DEVELOPMENT OF AN ASSESSMENT METHOD FOR HAZARDOUS SUBSTANCES VALUE IN AUTOMOTIVE COMPONENTS FOR SUPPORTING GREEN MANUFACTURING

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Abstract

This aim of this research is to develop an assessment method for hazardous substances value in automotive components for supporting green manufacturing. Basically, the green manufacturing focuses on reducing environmental risks and impacts of industrial activities through elimination of resource waste, pollution and use of material containing hazardous substances. In this research, the method will be used to assess the hazardous substances contained in automotive components quantitatively. Based on the values, the hazard level of components could be compared relatively. This research has retrieved hazardous substances information from the Material Safety Data Sheet (MSDS) of the component. After that the hazardous substances were assessed based on the Hazardous Materials Identification System (HMIS). Furthermore, the information would be processed using a weighting method to obtain a single value. This research has assessed several automotive components by using the method as case studies. The results of assessments are brake pad 6.6, brake pad with asbestos 7.6, brake shoe 7.0, brake shoes with asbestos 13.2, clutch disc 9.2, and clutch disc with asbestos 8.6.

Keywords: Assessment methods, Hazardous substances, Product model

Introduction

Generally, every waste from products negatively impacts the environment as pollutants or contaminants that could interfere with human health. In addition, the human health could also be affected directly by the hazardous substances that are presented in the product. On the other hand, the sustainable development is a concept that is applied to reduce the negative impacts of waste. In line with the concept of sustainable development, the green technology concept is a technology concept that aims for low negative impact on the environment for all phases of a product life cycle. Furthermore, the green technology concept approach in the manufacturing sector has been known as green manufacturing. The implementation of the green manufacturing requires a lot of data, such as chemical composition of the materials, hazardous substances, and recycling methods.

This research attempts to develop an assessment method for hazardous substances in a product. The development of method has been carried out by adapting existing assessment methods and adding weighting method. Furthermore, the output of assessment method would be used to compare the value of hazardous substances contained in several products.

Concept of Method Development

In this research, assessment methods for hazardous substances have been adapted from the Eco Indicator method 95 and 99 developed by PRe Consultant [1]. Briefly, the concept of

Eco Indicator 95 and 99 is identification of the eco-friendly level of products based on generation of waste during manufacturing processes. The output of identification is then divided into three categories that are fatalities, impairment, health and ecosystem impairment. All three categories were then rated by using subjective damage assessment to result in a single value namely an eco-indicator value. Based on this method, the assessment could be conducted from substance level until product level.

In this research, the method development has been carried out in four steps. The first step is to determine standards and methods for identifying hazardous substances. The second step is to provide the level of substances. The third step is to determine the proper method for performing the assessment rate of the product. The fourth step is to assess the level of products.

Standards and Methods for Identifying Hazardous Substance

There are several standards and methods for identifying hazardous substances such as Hazardous Materials Identification System (HMIS), Environmental Protection Agency (EPA), and Chemical Abstract Service (CAS). In general, HMIS has similar definitions with schemes and definitions developed by other standards such as America National Standards Institute (ANSI), the National Institute for Occupational Safety and Health (NIOSH), or the Occupational Safety and Health Administration (OSHA).

Briefly, the assessment processes in HMIS is compiled based on information contained in the Material Safety Data Sheet (MSDS) [2]. In the method, chemicals could be assessed either as elements or compounds. Assessment of an element is carried out by looking up a table provided by the HMIS. If the element is not found in the table, the assessment can be carried out by referencing to the MSDS of the element. Assessment of a compound can be carried out by giving judgment on significant elements of the compound. In general, the compound could be assessed if it has more than one percent weight or volume of total but the rules do not apply if the compounds are carcinogens. Based on the Hazard Communication Standard (HCS), assessments of carcinogens have to be done if the weight or volume of compound is over one-tenth of a percent of total weight or volume of the compound. Furthermore, standards and methods of HMIS divide level of hazardous substances into three aspects, namely health, flammability, and physical hazard. In HMIS, the assessment uses values from 0 to 4, with 0 means the lowest level of hazard and 4 means the highest.

There are two criteria aspects of health, namely chronic and acute hazard. According to OSHA, chronic effects generally occur as a result of long-term exposure, and are of long duration. In HMIS rating label, chronic hazards are marked by asterisk (*) and if a compound does not contain chronic hazard then it is marked by slash (/). Furthermore, an acute hazard is marked by a value from 0 to 4. In the system, the flammability aspect includes combustible liquids, flammable liquids, and pyrophorics. According to OSHA, any liquid that has a flash point below 100^0F (37.8^0C) is classified as flammable liquids. In the system, the criteria of flammability adopt OSHA definitions. Furthermore, the assessment of physical hazard includes 7 criteria i.e. water reactivity, organic peroxides, explosive, compressed gases, pyrophoric, oxidizer, and unstable reactive. Although all of seven criteria will be assessed and resulting in values from 0 to 4, only a highest value will be taken.

The Centre for Clean Products and Clean Technologies of University of Tennessee in cooperation with EPA, has developed a method of providing an assessment of chemical substances [3]. The method incorporates estimates of the effect of toxic chemicals and the potential impact on the environment. The effects in the method include effect to human, effect to environment and effect produced by exposure of chemical substances. Generally,

the method has 3 steps. The first is to collect experimental data and estimating data for not available data. The second is to predict the effect of toxic chemicals and the potential of chemical exposures. The last is to develop an algorithm to combine and conduct evaluation criteria of weighting.

The CAS number is a unique identification number for a substance like chemical elements, compounds, polymers, biological sequences, mixtures and alloys. CAS is a division of the American Chemical Society. A CAS Registry Number is separated by hyphens into three parts, the first consisting of up to 7 digits, the second consisting of two digits, and the third consisting of a single digit serving as a check digit. The rating that follows the CAS number is an attribute that indicates the potential danger of the substance to impact the environment. The value of this attribute ranges from 0 to approximately 21, with 21 being the greatest (negative) potential environmental impact. The value of the rating is given in logarithmic scale, meaning that a substance that has the rating 15 for example, will have 10 times the potential impact of a substance with a rating of 14. The ratings are issued by CAS and updated annually [4].

Each method for identifying hazardous substances has advantages and disadvantages. The comparison of the 3 methods, HMIS, CAS and U.S. EPA, is shown in Table 1 are.

Table 1. Comparison of Methods for Identification of Hazardous Substances

	Rating		
	HMIS	**CAS**	**U.S. EPA**
Rating Interpretation	1	3	2
Rating Range	1	2	3
Information level	3	1	3
Data Access	3	?	1
Data Updating	2	2	?
No possibility of The Same Rating for Difference Substance	1	3	3

Note: 3: easy/detail/wide/good; 2: fair; 1: not easy/complicated/narrow/bad; ?: NA data

Assessment Method at Level of Substance

The assessment method at level of substance is done in two steps. The first step is to capture the data required for the assessment from the Material Safety Data Sheet (MSDS), namely the composition of substance of the product and their fractions. The substance that has 1 percent or more of fraction or it could potentially cause cancer or carcinogenic will be assessed, otherwise it will be ignored. The second step is to assess each substance in the product based on HMIS. Each substance is assessed for health, flammability, and physical hazard aspects.

Assessment Method for Products

In this research, the assessment method for a product is carried out by using a weighting method. Based on The Principle of Risk-Based Decision Making, the implementation of the weighting method consists of several steps [5]. The first step is to determine attributes. The second step is to determine the weights for each attribute. The third step is to define an attribute that is used as a reference. The fourth step is to define the weighting factors for each attribute. The last step is calculation of the total value, after weighting each attribute.

Assessment Method at Product Level

Based on the previous paragraphs, the assessment of the level of hazard of the product is carried out in several steps. The first step is determining the attributes namely health (H), flammability (F), and physical hazards (PH). The attributes are selected based on the aspects of the HMIS. The second step is determining weights for each attribute. In this research, the weights of each attribute have been determined based on statistical data of the number of incidents caused by hazardous substances. The statistical data as the base of weight values is shown in Figure 1.

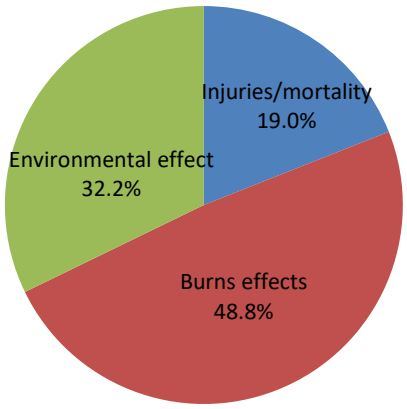

Figure 1. Percentage of accidents caused by hazardous substances

The data shown in Figure 1 have been collected from 28,213 data of incidents [6]. Based on Figure 1, the biggest percentage of accidents (48.8%) is caused by fires or explosions. The second rank of accidents (32.2%) has impacts on environment and there is 19% of accidents have impacts directly to human beings. Furthermore, the presented data could be used as references for determining the weights for the specified attributes. Based on the data, the weight for Health (H) is 19.0%, flammability (F) is 48,8%, and physical hazards (PH) are 32.2%.

The third step is determination of the attribute as a reference. In this research, the reference attribute is health (H) because it has the lowest weight. After determining the reference attributes, the fourth step is determination of the weighting factors for each attributes. In this research, the weighting factor for the reference attribute was one. The weighting factor for the flammability (F) and physical hazard (PH) attributes have been determined relatively based on the reference attribute, namely 1.7 and 2.6 consecutively. The last step is calculation of the total value after determining the weighting factors. The total value has been calculated by aggregating the value of each attributes multiplied by their weight factor for all substances contained in the product (see Equation 1).

$$\text{Total value} = \Sigma[(H \times 1) + (F \times 2.6) + (PH \times 1.7)] \quad (1)$$

The result from Equation 1 is a representation of relative hazardous level of the product. Furthermore, the result could be compared with the result of another product. A product that has a lower value means it is more environmentally friendly than another product that has higher value.

Case Study

Several automotive components have been assessed by using the method as case studies. The components were brake pads, brake shoes, and clutch discs.

Non Asbestos Brake Pad

The first case study is a non-asbestos brake pad. Based on information obtained from the MSDS, the chemical composition of the non-asbestos brake pad is shown in Table 2.

Table 2. Chemical Composition of the Non Asbestos Brake Pad [7]

CAS No.	Name	Fraction (%)
7727-43-7	Barium Sulfate	5
7440-44-0	Carbon	25
60676-86-0	Silica Amorphous Fused	10
1309-48-4	Magnesium Oxide	0.2

The assessments of non-asbestos brake pad have been conducted according to HMIS. The substances of the brake pad which have a fraction less than 1% could be ignored. Also all substances which are carcinogenic with a fraction of less than 0.1% could be ignored. Based on these criteria, the substances of the non-asbestos brake pad are shown in Table 3.

Table 3. HMIS Values for the Non Asbestos Brake Pad Chemical Composition [2]

CAS No.	Name	H	F	PH	Detail
7727-43-7	Barium Sulfate	1	0	0	Eye, skin, respiratory
7440-44-0	Carbon	1*	1	0	Eye, skin, respiratory, flammable
60676-86-0	Silica Amorphous Fused	1*	0	0	Eye, skin, respiratory
1309-48-4	Magnesium Oxide	1	0	0	Eye, skin, respiratory

In general barium sulfate, carbon, silica amorphous fused, and magnesium oxide are hazardous substance and harmful to human health. They could irritate the eyes, skin, and respiratory system. Also carbon and silica contents are carcinogens. Based on the HMIS assessment and to facilitate the identification of hazardous materials in the product, then the results could be described on a radar diagram as shown in Figure 2.

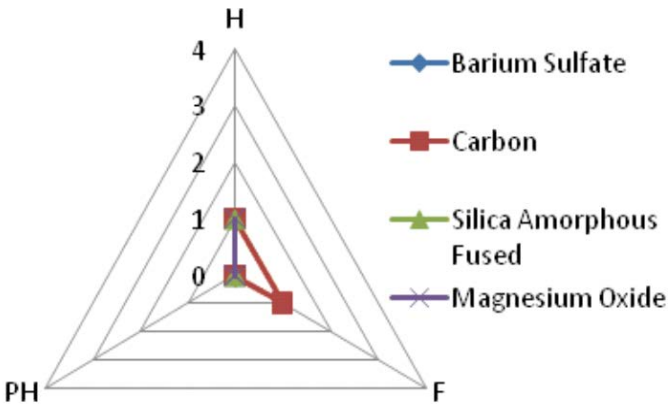

Figure 2. Radar diagram of a non-asbestos brake pad

From Figure 2, the radar diagram showed that the carbon content in the non-asbestos brake pad is the most hazardous substance in the component, because it has the most extensive large area compared to other chemicals. The hazardous level of human health is not too high, for all substances the values are 1 based on HMIS. The level of flammability is categorized as can-burn because of the carbon content in the component. For the environmental aspect, the non-asbestos brake pad is harmless because it has zero HMIS value. Furthermore, the comparison value of the non-asbestos brake pad after applying weighting factor is shown in Table 4, where the comparison value of the non-asbestos brake pad is shown to be 6.6.

Table 4. Calculations of the Comparison Value of the Non Asbestos Brake Pad

CAS No.	Name	Value
7727-43-7	Barium Sulfate	1
7440-44-0	Carbon	3.6
60676-86-0	Silica Amorphous Fused	1
1309-48-4	Magnesium Oxide	1
Comparison Value		6.6

Asbestos Brake Pad

The second case study is an asbestos brake pad. Based on information obtained from the MSDS, the chemical composition of the non-asbestos brake pad is shown in Table 5.

Table 5. Chemical Composition of the Asbestos Brake Pad [8]

CAS No.	Name	Fraction (%)
7727-43-7	Barium Sulfate	5-20
7782-42-5	Graphite	1-5
9003-35-4	Phenol Resin	10-20
1332-21-4	Asbestos	30-50

The assessments of non-asbestos brake pad have been conducted according to HMIS. The substances of the brake pad which have a fraction less than 1% could be ignored. Also all substances which are carcinogenic with a fraction of less than 0.1% could be ignored. Based on these criteria, the substances of the non-asbestos brake pad are shown in Table 6.

Table 6. HMIS Values for the Asbestos Brake Pad Chemical Composition [2]

CAS No.	Name	H	F	PH	Detail
7727-43-7	Barium Sulfate	1	0	0	Eye, skin, respiratory
7782-42-5	Graphite	1*	0	0	Eye, skin, respiratory
9003-35-4	Phenol Resin	2	1	0	Eye, skin, flammable
1332-21-4	Asbestos	1*	0	0	Eye, skin, respiratory

Based on HMIS assessment, the asbestos brake pad contains asbestos that could potentially interfere with human health, because it may cause irritation to eyes, skin and respiratory system. Also deposits of graphite and asbestos on the asbestos brake pad could be carcinogenic. Furthermore, HMIS value of the asbestos brake pad can be described on a radar diagram as shown in Figure 3.

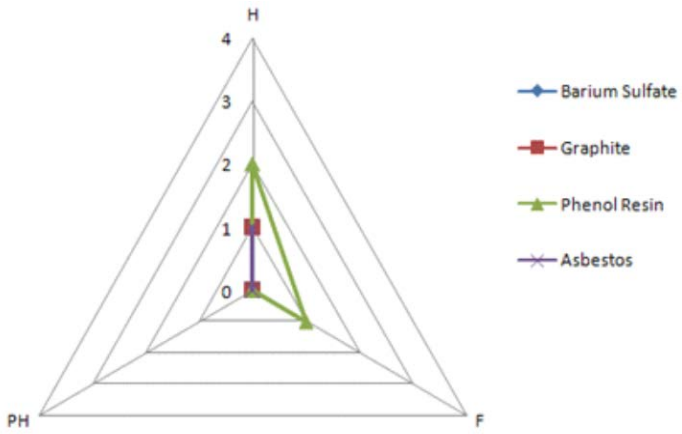

Figure 3. Radar diagram of an asbestos brake pad

Based on Figure 3, it may be seen that generally the asbestos brake pad is hazardous because it contained phenol formaldehyde with HMIS value of 2 points. Asbestos and graphite contained in the asbestos brake pad are also potentially cause cancer (carcinogens). The level of flammability is categorized as can-burn because of carbon and phenol formaldehyde content in the component. Furthermore, the comparison value of the asbestos brake pad after applying weighting factor is shown in Table 7. The comparison value of the asbestos brake pad is found to be 7.6

Table 7. Calculations of the Comparison Value of the Asbestos Brake Pad

CAS No.	Name	Value
7727-43-7	Barium Sulfate	1
7782-42-5	Graphite	1
9003-35-4	Phenol Resin	4.6
1332-21-4	Asbestos	1
Comparison Value		7.6

Non Asbestos Brake Shoe

The third case study is a non-asbestos brake shoe. Based on information obtained from the MSDS, the chemical composition of the non-asbestos brake shoe is shown in Table 8.

Table 8. Chemical Composition the Non Asbestos Brake Shoe [9]

CAS No.	Name	Fraction (%)
26125-1	Aramid	Trade secret
7727-43-7	Barium Sulfate	Trade secret
7782-42-5	Graphite	Trade secret
12001-26-2	Mica	Trade secret
65997-17-3	Fibrous Glass	Trade secret
64743-05-1	Petroleum Coke	Trade secret
1309-48-4	Magnesium Oxide	Trade secret
Mixture	Organic Resin	Trade secret

Assessment of non-asbestos brake shoe has been conducted according to HMIS. The substances of the non-asbestos brake shoe which have a fraction less than 1% could be ignored. Also all substances which are carcinogenic with a fraction of less than 0.1% could be ignored. Based on these criteria, the substances of the non-asbestos brake shoe are shown in Table 9.

Table 9. HMIS Value for the Non Asbestos Brake Shoe Chemical Composition [2]

CAS No.	Name	H	F	PH	Detail
26125-1	Aramid	1	0	0	Eye, skin, respiratory
7727-43-7	Barium Sulfate	1	0	0	Eye, skin, respiratory
7782-42-5	Graphite	1*	0	0	Eye, skin, respiratory
12001-26-2	Mica	1*	0	0	Eye, respiratory
65997-17-3	Fibrous Glass	1	0	0	Eye, respiratory
64743-05-1	Petroleum Coke	1	0	0	Eye, skin, respiratory
1309-48-4	Magnesium Oxide	1	0	0	Eye, skin, respiratory

The substances listed in Table 9 are hazardous substances which have HMIS values. Substances that do not have HMIS values are assumed as non-hazardous substances and are not listed in the Table 9. Generally, the non-asbestos brake shoe could potentially interfere with the human health, because it may cause irritation to eyes, skin, and respiratory system. Also deposits of graphite and mica in a non-asbestos brake shoe could be carcinogens. Furthermore, the HMIS value of the non-asbestos brake shoe could be described on a radar diagram as shown in Figure 4.

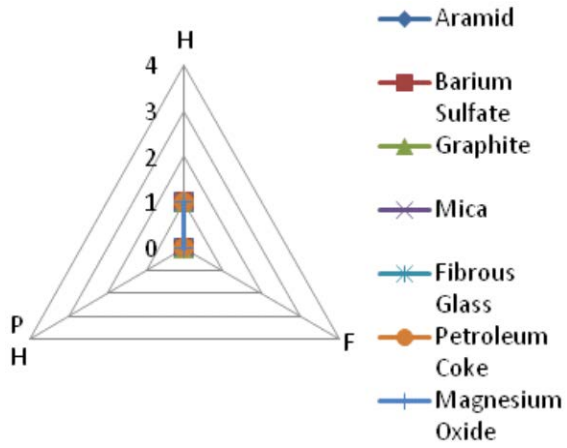

Figure 4. Radar diagram of the non-asbestos brake shoe

Based on the radar chart in Figure 4, the hazardous level in health aspect of the non-asbestos brake shoe is categorized as low rated with HMIS values of 1. Furthermore, for flammability and environmental aspects, the non-asbestos brake shoe does not have potential negative impacts shown by 0 HMIS values. The comparison value of the non-asbestos brake shoe after applying weighting factor is shown in Table 10, and the total value is found to be 7.

Table 10. Calculations of the Comparison Value of the Non Asbestos Brake Shoe

CAS No.	Name	Value
26125-1	Aramid	1
7727-43-7	Barium Sulfate	1
7782-42-5	Graphite	1
12001-26-2	Mica	1
65997-17-3	Fibrous Glass	1
64743-05-1	Petroleum Coke	1
1309-48-4	Magnesium Oxide	1
Comparison Value		7

Asbestos Brake Shoe

The fourth case study is an asbestos brake shoe. Based on information obtained from the MSDS, the chemical composition of the asbestos brake shoe is shown in Table 11.

Table 11. Chemical Composition of the Asbestos Brake Shoe [10]

CAS No.	Name	Fraction (%)
12001-29-5	Asbestos	50-70
7727-43-7	Barium Sulfate	5-20
7782-42-5	Graphite	1- 5
14807-96-6	Talc (powder)	< 5
14808-60-7	Silica Dust	< 5
1333-86-4	Carbon Black	< 2
9003-35-4	Phenolic Resin	< 2

Assessments of non-asbestos brake shoe have been conducted according to HMIS. The substances of the non-asbestos brake shoe which have a fraction less than 1% could be ignored. Also all substances which are carcinogenic with a fraction of less than 0.1% could be ignored. Based on these criteria, the substances of the non-asbestos brake shoe are shown in Table 12.

Table 12. HMIS Value for the Non Asbestos Brake Shoe Chemical Composition [2]

CAS No.	Name	H	F	PH	Detail
12001-29-5	Asbestos	1*	0	0	Eye, skin, respiratory
7727-43-7	Barium Sulfate	1	0	0	Eye, skin, respiratory
7782-42-5	Graphite	1*	0	0	Eye, skin, respirator
14807-96-6	Talc (powder)	1*	0	0	Eye, skin, respiratory
14808-60-7	Silica Dust	1	0	0	Eye, skin, respiratory, kidney
1333-86-4	Carbon Black	1*	1	0	Eye, skin, respiratory, flammable
9003-35-4	Phenolic Resin	2	1	0	Eye, skin, flammable

Based on the assessment of HMIS, the asbestos brake shoe could potentially interfere with human health, cause irritation to eyes, skin, kidney, and respiratory system. Deposits of asbestos, talc, graphite, and carbon could be carcinogens. Furthermore, the HMIS values of the asbestos brake shoe are shown in Figure 5.

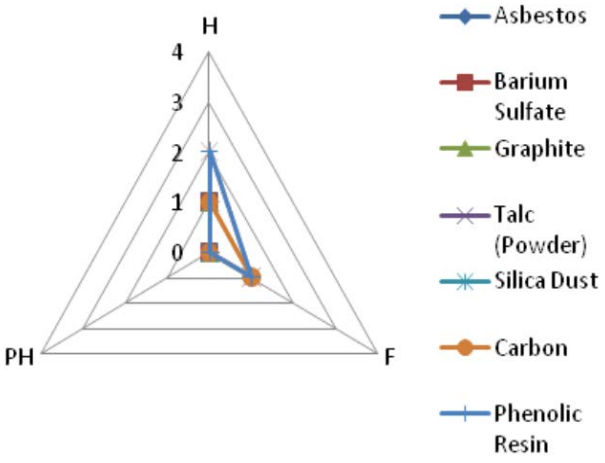

Figure 5. Radar diagram of the asbestos brake shoe

From Figure 5, the asbestos brake shoe is a fairly high level hazardous component. The component contains phenolic resin that could be classified as a hazardous substance and the value is 2. Also content of asbestos, talc, graphite, carbon, and phenol are carcinogens. Furthermore, for flammability aspect, the value of the asbestos brake shoe is 2. The comparison value of the asbestos brake shoe after applying weighting factor is summarized in Table 13, where the total value for the asbestos brake shoe is 13.2.

Table 13. Calculations of the Comparison Value of the Asbestos Brake Shoe

CAS No.	Name	Value
12001-29-5	Asbestos	1
7727-43-7	Barium Sulfate	1
7782-42-5	Graphite	1
14807-96-6	Talc (powder)	1
14808-60-7	Silica Dust	1
1333-86-4	Carbon Black	3.6
9003-35-4	Phenolic Resin	4.6
Comparison Value		13.2

Non Asbestos Clutch Disc

The fifth case study is a non-asbestos clutch disc. Based on information obtained from the MSDS, the chemical composition of non-asbestos clutch disc is shown in Table 14.

The assessments of non-asbestos clutch disc have been conducted according to HMIS. The substances of the non-asbestos clutch disc which have a fraction less than 1% could be ignored. Also all substances which are carcinogenic with a fraction of less than 0.1% could be ignored. Based on these criteria, the substances of the non-asbestos clutch disc are shown in Table 15.

Table 14. Chemical Composition of the Non Asbestos Clutch Disc [11]

CAS No.	Name	Fraction (%)
7782-42-5	Graphite	< 2
9003-35-4	Cured Phenolin Resin	< 30
1333-86-4	Carbon Black	< 5
1317-37-9	Metal Sulphides	< 0.05
9006-04-6	Rubber	< 1
65997-17-3	Inorganic Fiber	< 1
-	Other Filler	< 10

Table 15. HMIS Value for the Non Asbestos Clutch Disc Chemical Composition [2]

CAS No.	Name	H	F	PH	Detail
7782-42-5	Graphite	1*	0	0	Eye, skin, respiratory
9003-35-4	Cured Phenolin Resin	2	1	0	Eye, skin, flammable
1333-86-4	Carbon Black	1*	1	0	Eye, skin, resp., flammable

Based on the assessment of HMIS, the non-asbestos clutch disc could potentially interfere with human health, and cause irritation to eye, skin, and respiratory system. Graphite and carbon content are carcinogenic substances. The content of metal sulphide is ignored because it is below 0.1%. Furthermore, the HMIS values of the non-asbestos clutch disc are shown in Figure 6.

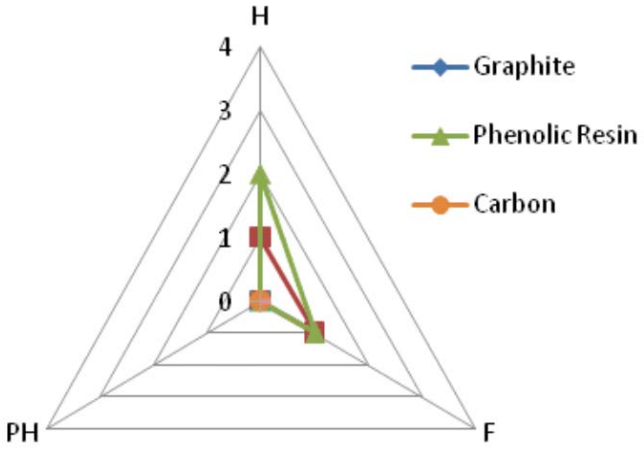

Figure 6. Radar diagram of the non-asbestos clutch disc

Based on Figure 6, the non-asbestos clutch disc contains hazardous substances. Content of graphite on the component is a low level hazardous substance but in long run it is dangerous because of its carcinogenic nature. The carbon content in the component is able to burn with 1 point of flammability rating. The content of resin also is a hazardous substance with the value of 2. This substance is also classified as a burnable substance. The metal sulfides in this component generally are low level hazardous substance for health, but it is classified as a burnable substance and could react with other substances. The comparison value of the non-asbestos clutch disc after applying weighting factor is shown in Table 16, and the total value is found to be 9.2.

Table 16. Calculations of the Comparison Value of Non Asbestos Clutch Disc

CAS No.	Name	Value
7782-42-5	Graphite	1
9003-35-4	Cured Phenolin Resin	4.6
1333-86-4	Carbon Black	3.6
Comparison Value		9.2

Asbestos Clutch Disc

The sixth case study is an asbestos clutch disc. Based on information obtained from the MSDS, the composition of chemical substance of the asbestos clutch disc is shown in Table 17.

Table 17. Chemical Composition of the Asbestos Clutch Disc [12]

CAS No.	Name	Fraction (%)
9003-35-4	Cured Phenolin Resin	=< 30
1201-29-5	Asbestos	=< 15
7439-89-6	Iron	=< 3
1309-37-1	Iron Oxide	=< 3
7782-42-5	Graphite	=< 2

The assessments of asbestos clutch disc have been conducted according to HMIS. The substances of the non-asbestos clutch disc which have a fraction less than 1% could be

ignored. Also all substances which are carcinogens with a fraction of less than 0.1% could be ignored. Based on these criteria, the substances of the asbestos clutch disc are shown in Table 18.

Table 18. HMIS Value for the Asbestos Clutch Disc Chemical Composition [2]

CAS No.	Name	H	F	PH	Detail
9003-35-4	Cured Phenolin Resin	2	1	0	Eye, skin, flammable
1201-29-5	Asbestos	1*	0	0	Eye, skin, respiratory
7439-89-6	Iron	1	0	0	Eye, skin, respiratory, CNS
1309-37-1	Iron Oxide	1*	0	0	Eye, skin, respiratory
7782-42-5	Graphite	1*	0	0	Eye, skin, respiratory

Based on the assessment of HMIS, the asbestos clutch disc could potentially interfere with human health, cause irritation eye, skin, and respiratory system. Deposits of asbestos, iron oxide, and graphite are potentially carcinogens. Furthermore, the HMIS values of the asbestos clutch disc are shown in Figure 7.

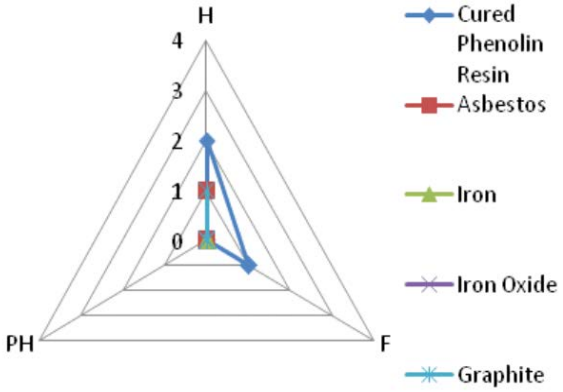

Figure 7. Radar diagram of the asbestos clutch disc

From Figure 7, it may be seen that the phenolin resin is the most hazardous substance in health and ability to burn aspects. For the health aspect, the phenolin resin is categorized as a hazardous substance. This is identified by the value of 2 on HMIS rating. Asbestos, Iron oxide, and graphite contained on the asbestos clutch disc is classified as low level hazardous substances in health aspect. The comparison value of the asbestos clutch disc after applying weighting factor is shown in Table 19 and the total value is found to be 8.6.

Table 19. Calculations of the Comparison Value of Asbestos Clutch Disc

CAS No.	Name	Value
9003-35-4	Cured Phenolin Resin	4.6
1201-29-5	Asbestos	1
7439-89-6	Iron	1
1309-37-1	Iron Oxide	1
7782-42-5	Graphite	1
Comparison Value		8.6

Conclusions

The assessment method of hazardous levels of the substance has been conducted according to the information of Hazardous Materials Identification System (HMIS). There are 3 aspects used in this assessment method, namely health, flammability, and physical hazard. The method also used a weighting factor for health, flammability, and physical hazard aspects. Based on these, the comparison value could be calculated. Furthermore, the comparison value could be used to compare the hazardous level of components. This assessment method could only be implemented for a single component and not for multi components like a product.

The research also has conducted several case studies. The resume of the case studies are shown in Table 20. Based on Table 20, the non-asbestos brake pad is more environmentally friendly than the asbestos brake pad. Also the non-asbestos brake shoe is about twice more environmentally friendly than the asbestos brake shoe. The last, the non-asbestos clutch discs is less environmentally friendly than the asbestos clutch disc, because it contains carbon black.

Table 20. Comparison Value of some Automotive Components

Product Name	Total Value
Non asbestos brake pad	6.6
Asbestos brake pad	7.6
Non asbestos brake shoe	7.0
Asbestos brake shoe	13.2
Non asbestos clutch disc	9.2
Asbestos clutch disc	8.6

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