waste most of the industries' practice is to dispose the hazardous waste with the municipal waste.

Equally when the industrial hazardous waste avoidance or minimization is intolerable then the most acceptable way of managing such waste is reuse recycle or disposal in a correct way. The reuse, recycle or energy recovery can be done inside the same industry that generate waste or through another industry which has a need and the capacity of using such waste as a raw material or energy. Similarly, the waste generator can do the industrial hazardous waste disposal itself depending on the ability or through another organization which has the capability. The reuse, recycling, energy recovery or disposal of Industrial Hazardous Waste through an organization outside the waste generator is considered as a collaborative approach for industrial hazardous waste management. Figure 3.2 presents a collaborative industrial waste management system established in Kalundborg, Denmark. The system involves an oil refinery, a cement factory, a pharmaceutical firm, a coal-fired electrical power station, a plaster board plant and a construction industry. Kalundborg collaborative industrial waste management system eventuates within the closely located factories and it is not limited only to hazardous waste.

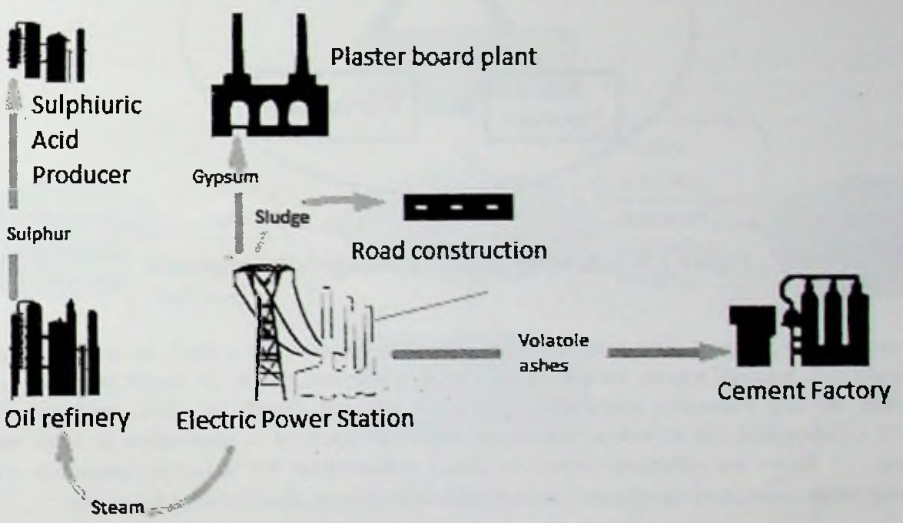


**Figure 3.2: Collaborative industrial waste management Kalundborg, Denmark**
*Source*: Peck, 2012

Many industrial hazardous wastes streams are or could be valuable raw materials for other industrial processes (Shen, 1999). Accordingly, the benefits associated with such collaborative approach for industrial hazardous waste management are,

a. Reduced risk of liability
b. Cost savings
c. Improved company image
d. Public health and environmental benefits

Many researchers have identified collaborative approach for industrial hazardous waste management as an effective method of managing such waste (Nemerow 2007: Haq and Chakrabarti, 1998). For examples, in Chile used oil and oil-contaminated materials are used oil as alternative fuel in high energy demanding facilities (i.e., cement facilities) (Navia and Bezama, 2008). Navia and Bezama (2008) found that spent oils in the mining facility used as raw material for the production of the explosives. Moreover, it was found that Bark, sawdust, and shaves produced in sawmill and wood remanufacturing facilities are recovered and burned in the different plant boilers for energy recovery. In addition substitution of hazardous waste derived fuel for convention fossil fuel in cement and aggregate kilns (James, Eckert and Guo, 1997).

Consequently, the said researches argued that the collaborative industrial hazardous waste management could happen in diverse conducts. The dropping use of energy and the use of industrial by-products as feed stocks for processes other than the ones that shaped them are central to this approach (Ehrenfeld and Gertler, 2007). Moreover, as illustrated in the Figure 3.3 the collaboration can be done directly within the industries or through an intermediary (Navia and Bezama, 2008).

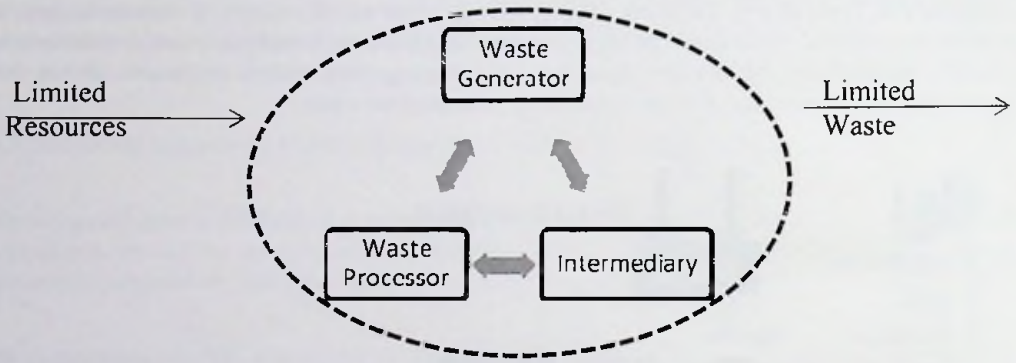


**Figure 3.3: Schematic model of Collaborative approach**

Jacobsen (2006) argued that manufacturing industries produce two kinds of wastes. One is basically sole material wastes, such as unused or dirty solvents, paints, or plastic or metal scrap. Further the said researcher stated such wastes can be used directly by other companies. The direct collaboration for industrial hazardous waste management is materialises in such cases. Figure 3.4 shows the schematic model of direct collaboration for industrial hazardous waste management.

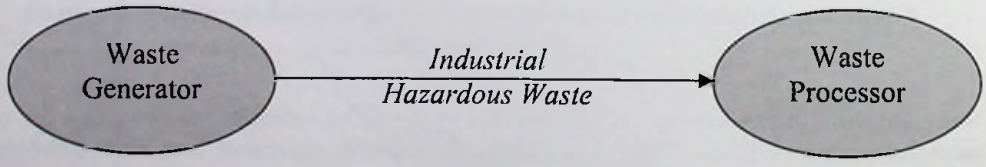


**Figure 3.4: Schematic model of Direct Collaboration**

Here waste generator is the industry that generate hazardous waste and the waste processor is any industry which can reuse, recycle, recover energy or disposal the waste generator's hazardous waste.

Nemerow (2007) stated that the concept of regional exchanges or markets for transferring hazardous materials from one supplier to another user is a novel and intriguing potential solution to the dilemma facing society.

Waste management through waste collectors is a different practice that comes under collaborative approach. Both informal waste collection and formal waste collection can include in the approach. Wilson, Velis and Cheeseman (2006) identified Itinerant waste buyers, Street waste picking, Municipal waste collection crew and waste picking from dumps as the informal waste collection whereas Bai and Sutanto (2001) identified the licensed waste collectors as the formal waste collectors. Haq and Chakrabarti (1998) described the collaborative approach as waste exchange. Moreover, Haq and Chakrabatri pronounced waste exchange is a simple process whereby the waste stream or waste products of particular industrial application areused or reused by another industry. Further, the said researchers divided the waste exchange into two approaches as Active exchange and Passive exchange.

Figure 3.5 further elaborates the types of intermediary approaches used in the world for industrial hazardous waste management. It should be noted that particular organisation can use both active and passive waste exchange approaches for the industrial hazardous waste management.

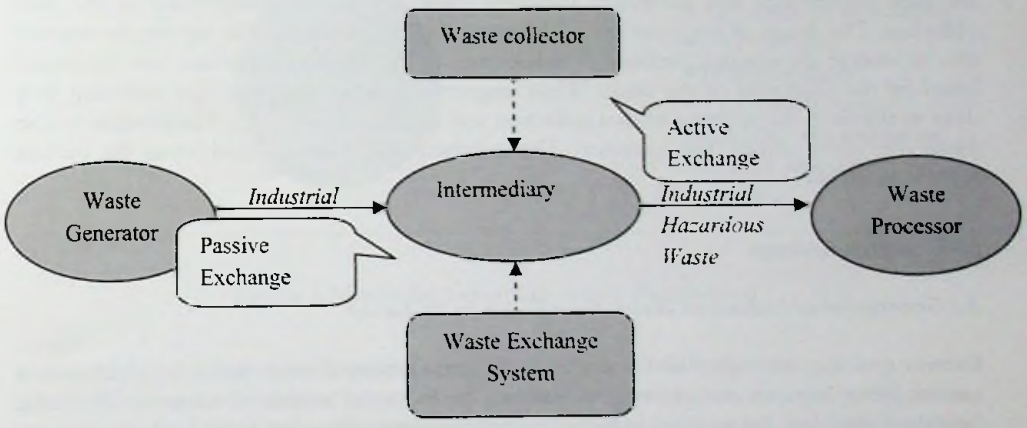


**Figure 3.5: Schematic model of Collaboration through an intermediary**

These are few examples for the collaborative approaches for manage the industrial hazardous waste used in the world. However, depending on the types of hazardous waste generate the approaches may vary.

Even though, the industrial hazardous waste can be managed through the collaborative approaches, the application of collaborative approach has limited to Waste programme and Holcim Lanka LTD in Sri Lanka. This situation may be a result of the challenges in implementing the collaborative approach.

Even the collaborative approach seems like a much tolerable option for manage the industrial hazardous waste in Sri Lanka it has challenged due to many reasons. The challenges or the

obstacles for the implementation of such approach are (De Alwis 2013, Worrell &Vesilind, 2011),

- Reluctance of industry – lack of pioneers
- Lack of enforcement
- Alternative options much convenient
- Organisational lethargy
- Uncertainty of supply
- Legal restrictions
- Uncertain markets
- Location of waste - if the source of waste generator is too far away from the waste receiver, the cost of the transport can beyond the profit of waste usage as a raw material.
- Administrative and institutional constraints

These are the probable barriers in implementing a collaborative approach for industrial hazardous waste management in Sri Lanka. However, to gain maximum output from a certain source and for the sustainable future these barriers should overcome.

## 4.0 Methodology

The survey method is adopted to find out the most appropriate collaborative approaches for industrial hazardous waste management in Sri Lanka. Semi-structured interviews were selected together relevant information from experts who involve in solid waste management and industrial activities because semi-structured rather than structured interview enable sufficient flexibility to approach different respondents differently while still covering the same areas of data collection (Noor, 2008). The sample size of the study was limited to sixteen as at that point the data requirement was saturated. Interview guidelines were prepared prior to the data collection. The design of the interview guidelines was done in accordance to capture the required data to analyze the research problem. The questions of the interview guidelines were developed based on the objectives of the study. While interviewing, note taking and tape recording were done to maintain the accuracy of data collection and avoid losing data as it is impossible to note down everything during the interview. The collected data were analysed using the content analysis technique.

## 5.0 Research findings

### *5.1 Generation of Industrial Hazardous Waste in Sri Lanka*

Current practices on industrial hazardous waste management through industrial collaboration cannot probe without recognizing the varieties of Industrial hazardous waste in Sri Lanka. Literature identified the topmost industrial hazardous waste originators in Sri Lanka by industry wise.

Table 5.1 presents the gathered data on industrial hazardous waste generation in Sri Lanka by industry wise in year 2012. While the average hazardous wastage per annum taken through the data collected by interviews, the number of establishments in each type other than E - waste processing plants and Oil processing plants were taken from the published survey data of the Department of Census and Statistics Sri Lanka (The final survey on industrial establishments is done in 2011) assuming that there are no any new establishments after 2011.Number of establishments for E-waste processing and Oil processing was taken from the Government Information Centre of Sri Lanka. Moreover, the total wastage is calculated based on the assumption that the establishments in same industry sector have equal production capacity.

**Table 5.1: Industrial Hazardous Waste Generation in Sri Lanka**

| Industry | Average Hazardous Wastage(Per Annum) | No of establishments | Total Waste |
|---|---|---|---|
| Agrochemical repackaging | 48tons | 4 | 192 tons |
| Oil Processing | 867 tons | 2 | 1734 tons |
| Pharmaceuticals | 22 tons | 28 | 616 tons |
| Tyre manufacturing | 117 tons | 31 | 3627 tons |
| E-waste processing | 432 tons | 14 | 6048 tons |
| Insulated wire and cables | 528tons | 4 | 2112 tons |

*Sources*: Department of Census and Statistics Sri Lanka (Annual Survey of Industries), 2011; Government Information Centre of Sri Lanka, 2013

Literature revealed 50,000 metric ton of hazardous waste is annually generated in Sri Lanka. Figure 5.1 presents the ratio of contribution from each industry to the total Industrial Hazardous Waste production.

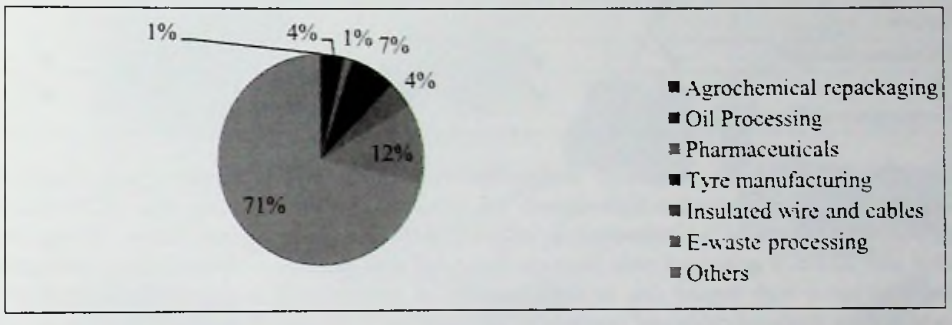


**Figure 5.1:Sectorial hazardous waste distribution**

The study found 16 types of hazardous waste. Some of these waste types are communal to all industries investigated, some are communal to several industries whereas some are germane only for a particular industry. As an example Chemical contaminated waste is common to all industries, Copper waste is common to E-waste processing and Metal manufacturing industries whereas Tyre waste is only applicable to Tyre manufacturing industries. Table 5.2 presents the findings on types of industrial hazardous waste generation in Sri Lanka.

**Table 5.2: industrial hazardous waste generation in Sri Lanka**

| Industry / Type of hazardous Waste | Agrochemical Repackaging | Waste oil handling and processing | E – Waste Processing | Tyre Manufacturing | Pharmaceuticals | Insulated wire and cables |
|---|---|---|---|---|---|---|
| Metal chips | | | ✓ | ✓ | | |
| Contaminated containers | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Agrochemical Packaging | ✓ | | | | | |
| Aluminium Dross | | | | | | ✓ |
| Alluminium Alloy | | | | | | ✓ |
| XLPE | | | | | | ✓ |
| Aluminium | | | ✓ | | | ✓ |
| Copper | | | ✓ | | | ✓ |
| Oil Sludge | | ✓ | | ✓ | | |
| Used oil | | ✓ | | ✓ | | |
| Pharmaceuticals | | | | | ✓ | |
| E - Waste | | | ✓ | | | |
| Tyres | | | | ✓ | | |
| Grease | | | | ✓ | | |
| Chemical Sludge | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Chemical Contaminated Waste | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

The study revealed that chemical sludge, chemical contaminated containers and chemical contaminated waste have a high impact of industrial hazardous waste due to chemical applications in most of the industries. In addition, even though Aluminium Dross, Aluminium Alloy and XLPE is generated only from the Insulated wire and cables manufacturing industries they also has a high impact due to their quantity of generation. For example ratio of XLPE wastage in an insulated cable and wire manufacturing plant is 3% out of their total production.

It was discovered that most of the industrial establishments in the same industrial category follow the same production routes to develop a product outcome. Resultantly, the types of waste generated are similar to each other in the same industry category. Nevertheless, the study found that the method of industrial hazardous waste management in an establishment could vary to another despite the fact that the types of waste are common to both. Certain establishments practice planed waste management systems while some are not. 3R (Reduce, Reuse, Recycle) concept, energy recovery, open dumping and land filling were the most well-known waste management systems. Moreover, study found that Reuse and Recycling is taking place within the same industrial processes and as well as between different industrial establishments.

### 5.2 current collaborative industrial hazardous waste management systems in Sri Lanka

The study found the current collaborative industrial hazardous waste management systems in Sri Lanka directly within the industries and through an intermediary. Some industrial establishments follow the both approaches. Further, the study revealed that collaborative industrial hazardous waste management through an intermediary transpires in two conducts: Active exchange and Passive exchange. However, it depends on the type of the waste and the waste processing industry.

### *5.2.1 Collaborative Industrial Hazardous Waste Management directly within the industries*

If an industrial establishment directly passes their waste to another for a waste utilization or disposal, without any intermediary it is considered as the direct collaborative industrial hazardous waste management (Section 3). As mentioned above the study revealed that most of the collaborative industrial hazardous waste management approaches eventuate directly within the industries. This happens in keeping with a contract between the waste generator and the waste processor. The waste consignment may be for a monetary value or for indisputability.

The identified existing collaborative industrial hazardous waste management approaches directly within the industries are shows in the Figure 5.2.

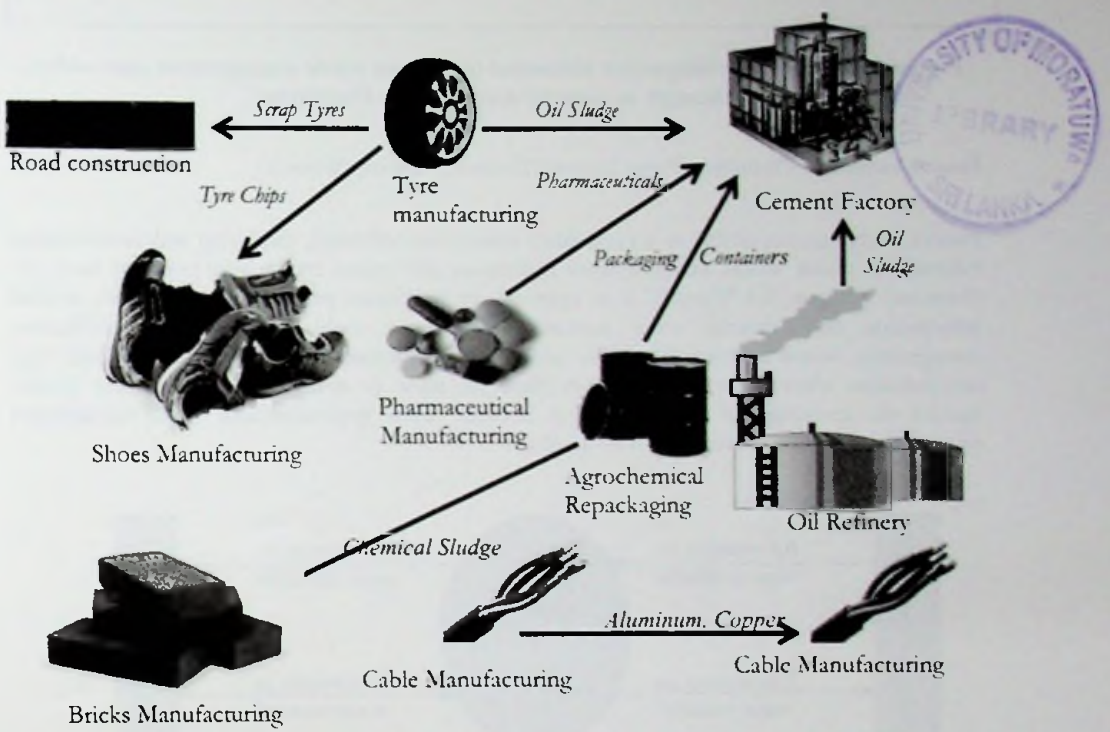


**Figure 5.2: Existing collaborative industrial hazardous waste management approaches directly within the industries**

5.2.2 Collaborative industrial hazardous waste management through an intermediary

Literature recognized that the collaborative industrial hazardous waste management through an intermediary could occur in two ways: Active exchange and Passive exchange. Through the data gathering, it was found that Collaborative Industrial Hazardous Waste Management through an intermediary in Sri Lanka transpires in the both ways.

Active exchange: Through waste collectors

The study found that some of the factories sell their waste to waste collectors who act as intermediaries. The waste collectors sell the collected waste to the potential users for a commission. Figure 5.3 shows the existing collaborative industrial hazardous waste management approaches through waste collectors.

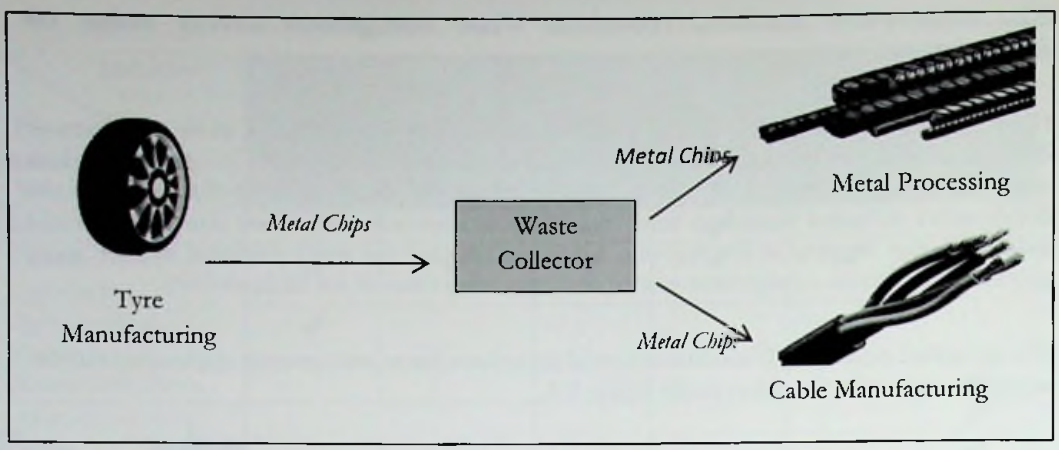


**Figure 5.3: Existing collaborative industrial hazardous waste management approaches through an intermediary (Active Exchange)**

Passive exchange: Through a Waste Material Exchange system (WasteX)

Passive exchange can define as a centralized station for collecting, displaying and disseminating information about wastes available from generators and wastes required by potential users. As illustrated in Figure 5.4 'WasteX' is an open source web based programme that affords detailed information on industrial waste material available to enable possible waste collection, management, re-use and recycling. This provides the industries with a platform on which they can publicize what waste materials they have for trade or necessitate. Basically, the project enables the exchange of industrial waste between waste generators and waste management organisations (Waste processors) in Sri Lanka.

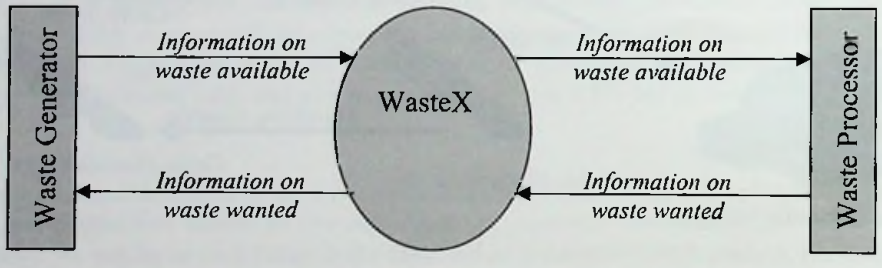


**Figure 5.4: Waste exchange scenario through WasteX**

The study found that in the initiation of the project in 2010, eight organisations were registered in it. Presently some of the investigated organisations do not have any idea on 'WasteX' while particular experts expressed the indication that at present no one is involved in it.

## 6.0 Proposed framework for industrial hazardous waste management through industrial collaboration

The study divulged 16 number of hazardous waste types. Moreover, it was identified that this waste is managed in dissimilar ways in diverse industrial establishments. Moreover it found that even the industrial establishments in same industrial category generates the same types of waste the method of managing may differ to each other. Therefore, one establishment may manage the industrial hazardous waste in a collaborative method while others manage them within the plant

or has no any managing method other than open dumping or land filing. Therefore, as illustrated in Figure 6.1 the developed framework for industrial hazardous waste management through industrial collaboration includes the existing approaches too. The framework was developed by means of expert's accepted wisdom, existing tactics together with the literature findings. Moreover, it proposes alternative options for the current collaborative approaches. The proposed methods can be practiced directly within the industries or through an intermediary.

Moreover, the initially designed framework was analysed by the industrial hazardous waste management experts and the evaluated framework is presented. The experts evaluated the framework based on economic feasibility, technical feasibility and environmental feasibility.

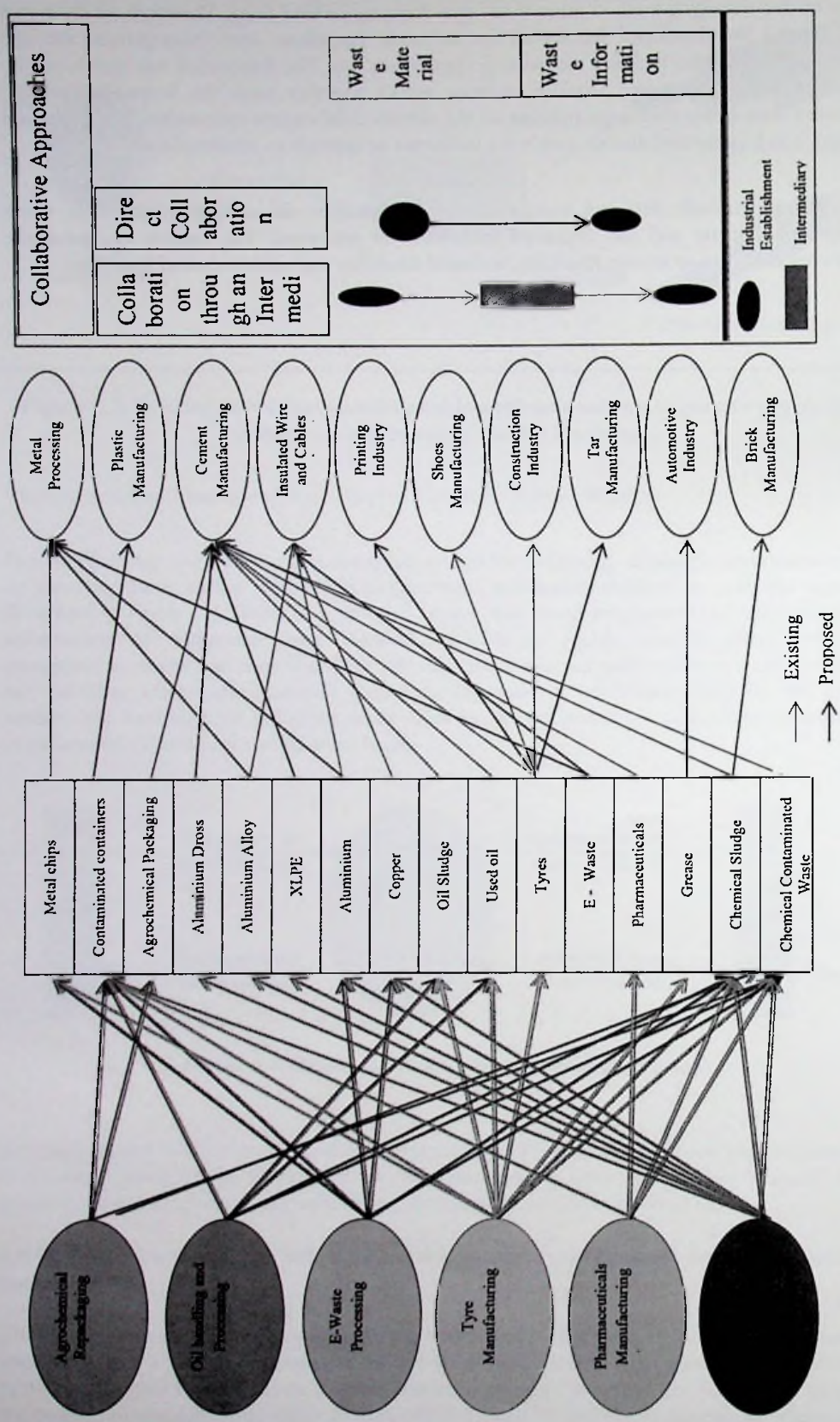


**Figure 6.1: Framework for industrial hazardous waste management though industrial collaboration**

## 7.0 Conclusions

Improper management of Industrial hazardous waste creates problems to the environment as well as living beings. The cost associated with the proper management of industrial hazardous waste may high due to its characteristics. Therefore, the study was conducted in order to find the ways of collaborative industrial hazardous waste management within the industries. Findings revealed that in present there are many collaborative stratagems directly within the industries and/or through an intermediary are working while more opportunities to awaken. Accordingly, the literature findings together with the experts' ideas the suggestions for improvement were developed. The study recommends the industrialists to consider the suggestions for industrial hazardous waste management for a cost effective, sustainable business operation.

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