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A Clinical Audit for Compliance on the Innovated Radiographic Technique at a Radiologic Unit

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This study identified X-ray laboratory users' compliance with the innovated radiographic technique and evaluated it's effectiveness in decreasing risks of repeating unnecessary X-ray exposure. The use of various steps in the standard operating procedures of radiography, proper radiographic technique and critique, practical protection measures, and radiographic positioning practice in X-ray laboratory at a private radiographic academy in Indonesia were audited. Thirty participants were used as the simple random sample. The demographic distribution was divided into, gender, nationality, and practical experience. Generally, out of 30 participants, 20 (67%) complied, and 10 (33%) did not. Radiograph image results showed that proper radiographic technique was effective in decreasing repetitive exposure among X-ray laboratory users.

Key words: Clinical audit; radiographic technique; X-ray laboratory; wrist joint; innovation; radiography

The steps in the standard operating procedures of radiography (Meschan 1979), proper radiographic technique (Brennan & Johnston 2002), radiographic critiques (Mohd 2008), radiographic positioning practice and practical protection measures (Whitley *et al.* 2005), standard operating procedure of radiographic positioning practice in X-ray laboratory radiologic academy – the innovated radiographic technique – were audited.

According to the National Institute for Clinical Excellence, clinical audit provides practitioners with a systematic response that compares the care provided to best practice while preserving the central role of the clinical team in agreeing and implementing plans for change (Excellence 2002).This study is necessary to be conducted in a private owned radiologic academy in Indonesia to make a good change in the system.

According to Jones and Cawthorn (2002), when a clinical audit is conducted well, it provides improved methods and systems (the innovated radiographic technique) in which the quality of procedure for service users becomes supportive and developmental. That is why the innovated radiographic technique for X-ray laboratories was anticipated to improve and develop the practice of radiographic technique among X-ray laboratory users.

This study hopes to improve the behaviour of radiographers whereby it also leads to an unbiased evaluation of the effectiveness of X-ray laboratory users in decreasing the poor quality of radiological diagnostic images which as a result often leads to a repetition of shooting radiographs (Surić Mihić *et al.* 2008).

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Radiographers must follow the protocols and standards set by actively participating in establishing and further developing protocols to ensure consistency of diagnostic quality images and improved practices to reduce human radiation exposures (Herrmann *et al.* 2012).

Unlike in other professions where the purpose of the simulation is to practice procedures to minimize error, in medical imaging, there is great value in being able to visualize the effect of incorrect technique as this reinforces the importance of accurate positioning and allows reflection on corrective approaches (Bridge *et al.* 2014).

On account of these issues, this clinical audit aims to evaluate the compliance on the innovated radiographic technique among X-ray laboratory users in a private owned radiologic academy in Indonesia. In addition, it also aims to identify which demographic variables, such as gender, nationality and clinical practical experience which complies with the practice of the innovated radiographic technique. A conclusion is also offered.

BACKGROUND

Ionizing radiation may affect different living biological systems and organs such as gastrointestinal, central nervous systems, gonads or even whole body and result in somatic and genetic effects based on the number of exposures (Talab *et al.* 2016) (refer *Table 1*).

The Publication No. 732 of the International Commission on Radiological Protection (ICRP) recommended the use of diagnostic reference levels for patients who have undergone the common diagnostic procedure as a measure for the optimization of protection in medical exposures (Surić Mihić *et al.* 2008). The human users' exposure dosage may reduce up to 75% by complying with the appropriate imaging techniques (Talab *et al.* 2016).

Therefore, the ICRP recommendation can protect human users against radiation damage (Prasad *et al.* 2014).

The innovated radiographic technique is a quality improvement which spanned from the principles of the ICRP recommendations. Furthermore, by reviewing available literature, the author was able to validate the innovation which would lead to a more credible result.

Table 1. Ionizing radiation effects and their risk to humans (Talab *et al.* 2016)

	Deterministic/Non-stochastic
1.	Skin erythema/necrosis/epilation
2.	Cataract
3.	Sterility
4.	Radiation sickness
5.	IUGR/teratogenesis/fetal death
	Stochastic
1.	Cancer
2.	Hereditary defect (e.g. down syndrome)

LITERATURE REVIEW

The ICRP recommendations address the following:

(1) Proper positioning of the patient or his anatomic part on the central ray, proper choice of grid and cone, choice of screen (cassette) or non-screen technique;

(2) Choice of optimum exposure factors, removal of film from cassette in darkroom;

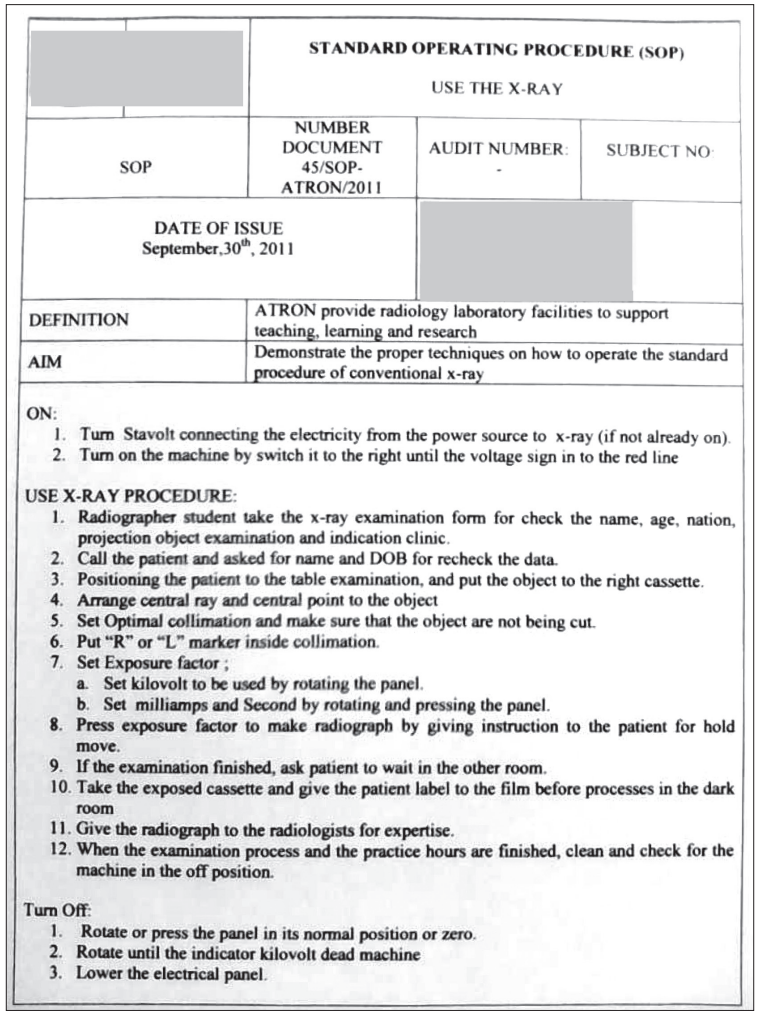
(3) Transfer of the film to hanger (for wet film developing) or to an autonomic processing unit, passage of film, either automatically or manually, through development, stop-bath, fixation, wash and dry, sorting and attachment of dried films to the consultation request form and old film envelope, ready for interpretation by the radiologist;

(4) Submission of consultation report to the referring physician; and

(5) Return of the duplicate report as well as the films to the appropriate files are the standard operating procedures (*Figure 1*) of radiography that is to be complied by radiographers (Meschan 1979).

When critiquing your radiograph (Step 2) it is useful to look at the aspects that make up a good image. One way to ensure that all areas are covered is to use an acronym such as: positioning; anatomy of interest; collimation; exposure factors; markers; normality/anomaly; and remote operators radiographic licensing (Mohd 2008).

Lastly, the operators carrying out the medical exposures are to take practical steps to protect the human users who may be involved in: preparation, identification, addressing particular issues, e.g. paediatrics, females, selection of imaging equipment, type of image receptor, patient positioning, exposure technique, image projection, beam collimation, exposure parameters, patient protective equipment and shielding (Whitley *et al.* 2005).



STANDARD OPERATING PROCEDURE (SOP)

USE THE X-RAY

SOP	NUMBER DOCUMENT 45/SOP-ATRON/2011	AUDIT NUMBER: -	SUBJECT NO:
DATE OF ISSUE September,30th, 2011			
DEFINITION	ATRON provide radiology laboratory facilities to support teaching, learning and research		
AIM	Demonstrate the proper techniques on how to operate the standard procedure of conventional x-ray		

ON:

1. Turn Stavolt connecting the electricity from the power source to x-ray (if not already on).
2. Turn on the machine by switch it to the right until the voltage sign in to the red line

USE X-RAY PROCEDURE:

1. Radiographer student take the x-ray examination form for check the name, age, nation, projection object examination and indication clinic.
2. Call the patient and asked for name and DOB for recheck the data.
3. Positioning the patient to the table examination, and put the object to the right cassette.
4. Arrange central ray and central point to the object
5. Set Optimal collimation and make sure that the object are not being cut.
6. Put "R" or "L" marker inside collimation.
7. Set Exposure factor ;
   a. Set kilovolt to be used by rotating the panel.
   b. Set milliamps and Second by rotating and pressing the panel.
8. Press exposure factor to make radiograph by giving instruction to the patient for hold move.
9. If the examination finished, ask patient to wait in the other room.
10. Take the exposed cassette and give the patient label to the film before processes in the dark room
11. Give the radiograph to the radiologists for expertise.
12. When the examination process and the practice hours are finished, clean and check for the machine in the off position.

Turn Off:

1. Rotate or press the panel in its normal position or zero.
2. Rotate until the indicator kilovolt dead machine
3. Lower the electrical panel.

Figure 1. The innovated radiographic technique.

METHODOLOGY

Primarily the auditors qualified as a radiographer evaluated the innovated radiographic technique. The participants involved in the audit are the X-ray laboratory instructors and their students in semester four. A simple random sampling was used to select the subjects.

Secondly, the auditors ensured that the innovation was presented to the operations management for approval which was then shown to the deans to ensure that it was operational and in coordination with the lecturer's or X-ray laboratory instructor's schedule. The auditors also made sure that the X-ray laboratories were supplied with facilities such as lead apron, marker placement, exposure factor chart, and the X-ray machine.

Steps of the innovated radiographic technique was posted on the walls of the selected laboratories with the seal of approval from the academy's operations management. The posters were 9.14 cm long, and 6.09 cm wide which was similar to A-3 sized papers and the letters were typed in big font size 40, written both in the Indonesian and English language. It was anticipated that the laboratory instructors would emphasize to their students to comply with the approved innovated radiographic techniques.

Finally, an additional risk of safety for human subjects was approved by the department of research and a copy to the operations management to commence the audit was given.

The audit was carried out for a maximum of 3 days. Since the auditor (in this case, the author) used ten radiographers and students in semester 4, the total number of participants were 30. The auditors ensured that the audit would not be repeated since the prospective subjects – both students and teachers – were not informed that they were being observed.

Portfolios of the participants were organized and it was ensured that it followed the guidelines of the Quality Assurance Agency (Moore 2005). Each participant was given index numbers for data analysis. Each index number was given to the participants so that the portfolio would be easily accessed when they wished to refer to the results of their published findings in this clinical audit.

The auditor (the author) before starting the audit went into a console/control table room with a glass window and sat inside while observing the participants. The selected participants were anticipated to have no problems with the Indonesian/English language, encrypted on the innovated radiographic techniques posted on the walls.

Prospective subjects/participants who did not comply with the method of radiographic techniques was category used as non-compliance, while those who complied belonged to the category of compliance.

After the participants had used the X-ray laboratory, whether they complied with the procedure following the innovated radiographic techniques or not, were asked to process the X-ray films in the dark room. This concluded the evaluation.

Steps in processing the films in the darkroom was not audited. The dark room in the place for film processing was ready to be used after the X-rays were done and the innovated radiographic techniques were performed.

The radiograph films after being processed in the dark room were collected and labeled as 'compliance' and 'non-compliance'.

FINDINGS

Thirty participants were given the consent to be innovated in this audit procedure. The participants who belonged to the non-compliance category were evaluated to have miscommunicated the innovated standard radiographic techniques posted on the walls. Those who demonstrated all the steps of the innovation belonged to the compliance category.

Table 2, shows the identified demographic distribution of the 30 participants that were categorized as compliant and non-compliant with the innovated standard radiographic techniques in the X-ray laboratory. Out of 30, there were more participants who complied n= (20 or 67%) than those who did not comply n= (10 or 33%).

The selected private academy had more participants who practiced in Central Hospital Governance as compared with those who did not.

According to *Table 2*, participants who were from female high school (science majors) complied most on the methods (six compliance), followed by those from male high school (social majors) (four compliance) and by the same gender as the vocational high school (2 compliance).There were more males who did not comply from the vocational high school (3 non-compliance) followed by the high school of social majors (2 non-compliance). While the females from high school science and social majors had more non-compliance (2/30) followed by the participants from the vocational high school (1/30).

Table 2. The findings of both compliance and non-compliance to radiographic technique in the X-ray laboratory.

Categories	Male	Female	Jakarta	Non-Jakarta	Practice in Central Hospital Governance	Non-practice in Central Hospital Governance
Compliance	5	6	7	4	9	2
	4	2	1	5	4	2
	2	1	1	2	1	2
Non-compliance	0	2	0	2	1	0
	2	2	1	3	3	1
	3	1	1	3	1	3

There were more non-locals of Jakarta who complied (11/30) as compared with those who were locals of Jakarta (9/30). The selected private academy had more locals of Jakarta as compared with the non-locals of Jakarta.

There were more subjects who practiced in Central Hospital Governance who complied (14/30) as compared with those who did not (6/30).

The statistical figures identified compliance of radiographic techniques in the X-ray laboratory. Data analysis using percentage was appropriate for this clinical audit to easily convert a group of figures into one value and when it is dispersed into several values would still be easily averaged. The picture in *Figure 2*, is the result of a good compliance to proper positioning.

Figure 2. Radiographic technique of the wrist joint.

Figure 3, shows the comparison of compliance and non-compliance. A very few evidence of compliance was shown on the radiographic image films after being processed in the dark room.

ACTION PLAN FOR CHANGE MANAGEMENT

Planning how to communicate the posters was addressed to enhance the change management of the innovated procedure. Those who did not practice in Central Hospital Governance and who were non-compliant might have also experienced barriers in communication skills. Handbooks may be an action plan to change the communication process.

The innovated radiographic techniques audited in this private academy in Indonesia could use a handbook to enhance learning in the workplaces. However, the handbook should achieve the aim to provide an element of professional practice pertinent to reduce the errors on X-ray photo shooting. This would distinguish the challenges of implementing the innovation.

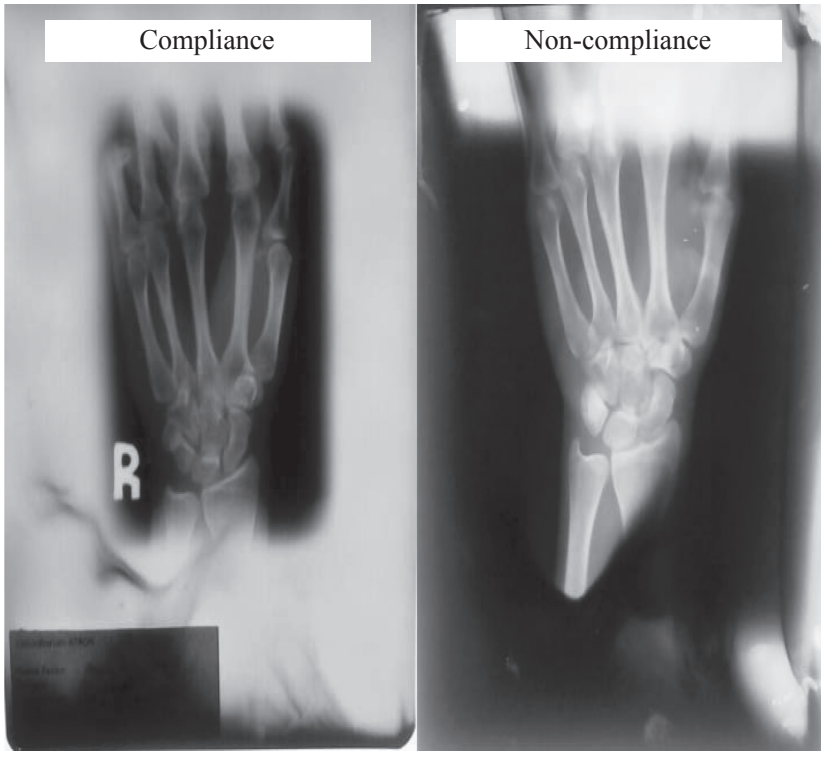


Figure 3. Comparison of compliance and non-compliance.

Auditing the correct way by using the apparatuses to radiographic techniques was the primary step. However, the process of change could be threatened if the user did not have the full knowledge on how to operate the machine. In order to avoid this weakness, the auditors after conducting the audit could ensure that the standard operating procedures were explained to the X-ray laboratory users.

However, the observation started primarily without the participants knowing that they were being observed. This might perhaps be the reason why the students and instructors did not demonstrate competency in using the machine.

own students who would use the laboratory at their workplaces after giving them seminars and training.

These laboratory users (whether they were students or laboratory instructors) would be identified as potential harm to the likely success of the change process if they did not comply with the innovated radiographic techniques in X-ray laboratory after giving them seminars and training.

Hence, clinical audits should constantly be conducted semi-annually to freeze the change process (*Table 3*).

Table 3. The clinical audit that should constantly be conducted.

What we want them to do? (Innovated radiographic techniques)	What they are doing? (Findings)	What they need to do? (Action plan)
Using Standard Operational Procedure Laboratory	☐ Complied ☐ Not complied	Read the posters on the walls
Steps in the production of radiograph	☐ Complied ☐ Not complied	Read the handbook and attend seminars and training
Demonstrate the PACEMAN	☐ Complied ☐ Not complied	Attend seminars and training and disseminate information

In order to evaluate the effectiveness of the innovation in making X-ray laboratory users to demonstrate competency in complying with the innovation, the auditors could give X-ray laboratory instructors seminars and trainings to emphasize on the innovated radiographic techniques.

It could be anticipated that the laboratory instructors would disseminate the information and their knowledge of the innovation to their

CONCLUSION

Out of the 30 participants, 16 were male participants and 14 were female participants. Of the 14 females, nine were compliant (64%), and five were non-compliant (36%). Of the 16 males, 11 were compliant (69%), and five were non-compliant (31%). It was also identified that factors affecting radiation dosage during radiographic examinations included applied

tube voltage (kVp), tube current (mA), exposure time (s), filtration, focal spot to skin distance, film-screen speed, collimation, and patient size which was needed to be addressed among radiographers to take into consideration.

It was therefore concluded that auditing innovated radiographic techniques in X-ray laboratory was deemed necessary to identify and evaluate an unbiased outcome of X-ray quality image since radiographic techniques after using the X-ray laboratories decreased the risk of unnecessary harm to human users.

The innovated radiographic technique in X-ray laboratory was successful although this audit showed a percentage of deviation from the point of complete compliance due to communication barriers. More participants complied (20 or 67%) than those who did not comply (10 or 33%).

A poor radiographic technique, in turn, might lead to unnecessary exposures to X-radiation, poor image quality, repeated views and examinations, patient discomfort or further injury because of poor positioning and the possibility of a missed diagnosis or misdiagnosis. The knowledge of radiographers regarding optimal techniques in reducing unnecessary X-ray exposure by applying the recommended exposure protocols would be a foundation to reaffirm reducing the danger of cancer induction as far as possible during repeated X-rays examination. Improvement of the professional and public reputation of the radiological department as a result of education and active work approach is important.

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Optimization of the Photochemical Degradation of Textile Dye Industrial Wastewaters

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In this study, the photochemical degradation via photo-Fenton process was carried out to degrade dyes in textile industrial wastewaters. Experimental design methodology was also applied for optimizing effects of factors which influence the effective treatment such as ferric dose, hydroperoxide dosage, initial pH, reaction time and initial chemical oxygen demand (COD). Two independent variables namely colour and COD removal efficiencies were used to evaluate the treatment yield. Under the optimal conditions, ca. 99% and ca. 88%, colour, and COD were removed, respectively.

Key words: Photo-Fenton; textile industrial wastewater; design of experiment

Recently, Vietnam's textile and garment industry are playing a significant role in national socio-economic development (Agency VTP 2014). However, this sector consumes a lot of water (EPA 1996). Consequently, it is also one of largest groups of industries causing severe water pollution (Torrades & García-Montaño 2014); they also mentioned that textile mills damaged the quality of the environment by emitting high suspended solids, high temperature, unstable pH, high chemical oxygen demand (COD), low biological oxygen demand (BOD) as well as great colourization (Torrades & García-Montaño 2014).

On the other hand, textile wastewater usually contains organic compounds which are unable to be degraded by biological or even chemical treatments (Uygur & Kök 1997; dos Santos *et al.* 2007) and can be harmful to environments (dos Santos *et al.* 2007).

Up to now, various methods at the laboratory, pilot or full-scale have been applied for textile wastewater treatment. However, most of them are quite inefficient due to toxic and non-biodegradable substances of textile wastewaters (dos Santos *et al.* 2007; Forgac *et al.* 2004). To overcome some drawbacks of currently mentioned methods, researchers focus on advanced oxidation processes (AOPs) such a photo-catalysis method. Typically, Fenton and photo-Fenton techniques which were reported in few published articles have been carried out for treating textile wastewaters (Alinsafi *et al.* 2007; Lucas & Peres 2006; Meric *et al.* 2004; Lee & Shoda 2008) especially the removal of COD and colourization (Uygur & Kok 1999; Forgaes *et al.* 2004; Meric *et al.* 2004; Lee & Shoda 2008; Arslan-Alaton *et al.* 2009) because of their advantages (Torrades & Garcia-Montana 2014; Arslan-Alaton *et al.* 2009). Moreover, José Blanco *et al.* (2012) carried out experiment on textile wastewater via the combination

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of Fenton and biological-Fenton coupled processes. They concluded that Fenton reaction and combination of biological treatment and Fenton reaction were proper treatments to this kind of wastewater. According to the results, Fenton process should be followed by biological treatment for saving energy and cost.

In the experimental point of view, the design of the experiment (DOE) was also employed to find out the optimal conditions of independent variables to overcome some disadvantages of the one-factor-at-a-time method such as more runs, without interaction information or missing optimal setting of factors (Hartmann *et al.* 2010; Montgomery 2005; Tan-Hiep & Chen 2013). Therefore, this study presents the application of 2-level fractional factorial design for degrading textile dye wastewater via the photo-Fenton process.

MATERIALS AND METHODS

Samples and Chemicals

Characteristics of six loads of textile wastewater (TW) samples gathered from the textile and garment industrial zones in Ho Chi Minh City, and Khanh Hoa Province (Vietnam) were mentioned in *Table 1*.

COD and colour of all collected samples were analyzed according to fulfill using APHA standards (Standard Methods) (APHA 1998). Other chemicals were also of standard analytical reagents. The taken samples were stored at 4°C before use.

Fenton and Photo-Fenton's Reaction

Fenton's reaction is the dark reaction of ferrous iron (Fe^{2+}) with H_2O_2. It is a series of reaction to generate •OH radicals and Fe^{2+} ion.

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + \bullet OH + {}^{-}OH \quad (1)$$

$$Fe^{3+} + H_2O_2 \rightarrow FeOOH^{2+} + H^{+} \quad (2)$$

$$FeOOH^{2+} \rightarrow HO_2\bullet + Fe^{2+} \quad (3)$$

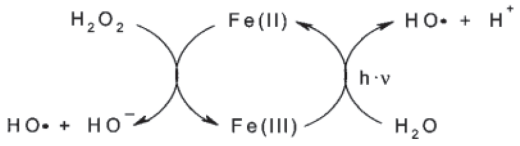
$$HO_2\bullet + Fe^{3+} \rightarrow Fe^{2+} + O_2 + H^{+} \quad (4)$$

More recently, some researchers integrate the UV radiation and ozone with Fenton's reaction for treating the toxic wastes (Forgaes *et al.* 2004; Arslan *et al.* 2009; Hartmann *et al.* 2010). The mechanism of the Fenton and photo-Fenton's reaction *Scheme 1* was reported in the published literature (Arslan-Alaton *et al.* 2009; Sohrabi *et al.* 2014).

Table 1. Values of colour and chemical oxygen demand of taken textile wastewaters.

Loads	Colour, PCU[(a)]	COD (ppm)
A[(b)]	761.3	249 .0
B[(b)]	774.7	161 .0
C[(c)]	19 760–31 616	428.8–686.1
D[(c)]	23 712–35 568	514.6–772.0
E[(c)]	33 592–41 496	729.0–900.5
F[(c)]	31 616–39 520	686.1–857.6

[(a)] Platinum-cobalt Unit; [(b), (c)] Stand for samples taken from industrial zones in Khanh Hoa Province, and Ho Chi Minh City, respectively.



Scheme 1. Mechanism of the photo-Fenton's reaction (Arslan-Alaton *et al.* 2009).

Kusic H. *et al.* (2006) mentioned that the Fenton's techniques and a combination of UV and H_2O_2 are the widely used methods compared to other chemical AOPs. Therefore, photo-Fenton in which ferric ion instead of ferrous ion was applied in this case.

Experiments

In this work, the photo-Fenton's reaction took place in a glass-jacket immersion-type UV-reactor which was modified from the system developed by Hansson *et al.* (2012).

All runs were carried out with a volume of 0.5 l of textile wastewaters. All investigated parameters were listed in *Table 2*, while the unlisted ones such as agitation speed and temperature reaction were kept constant as 400 rpm and ca. 30°C, respectively. In this case, water was used as a coolant to maintain the reaction temperature constant.

After the desired durations, the pH value of the treated wastewaters was neutralized to ca. 6.5 and continuously agitated for 5 min at 400 rpm for quenching the photo-Fenton reaction, while the UV radiation was switched off (Zhu *et al.* 2011).

Design of Experiment and Statistic Analysis

According to the published literatures (Uygur & Kok 1999; Alinsafi *et al.* 2007; Lucas & Peres 2006; Meric *et al.* 2004; Lee & Shoda 2008; Arslan-Alaton *et al.* 2009; Hartmann *et al.* 2010; Sohrabi *et al.* 2014; Kusic *et al.* 2006), the main factors or independent variables that can influence the removal efficacy of COD and colour from textile wastewater are initial pH, UV radiation duration (min), dosage (mmol) of Fe(III) and H_2O_2 (HP) as well as the original COD (ppm), while the response variables are removal efficiency of colour (Y1, %) and COD (Y2, %).

In this report, the fifth batch was selected as a demonstration of the application of design of experiment to do research in environmental issues. Uncoded and coded factors with their

Table 2. The uncoded/coded factors and their concerned levels in this work.

Uncoded/ Coded	Name of factors	Factor levels	
		Low (–1)	High (+1)
pH/X_1	pH	3.0	4.0
t/X_2	UV radiation duration (min)	30	40
Fe(III)/X_3	Dosage of Fe(III) (mmol)	0.75	1.0
HP/X_4	Dosage of H_2O_2 (mmol)	8.0	12.0
COD/X_5	Initial COD (ppm)	729.0	900.5

levels were listed in *Table 2*.

All statistical analyses, and design of experiment were done by using *MS-Excel* with calculated appropriate formula were conducted by Montgomery 2005 (Tấn-Hiệp & Chen 2013) as well as with a statistical software viz. SAS JMP®. The response variables were predicted by using the first-order equation as below in *Equation 5*.

$$\hat{Y} = \beta_o + \sum_{j=1}^{k} \beta_j X_j + \sum \sum_{i<j} \beta_{ij} X_i X_j + \varepsilon \quad (5)$$

where k, $\hat{Y}$, β_j, β_{ij} and ε mean number of independent variables, predicted the response variable, linear regression coefficients, interactive coefficients, and the residual or random error, respectively (Montgomery 2005).

In this study, a two-level fractional factorial design (FFD) for fitting the first-order model expressed as *Equation 5*, shown in *Table 3* was duly carried out. The patterns, the dependent (Y) and predicted ($\hat{Y}$) dependent variables were listed in *Table 3*, respectively.

The last row in *Table 3* describes the average results gained from the experiments conducted at the central point. Also, the run order was randomly performed to minimize errors.

Table 3. The patterns, response and predicted response variables.

Patterns	Y_1 (%)	Y_2 (%)	$\hat{Y}_1$ (%)	$\hat{Y}_2$ (%)
---- +	75.6	46.7	75.6	44.9
+----	61.8	35.9	61.8	36.6
-+---	86.6	55.2	86.6	55.5
++ --+	75.0	51.7	75.0	52.5
-+--	86.1	59.6	86.1	61.4
+-+-+	78.6	55.2	78.6	54.5
-++ -+	77.7	53.1	77.7	52.8
+++ --	87.4	60.5	87.4	59.7
--- +-	97.3	64.9	97.3	64.1
+--++	68.7	41.0	68.7	40.7
-+-++	90.7	60.9	90.7	60.2
++ -+-	94.7	58.7	94.7	60.5
--+++	92.3	62.3	92.3	63.1
+-++ -	65.6	29.8	65.6	30.1
-+++ -	97.0	69.3	97.0	70.0
+++++	92.4	70.9	92.4	69.1
00000	89.9	58.9	–	–

RESULTS

Examination of Untreated Textile Wastewater

The taken TWs were characterized by monitoring parameters such as initial pH, COD, colour, and surfactants, and *Table 1* shows the extracted results.

Statistical and Multiple Regression Analysis

Effects of main factors and interactions. *Figure 1* shows the influence of five main factors on the removal efficacy of colour and COD in the case of the fifth batch of TW.

Two first and the fourth variables (X_1, X_2 and X_4) would be strongly affected by removal efficiency, while the third and the last one would be of insignificant influence. Therefore, the higher levels of X_2 and X_4 the higher efficiencies of both colour and COD removal could be obtained because of their positive linear influence. The influences of X_1 and X_2 on the dependent variables are quite similar but in an opposite direction. Typically, the initial pH value should be decreased to get higher colour and COD removal. Those are also the strongest effects. This statement is consistent with the conclusion of low pH values as running the Fenton's or photo-Fenton reaction (Arslan-Alaton *et al.* 2009; Hansson *et al.* 2012).

In the interaction point of view, the highest effect resulted from the interaction between initial pH and UV radiation duration (X_1X_2) in both colour and COD removal. The effects of the rest are moderate and presented in *Table 4*. In this case, the higher interactions were neglected because of their insignificant effects. *Table 4* expresses an ANOVA analysis for the reduced models at probability of 95.0%.

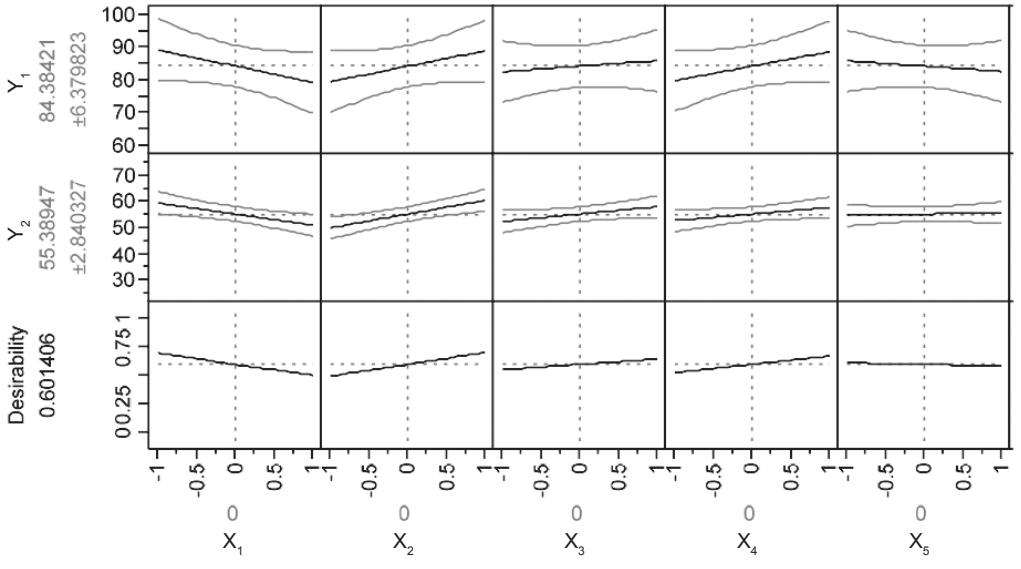


Figure 1. Effects of main factors on response variables.

Table 4. ANOVA for reduced models.

Terms	$\|t\|^{(d)}$	$\|t\|^{(e)}$	Terms	$\|t\|^{(d)}$	$\|t\|^{(e)}$
Inter.	466.4	252.8	X_1X_4	11.5	13.2
X_1	27.8	19.7	X_2X_3	–	–
X_2	26.5	24.5	X_2X_4	9.2	11.2
X_3	9.4	13.2	X_3X_4	12.3	9.3
X_4	24.6	11.5	$X_1X_2X_3$	–	4.9
X_5	9.0	–	$X_1X_2X_4$	12.4	10.6
X_1X_2	26.0	21.6	$X_1X_3X_4$	12.1	6.4
X_1X_3	7.3	–	$X_2X_3X_4$	12.6	17.3

$^{(d),(e)}$ Stand for Y_1 and Y_2, respectively.

The reduced models for colour ($\hat{Y}_1$) and COD ($\hat{Y}_2$) are expressed in *Equations 2–3*, respectively.

$$\hat{Y}_1 = 82.97 - 4.94X_1 + 4.72X_2 + 1.67X_3 + 4.37X_4 - 1.59X_5 + 4.63X_1X_2 + 1.13X_1X_3 - 2.04X_1X_4 + 1.64X_2X_4 - 2.18X_3X_4 + 2.21X_1X_2X_4 - 2.14X_1X_3X_4 + 2.24X_2X_3X_4 \quad (6)$$

$$\hat{Y}_2 = 54.73 - 4.27X_1 + 5.31X_2 + 2.86X_3 + 2.49X_4 - 0.49X_5 + 4.68X_1X_2 - 2.86X_1X_4 + 2.42X_2X_4 - 2.01X_3X_4 + 1.06X_1X_2X_3 + 2.29X_1X_2X_4 - 1.38X_1X_3X_4 + 3.74X_2X_3X_4 \quad (7)$$

Checking model adequacy. The determine coefficient values, R^2, of 99.49% for decolouration and 99.26% COD removal meant that not only a good agreement between predicted and observed values but also the obtained mathematical models, *Equations 6–7*, could predict the removal efficiencies very well (Montgomery 2005; Tấn-Hiệp & Chen 2013).

Furthermore, $F_{exp.}$ values of these models were 9.7 and 8.3 respectively. In comparing to $F_{\alpha,df1,df2}$ of 19.0, these models were significant. Hence, they could be used for predicting the experimental results, *Figure 2*.

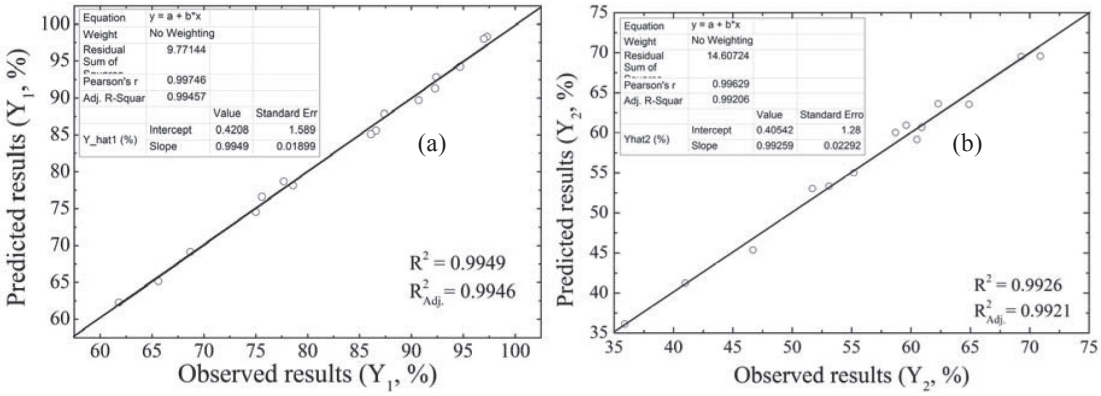


Figure 2. Observed vs. predicted removal efficacies of colour (a) and COD (b).

Optimization. The analyses obtained above implied that the actual optimum was outside these operating conditions previously investigated. Thus, the steepest ascent method was preferentially called up to find out the optimal operation conditions. The as-fitted multi-linear models shown as *Equations 6–7*, were used in this paper. The path of the steepest ascent is the line through the center of FFD moving the fastest to the fitted surface. Usually, it will go until no further increment in response is observed (Montgomery 2005; Tan-Hiep & Chen 2013).

In this study, the optimal condition is 2.70 of initial pH, the duration time of ca. 51 min, and 0.975 and 12.00 mmol of ferric and HP dose, respectively. Under the optimum condition, efficacies of colour and COD removal could be attained as high as of ca. 99.5% for decolouration and ca. 88.0% for COD removal.

CONCLUSIONS

Photo-Fenton's reaction using ferric could be conducted for degrading dyes in textile and garment wastewater collected from an industrial park in Khanh Hoa as well as Ho Chi Minh City (Vietnam).

It could be successful to apply DOE especially FFD for solving not only the specific example in this study (colour and COD removal) but also other problems of environmental engineering.

These optimal conditions were summarized as: (1) initial pH value of 2.7; and (2) UV radiation duration of ca. 51 min, the dosage of ferric and HP respectively of 0.975 and 12.00 mmol, and stirring speed of 400 rpm. The positive point of this study was the quality of treated TW which satisfied the Vietnam National Standards (Type B).

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Factors Influencing *ISO 14001* Firm's Perceived Environmental Performance in Malaysia

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The changes in the global environmental conditions have placed great challenges on governments, industries, and societies. Business organizations are often blamed for being the sources of these environmental problems. This study aimed to examine the factors influencing the perceived environmental performance of firms certified under the *ISO 14001* in Malaysia. A total of 268 manufacturing companies responded to the questionnaires. In this study, structural equation modeling was applied to test the hypotheses. It was found that the "environmental policy", "environmental training", "regulatory stakeholder's pressures", and "customer pressures", influence the firm's perceived environmental performance in which "customer pressures", was found to be the dominant factor. The measure of environmental performance was self-reported due to the lack of available data. Therefore, perceived environmental performance was employed for this study which is a perceived measure based on the dimensions of the *ISO 14001* definition. This study provided a model to synthesize both internal (environmental policy and environmental training) and external (regulatory stakeholder's pressure and customer pressures) constructs that influenced a firm's perceived environmental performance. The empirical results and insights from interviews shed lights on the practitioners as to how to enhance a firm's environmental performance through green practices.

Key words: Green practices, environmental strategy, environmental performance, Malaysia; environmental management system

The changes of global environmental conditions have placed great challenges to governments, industries, and societies. Manufacturing and industries were blamed for being the major cause of environmental disasters that led to global warming (Fiksel 1996; Packard & Reinhardt 2000; Levy & Kolk 2002). Changes in global environment conditions will rapidly create an unprecedented economic gap (Margretta 2000, p. 59). Ecology and economy are inseparably interconnected; hence, the protection of the environment is an important part of economy values. Nevertheless, care and preservation of the environment are the responsibility of humans, and they should be accountable for the fate of the earth. According to the report on the *Climate Change Performance Index* (CCPI 2015; CCPI 2014), the environmental quality of Malaysia is declining at the level of 52 in 2015 and 51 in 2014.

These statistics have posed challenges to the nation growth and sustainability. One of the initiatives for Malaysia to manage these environmental challenges is related to the reduction of emission intensity on Gross Domestic Product (GDP). By the year 2020, Malaysia is committed to reducing up to

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40% of the carbon emission (*U.N. Climate Change Conference 2009*). While Malaysia has participated in the *United Nations Framework Convention on Climate Change* to address issues of global warming, it is found that both industrial player and community should place a greater commitment towards environmental preservation. A greener perspective towards environmental management should be applied across all business industries as it is aligned with the nation's aspiration for a better and healthier living environment (Najam 1999).

There are numerous studies conducted on environmental strategies in business fields. Hart's article (2000, p. 127) in the *Harvard Business Review* entitled, 'Beyond Greening: Strategies for a Sustainable World', where he diagnosed that the rapid growth in emerging economies cannot be sustained in the face of increasing environmental deterioration, and resource depletion. In the coming years, the responsibility to apply clean technologies and implement strategies that significantly reduce the environmental problem will befall largely to the industry, the economic engine for the future.

This study focused on what influenced the manufacturing firms in Malaysia to take up environmental management. A total of 643 certified firms under *ISO 14000* were chosen from the Federation of Malaysian Manufacturers directory (FMM) year 2013, and Standards and Industrial Research Institute of Malaysia (SIRIM) *Directory of Malaysian Certified online Databases December 2013* (SIRIM 2013) for this study. This small number represented only 1.62% of the total 39,669 (SMEs 2013) manufacturing firms in Malaysia. Through this study, it was evident their strong interests in taking a more strategic approach towards environmental management.

Recognizing the factors for the organizational commitments in environmental management is a must so that Malaysia can achieve both economic growth and ecological sustainability. We know that greater conservative efforts such as using the scientific technology and waste management system could and would contribute to better environmental management, but what drive these business firms to take the initiative towards their environmental performance. The purpose of this paper is to determine the structural relationships of factors affecting *ISO 14001* firm's perceived environmental performance in Malaysia. This paper begins with a literature review related to the firm's discerned environmental performance. Then, we develop the theoretical argument for illustrating this study including the perspective of resource-based view and stakeholder theory. Subsequently, we present a research framework, methodology and discuss findings.

LITERATURE REVIEW

Resource-based Theory

The resource-based view (RBV) can be rare, valuable, inimitable, and have the non-substitutable capability that sustains environmental excellence both in strategies and performance as argued by Bruce and Lynn (2010). RBV claims that source for competitive advantage is derived from organizational capabilities (Voola, Carlson & West 2004). Therefore, internal capabilities of firms are the main causes for its profitability differences (Barney 1991). *ISO 14001* Environmental Management System (EMS) implementation is unique in the sense where firms may group its resources into three categories (i.e. physical, human and organizational) to shape its capabilities that will enrich the value of a resource and further leads to competitive advantage. Additionally, it will bring significant effects on the firm's performance (both operation and business performance).

Stakeholder Theory

According to Freeman and McVea (2001, p.192), the fundamental task in a strategic management

process is to govern and incorporate the relationships and interests of shareholders, employees, customers, communities and other interested parties to ensure the enduring success of the firm. Freeman (1984) outlines how an organization fulfils its internal or external stakeholders through the pressures put forth by them. General conceptualization on Stakeholder Theory cited from Sarkis, Zhu and Lai (2011, p. 5) as follows:

"Stakeholder theory suggests that companies produce externalities that affect many parties (stakeholders), which are both internal and external to the firm. Externalities often cause stakeholders to increase pressures on companies to reduce negative impacts and increase positive ones."

Environmental Policy

According to Puig, Wooldridge, Michail and Darbra (2015), the presence of an environmental policy and environmental legislation are keys for environmental management. Firms that lack capability in business and environmental sustainability may place less emphasis on improving their environmental and economic performance together (Marcus & Anderson 2006).

According to Massoud, Fayad, El-fadel and Kamleh (2010), *ISO 14001* green management system is a certification that demonstrates a firm having a continuous commitment to improve its environmental performance. In other words, management clearly has established its commitment to environmental improvement either through the implementation of an EMS or *ISO 14000* certification. It has been noted that EMS policies and procedures should be monitored by all employees in the firm, hence generating an instinctive and systematic review and feedback programme (Crammer & Roes 1993; Zabihollah & Rick 2000). Also firms that recognize environmental performance need to align the managerial system with the performance evaluation system in their corporate environmental objectives (Epstein & Roy 1998).

Acknowledging the importance of environmental management, the principles outlined in the firm's environmental policy have turned into useful guidelines to drive its green practices to a higher level. In-house programmes are said to be a powerful motivator not only to create green awareness but also to ensure the achievement of its environmental mission. Ramus and Steger (2000) concluded that environmental policy will have a productive relationship to eco-initiatives which will improve company environmental performance. *ISO 14001* attests a company environmental policy and is continuously seeking improvement in its environmental performance (Massoud *et al.* 2010). Therefore, environmental policy enhances the firm's environmental performance.

Environmental Training

Research by Teixeira, Jabbour, and de Sousa Jabbour (2012) found that the themes addressed in the environmental courses are common to all hierarchical levels i.e. environmental policy, environmental management system, environmental auditing process, environmental impacts and aspects for each job position, eco-efficiency, and selective garbage collection. Beard (1996) argued that the environmental education and training for the employee is required for an effective corporate environmental strategy. This is because a new business culture with specific perceptions and value can be developed through environmental training. These new behaviours are needed to execute environmental programmes such as energy saving, efficient use of materials, recycling and reuse of products.

Fernanda, Jabbour and Simone (2012) added that the scopes of environmental, organizational innovation are closely related to the firm's environmental management

strategies. The effect of insufficient training may cause unwillingness of employee to participate in environmental efforts unless the firm exerts forces on the employee to the environmental policy (Nalini & Bonnie 2004). The environmental training provided to all the firms' employees should tremendously boost the general awareness and knowledge of employees on environmental issues. Thus, this leads to better and higher firm's environmental performance. However, some problems were encountered: employees reluctant to follow procedures, the lack of knowledge, including problems with the adoption of the new regulation (Hariz & Bahmed 2013), research findings by Daily, Bishop and Massoud (2012); Daily, Bishop and Steiner (2007); Daily, Bishop and Steiner (2003); Marshall and Mayer (1992) claimed that EMS training has a relationship to environmental performance whilst Hariz and Bahmed (2013) suggested that management commitment and support for EMS training has a relationship to environmental performance. Further study by Cole, Elliott and Strobl (2008) on firms in Ghana found that environmental training has positive influences on the firms' environmental performance.

Regulatory Stakeholder's Pressures

The reaction to the external pressure plays a major role in inspiring the spread on the importance of *ISO 14001* in China (Qi, Zeng, Tamb, Yin, Wu & Dai 2011). These forces from the governing legislation and stakeholders have supported the importance of EMS. The legislation is one of the institutional forces that steered a firm's corporate green responsiveness (Bansal & Roth 2000). According to Rusli, Abd Rahman, Ho and Abdullah (2013), complying with strict environmental regulations, support firms to improve the environmental performance and lead to the firm's competitiveness (Bacallan, 2000). In addition, Porter and Van der Linde (2000, p. 146); Loke, Khalid, Shafie and Sayaka (2014); Huang (2005) reported that the regulatory pressure is believed to be a major force for firm's environmental performance since it forces the firm to respond and react to the environmental findings.

Community Stakeholder's Pressures

The community is known as people who live in the same area or township. On the other hand, communities are composed of diverse individuals and organizations reside in patches of land or occupy the same geographic area (Daly & Cobb 1989, p. 172). The pressures from the environmental non-governmental organizations (NGOs) and local community are found to boost the likelihood of green businesses adoption by a firm (Bluffstone & Sterner 2006). The stimulus uses by NGOs, the community, and local societies act as an effective balance to match with formal regulation at large on pollution (Luken & Rompaey 2007). They observed that the firm's environmental behaviour is likely to be swayed by the trade and business which is linked to clean technologies adoption.

Executives are deemed to have many choices when social pressures are weak (Correa, Reche & Bario 2004). Further, Correa et al. (2004) noticed that in a given situation, the outside forces could sometimes influence how an organization tackle an environmental issue but do not standardize the commitment in the whole organization. Low social pressures may lead to executives having many choices to select from. Governing group of executives thus has more weights for greater environmental commitments. In addition, Boiral and Henri (2012) argued that implementation of EMS demonstrates the firm's responses towards external forces, and at the same time reflecting the firm's positive position for the community and social hope. Thus, this is in line with the previous studies by Shafie and Loke (2015); Walker, Sisto and McBain (2008); Zhu, Sarkis and Lai (2007); Cole, Elliott and

Shimamoto (2006); Huang (2005); Sharma (2000); Christmann (2000); Sharma and Vredenburg (1998); Ilinitch, Soderstrom and Thomas (1998); Lober (1996); Christie, Rolfe and Legard (1995) who demonstrated that community groups and environmental organizations will influence and will positively promote environmental performance of the firms.

Cole, Elliott and Shimamoto (2006) in their study on Japanese firms found that globalization has positive impacts on environmental management. Stakeholders that are exposed to global warming issues on a larger scale compared to waste problems expect firms to do more to improve their corporate image in the future as researched by Iwata and Okada (2011). Normative stakeholder's pressures from community, NGOs, media, and interest groups, generally lead to conformity of behaviour and satisfies a wide range of stakeholder needs rather than a narrow one (Simpson & Sroufe 2014).

Customer Pressures

Customer pressures form the most influential factor why firms impose green practices on their suppliers (Alvarez-Gil, Berrone, Husillos & Lado 2007; Carter & Carter 1998; Carter, Ellram & Ready 1998; Rao 2006). Customer awareness on the importance of environmental conservation had increased over the last decades (Min & Galle 1997). Customer pressures are instilled within the firm's supply chain when green practices are implemented to meet environmental and social needs (Rao 2007). This is particularly true when the manufacturing firms face pressures from stakeholders, involving end customers who have a preference to buy green products, along with an increasing number of legal regulations that form environmental standards for products (Hu & Hsu 2010; Shukla, Deshmukh & Kanda 2009). These regulations and emergent market pressures have urged some firms to find ways to alleviate their environmental impact and develop eco-friendly products (Zailani, Eltayeb, Hsu & Tan 2012). Sakr, Sherif and El-Haggar (2010) suggested that market pressure drives companies to implement the *ISO 14001* to achieve a green public image and to gain a competitive edge in markets that place certification as an entry precondition. External institutions also play a part in influencing the managerial perception of EMS implementation.

METHODOLOGY

Research Design and Sampling

The study was designed to test a structural model whether these variables namely environmental policy, environmental training, regulatory stakeholder's pressures, community stakeholder's pressures and customer pressures, that influence a firm's perceived environmental performance. Through the comprehensive literature review, these variables were identified. These variables have been integrated to yield five specific hypotheses to explore their relationships with the *ISO 14001* manufacturing firm's perceived environmental performance as shown in *Figure 1*.

In this study, the sampling frame represents all *ISO 14001* certified manufacturing firms in Malaysia which were obtained from the directory of Federation of Malaysian Manufacturers (FMM) year 2013 (FMM 2013) and from *SIRIM Directory of Malaysian Certified online Databases* as of December 2013 (SIRIM 2013). All manufacturing firms registered under *ISO 14001* were included in the study. Coincidently, they are all large firms. These 643 firms were selected because they have adopted green initiative and have higher awareness and experience dealing with environmental issues. Manufacturing firms were selected because operations and activities of these industries are commonly related to the environmental impact e.g. pollution, discharges of waste, etc. (IEA 2007; OECD 2009). The executive or manager was the targeted respondent for this study.

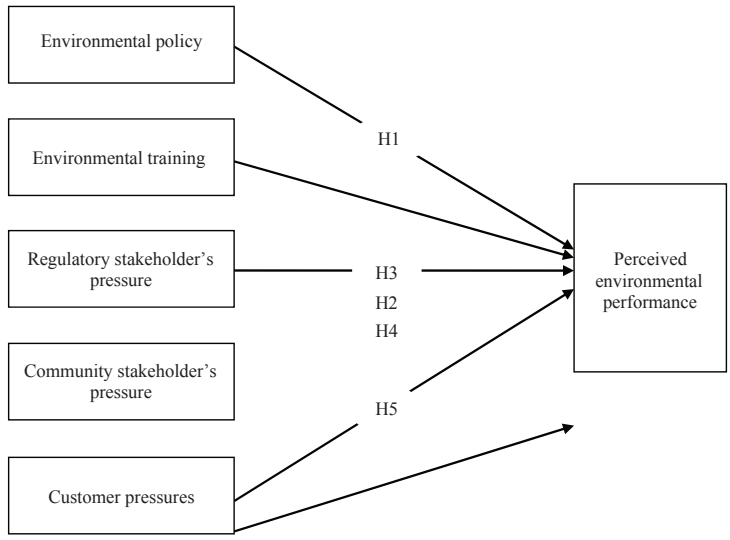

Figure 1. Research framework.

Five interviews were conducted to pretest the survey instrument. The respondents were selected from the environmental management representatives and the panel experts from the *ISO 14001* manufacturing firms. These interviews were carried out prior to the pilot test. The questionnaire was pilot tested on 30 respondents by applying the convenient sampling method from 15 firms to validate the questionnaire items before data collection. Data collection was carried out from February to June 2015.

The total population of the study was 643 firms. Thus, this was a census study; all the 643 firms were used in the study. However, after excluding the 15 firms used for the pretesting of the questionnaire, the population of the study was 628. A total of 628 questionnaires were mailed to the respondents. The help from SIRIM was also sought to deliver the questionnaire to the ISO certified firms when the auditors go for the site audit. A total of 268 of them were found completed and usable, yielding a response rate of 43% which is considered acceptable given the low reply expected from mail survey (Sekaran 2003) and generally low response rate for this type of correlational study in Malaysia (Eltayeb, Zailani & Ramayah 2011).

Profiling of the Participating Firms

Altogether 628 firms (FMM directory and SIRIM directory) from the manufacturing firms were involved in the survey. Coincidently, the participating firms came from large firms with more than 201 employees (SME Corp 2013). The majority of the respondents were from firms catering for both the domestic and international market (60.4%), followed by firms serving the international market (39.6%). The majority of firms have more than RM2 000 000 sales turnover.

In addition, when the responding firms were asked to indicate their certification body of *ISO 14001*, it was found that adoption for EMS was much greater under SIRIM as compared to others certification bodies. Firms that were certified under *ISO 14001* (SIRIM) were the highest (91%) compared to firms that were certified under others *ISO 14001* certification bodies (9%) such as SGS United Kingdom Limited (SGS), Lloyd's Register Quality Assurance Limited (Lloyd's), NQA Certification Ltd (NQA) etc. Thus it was also proven that *ISO 14001* as one of the most evident determinations on a firm's commitment towards adopting green efforts.

DATA ANALYSIS

Model Specification

For specification of the latent constructs, the loading for one of the indicators of each first construct was fixed at 1.0 in the model to create a scale for the latent construct. This process was done automatically with the features in *AMOS 22.0* software. The indicators for each underlying construct were grouped together to perform the confirmatory factors analysis (CFA) using the structural equation modeling (SEM) technique. After all the indicators were loaded to their respective latent variable, each construct was estimated individually prior to of all constructs being simultaneously estimated. In each estimated model, indicators that demonstrate poor loading were dropped, provided that they do not weaken reliability of the alpha coefficient, and then the measurement model was re-estimated. This was done to ensure that the data is a good fit to the measurement models. The cut-off value of 0.5 was used as the threshold of the factor loading assessment as recommended by Hu and Bentler (1999).

Environmental Policy, Environmental Training, Regulatory Stakeholder's Pressures, Community Stakeholder's Pressures, Customer Pressures, and Environmental Performance were each categorized into the following items. POL1 to POL5 for Environmental Policy, ET1 to ET7 for Environmental Training, REG1 to REG5 for Regulatory Stakeholder's Pressures, COM1 to COM5 for Community Stakeholder's Pressures, CUS1 to CUS5 for Customer Pressures, and ENV1 to ENV6 for Perceived Environmental Performance.

For the environmental policy (POL), the poor reliability of the POL4 item indicated that it would not be suitable elements of environmental policy latent variable as initially posited. Therefore, this indicator was eliminated from further analysis. As for the environmental training (EnvTra) latent variable, indicators ET1, ET2 and ET7 were removed due to poor loadings. For the regulatory stakeholder's pressure (REG), the poor reliability of the REG1 item indicated that it would not be suitable elements of regulatory stakeholder's pressure (Regulatory) latent variable as initially posited. Therefore, this indicator was eliminated from further analysis. For the community stakeholder's pressure (Community) latent variable, indicator COM4 was removed due to poor loadings. While for the customer pressure latent variable, indicator CUS4 was removed due to poor loadings. Finally, for the perceived environmental performance latent variable, indicator ENV1 and ENV5 were removed due to poor loadings.

Before conducting the analysis for structural modelling, the validity and the reliability of the survey instrument were generated. Data used for final data analysis was 268. As shown in Table 1, the results indicated that all values for the validity and reliability tests were within the acceptable range. The chi-square value of zero, (0.000) for CFA measurement models indicates a perfect fit (Hu & Bentler 1999). For the badness of fit index when RMSEA value is >0.08, some model modifications are required to ensure the model fits the data. The measurement model could be modified by examining the item reliability and factor loading criteria (Fornell & Larcker 1981; Nunnally & Bernstein 1994; Hair, Ringle & Sarstedt 2011). The composite reliability (CR) and average variance extracted (AVE) were calculated from the CFA loadings. Convergent validity was confirmed for all the constructs with the AVE and CR values above the acceptable threshold level criterion, >0.50 (Fornell & Larcker 1981) and >0.7 (Hair, Black, Babin, Anderson & Tatham 2006) respectively (see *Table 1*). Except for items POL4, ET1, ET2, ET7, REG1, COM4, CUS4, ENV1, and ENV5, all factor loadings for each indicator were >0.5 indicating a high convergent validity. All Cronbach Alpha values were >0.70 demonstrating a high consistency of the items used to measure each variable (i.e. environmental policy, environmental training, regulatory stakeholder's pressure, community stakeholder's pressure, customer pressures and perceived environmental performance). Thus, it was concluded that the survey instrument for measuring the variables was valid and reliable.

Table 1. Results for confirmatory factors analysis loadings, validity and reliability test (n = 268).

Variables and Items	Cronbach's Alpha / Composite reliability	CFA loadings	AVE	CFI	TLI	Model fit indices RMSEA	χ^2	*df*	χ^2/df
Environmental Policy	0.843 / 0.845								
• Publishes an environmental policy (POL1).		0.77	0.580	1.000	1.000	0.000	1.982	2	0.991
• Has specific targets for environmental performance (POL2).		0.87							
• Publishes an annual environmental report (POL3).		0.65							
• Makes employees responsible for company environmental performance (POL5).		0.74							
Environmental Training	0.803 / 0.803								
• Participates in international fairs to exchange good-social environmental practices (ET3).		0.68	0.504	1.000	1.004	0.000	1.555	2	0.777
• Contracts consultants for specialized training (ET4).		0.73							
• Frequently integrates with third parties to exchange environmental knowledge (ET5).		0.71							
• Organizes a workshop to discuss experiences and best green management practices (ET6).		0.72							
Regulatory Stakeholder's Pressure	0.827 / 0.829								
My company formulates an environmental plan to:									
• Prevent of non-compliance penalties (REG2).		0.76	0.549	0.998	0.995	0.033	2.573	2	1.287
• Gain specific subsidies and tax exemptions offered by Malaysian government (REG3).		0.77							
• Gain financial incentive offered by international organizations such as United Nations (REG4).		0.74							
• Avoid the threat of current/future government environmental legislations (REG5).		0.69							

Table 1 (cont.). Results for confirmatory factors analysis loadings, validity and reliability test (n = 268).

Variables and Items	Cronbach's Alpha / Composite reliability	CFA loadings	AVE	CFI	TLI	Model fit indices RMSEA	χ^2	*df*	χ^2 /*df*
Acceptable Threshold Levels	Cronbach's Alpha - >0.60	≥0.50	>0.50	>0.90	>0.90	<0.08	-	-	-
Variables and Items	Cronbach's Alpha / Composite reliability	CFA Loadings	AVE	CFI	TLI	Model fit indices RMSEA	*χ2*	*df*	χ2 /df
Community Stakeholder's Pressure	0.799 / 0.801								
My company formulates an environmental plan to:									
• Minimize the negative effect on the natural environment (COM1).		0.77	0.504	0.996	0.987	0.051	3.379	2	1.690
• Prevent/reduce pollutions (COM2).		0.70							
• Gain trust from the community/public (COM3).		0.74							
• Respond to the promotion of health and safety of the society (COM5).		0.62							
Customer Pressures	0.792 / 0.800								
My firm's major customers:									
• Frequently require my firm to adopt green supply chain initiatives (CUS1).		0.77	0.505	0.994	0.983	0.058	3.821	2	1.911
• Withhold their contracts if my firm did not meet their environmental requirements (CUS2).		0.84							
• Have a clear policy statement regarding its commitment to the environment (CUS3).		0.62							
• Frequently encourage my firm to adopt green supply chain initiatives (CUS5).		0.58							

Table 1 (cont.). Results for confirmatory factors analysis loadings, validity and reliability test (n = 268).

Variables and Items	Cronbach's Alpha / Composite reliability	CFA loadings	AVE	CFI	TLI	Model fit indices RMSEA	χ^2	*df*	χ^2/df
Perceived Environmental Performance	0.800 / 0.804								
• Significant improvement in its compliance with environmental standards (ENV2).		0.63	0.508	0.991	0.973	0.074	4.889	2	2.444
• Significant reduction in emission of air pollutants (ENV3).		0.67							
• Significant reduction in energy consumption (ENV4).		0.76							
• Significant reduction in consumption of hazardous materials (ENV6).		0.78							
Acceptable Threshold Levels	Cronbach's Alpha - >0.60	≥0.50	>0.50	>0.90	>0.90	<0.08	-	-	-

Structural Model Evaluation

Using the SPSS AMOS (see *Figure 1*), the structural model was generated to examine these critical factors: environmental policy, environmental training, regulatory stakeholder's pressure, community stakeholder's pressure; and customer pressures performance on the firm's perceived environmental performance. In this study, multiple fit indices such as: (1) chi-square ($\chi 2$); (2) statistics to the degree of freedom (df); (3) the comparative fit index (CFI); and (4) Root mean square error of approximation (RMSEA) were used as suggested by Hair, Black, Babin and Anderson (2010). The goodness of fit index measures of the model was adequately fit.

In structural model (*Figure 1*), this model was improvised and tested by dropping the affective Community Stakeholder's Pressures variable and maintain other variables such as environmental policy, environmental training, regulatory stakeholder's pressures, customer pressures and perceived environmental performance. Two links connected the relations between, (1) Regulatory Stakeholder's Pressures and Environmental Policy; and (2) Regulatory Stakeholder's Pressures and Environmental Training. The structural model was analyzed for model fit.

The minimum acceptable value was achieved in reaching a convergent solution, thus yielding a $\chi 2=328.757$ with 164 degree of freedom, $p<0.001$. The selected goodness-of-fit statistics related to the hypothesized model were examined (*Figure 1*). In this structural model, the modifications were included: (1) removing the Community Stakeholder's Pressure (H4) variable; (2) adding a link between Environmental Policy and Regulatory Stakeholder's Pressure; and (3) a link between Environmental Training and Regulatory Stakeholder's Pressure. This structural model had greatly improved the goodness-of-fit indices (CFI=0.921, TLI=0.908, RMSEA=0.061, df=164, $\chi 2=328.757$, $\chi 2$/df=2.005). The evidence indicated that the model fitted the data well.

Exclusion of Community Stakeholder's Pressures (H4)

Earlier in the model research, community stakeholder's pressure was identified as one of the independent variables. Later, this variable was removed from the structural model after the test of good fitness indices showed poor results. This gave the indication that the community stakeholder's pressure shall not be integrated within the research model. The possible justification is that within the Malaysian environment, community and the NGOs have little influence over the firm's environmental performance. The researcher had explored such observation from the practitioner's perception. During the interview, the senior manager of the semiconductor firm revealed that the local community who stayed adjacent to or close to the industry premises was not disturbed by the firm's activities unless they have direct impacts on their health. She stated that:

"Since I joined this company in 1999, there's hardly any complaint received from the local community on our activities."

Comment 1.0

"Department of Environment (DOE) will come whenever there is a complaint made by the industries or the local community. For instance, a complaint from the neighborhood such as noise generated by the industries, DOE will not directly issue warning letters but will monitor and observe the problems together with the company. DOE will check our effort in solving the problems. The officers from DOE are very supportive and provide us with necessary guidelines."

Comment 2.0

Unlike in America or Japan, the community demands assurance from the industry that the company's operations would not affect their daily lives and activities. The local community also has greater power to question the activities of the local industry due to the accessibility of related environmental information. The local community in these countries involves actively in their national environmental agenda.

Thus, community stakeholder's pressure was found not significant related to environmental performance. Although the studies conducted by Sarkis, Gonzalez-Torre and Adenso-Diaz (2010); and Huang (2005) related to community stakeholder's pressures, showed a positive relationship between this factor to environmental performance. The results showed otherwise, and that this variable shall not be integrated within the research model. One possible justification is that within the Malaysian environment, community and the NGOs have little influence over the firm's environmental performance.

Effects of *ISO 14001* on Firm's Perceived Environmental Performance

The results revealed that only four variables: (1) environmental policy; (2) environmental training; (3) regulatory stakeholder's pressures; and (4) customer pressures had significantly impacted the *ISO 14001* firms perceived environmental performance. However, relationships between community stakeholder's pressures and the perceived environmental performance (H4) were found to be not significant. A further two new relationships were uncovered:

i) Regulatory Stakeholder's Pressure is positively and significantly related to Environmental Policy; and

ii) Regulatory Stakeholder's Pressure is positively and significantly related to Environmental Training.

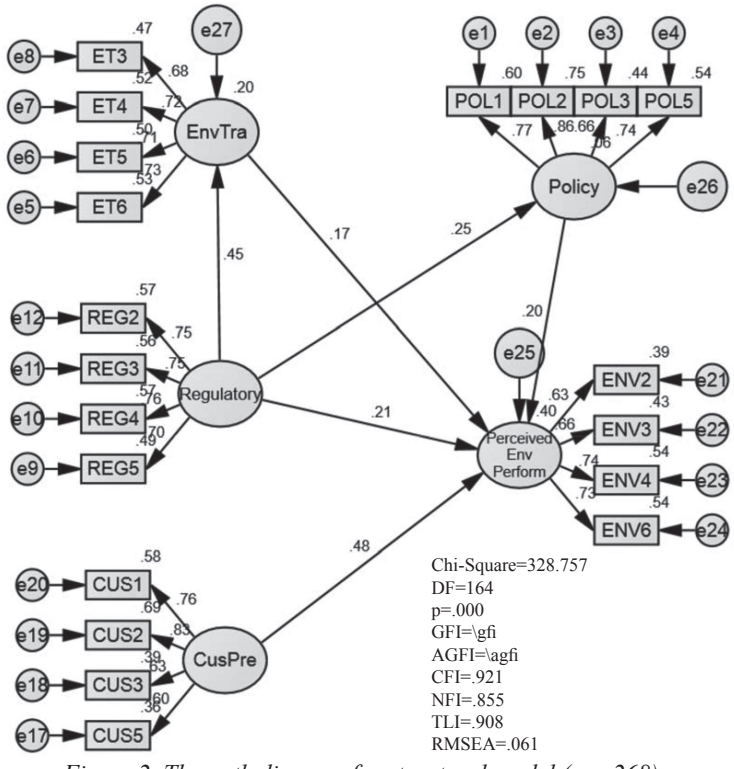

Figure 2. The path diagram for structural model (n = 268).

DISCUSSION AND RECOMMENDATIONS

This study aimed to identify the factors influencing the *ISO 4001* firm's perceived environmental performance. It had implications for the academics, practitioners and policy makers. It adds to the body of knowledge on green practices particularly within the manufacturing settings in Malaysia. The results could be valuable to the managers by providing greater insights into green practices in Malaysian firms.

In this study factors that influence the *ISO 14001* firm's perceived environmental performance was identified. Based on the research findings, it was found that environmental policy, environmental training, regulatory stakeholder's pressures and customer pressures play an important role in the firm's perceived environmental performance. Findings in this study revealed that these underlying factors were proven important to motivate firms to go green.

The firm's adoption of green environment agenda is motivated by internal and external factors. However, most researchers agreed that achieving high success rate on the implementation of the environmental strategy is not an easy task (Gonzalez 2005; Sinding 2000). This research aimed to determine the factors that influence the *ISO 14001* firm's perceived environmental performance. A research model with five hypotheses was constructed. Understanding these relationships is important as it can accelerate the firm's progress toward a more competitive environmental approach. It would subsequently affect its long-term profitability and sustainability in the market.

Overall, the findings from this study motivated firms to include environmental agenda into their corporate strategy as this empirical results have demonstrated that the firm's environmental performance could be enhanced by being green. In addition, this study provided aspiration to firms that have yet to implement EMS practices and to encourage them to be more eco-friendly. This is to minimize the environmental harms in order to preserve the ecosystem. Thus, in order to motivate companies to go green, a more concerted effort on environmental concerns is needed to revive the nation's economic growth, social cohesion and ecological balances (Loke *et al.* 2014). Practitioners, including environmental management representatives, could apply the ideas presented in this study to guide EMS practices.

CONCLUSIONS

The objective of this study was to investigate the factors influencing the *ISO 14001* manufacturing firm's perceived environmental performance in Malaysia. The study found that environmental policy, environmental training, regulatory stakeholder's pressures and customer pressures were the factors influencing the *ISO 14001* firm's perceived environmental performance.

The statistical results supported some of the previous research hypotheses. Employee policy, employee training, regulatory stakeholder's pressures, and customer pressures were found positively and significantly related to perceived environmental performance thereby supporting hypothesis H1, H2, H3, and H5. The results of H1 and H2 hypothesis were in continuity with the studies conducted by AnuSingh and Shikha (2015); Harjeet (2011) whilst H3 and H5 hypothesis results were similar to the studies by Sarkis, Gonzalez-Torre and Adenso-Diaz (2010). The results revealed that the firm's perceived environmental performance was linked to environmental policy, environmental training, regulatory stakeholder's pressure, and customer pressure. One of the hypotheses i.e. H4 failed to receive support. Community stakeholder's pressure was found not significantly related to environmental performance. Although the studies conducted by Sarkis, Gonzalez-Torre and Adenso-Diaz

(2010); Huang (2005) related to community stakeholder's pressures showed a positive relationship between this factor to environmental performance, the results showed otherwise and that this variable should not be integrated within the research model. One possible justification was, that within the Malaysian environment, community and the NGOs had little influence over the firm's environmental performance. This study discovered two new statistically significant relationships between: (1) regulatory stakeholder's pressure and firm's environmental policy; and (2) regulatory stakeholder's pressure and firm's environmental training. Sarkis, Gonzalez-Torre and Adenso-Diaz (2010) support the statistical results of this study. However, there is a lack of statistical evidence to support both of these new findings.

Overall, the qualitative findings supported the survey finding in which the environmental performance of the participating firms in Malaysia was influenced by the following factors: the firm's environmental policy and training, regulatory and customer pressures. It was also found that the pressure from regulatory stakeholders had exerted a strong impact on the firm's environmental policy formulation and implementation as well as related environmental training. This study employed underpinning theories such as resource-based view and stakeholder theory and specifically synthesized both external (regulatory stakeholder's pressure and customer pressures), and internal constructs (environmental policy and environmental training) in influencing the *ISO 14001* firm's perceived environmental performance. The research model presented a synthesized model that gave insights to policy makers and managers on environmental management and sustainability. The findings provided strong support for this study, as well as valuable insights about predictors of firm environmental performance.

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Decision-making Processes for a Patient Admitted to the Accident and Emergency Department Requiring Emergency Abdominal X-ray — A Case Study

Y. YULIAWATI

This study investigated the application of the various processes involved in decision-making for a case requiring radiologic emergency abdominal X-ray examination to the Accident and Emergency Department in a government-owned hospital in West Java, Indonesia. It is also aimed to evaluate the patient who was experiencing abdominal pain accompanied by bloating, vomiting, severe constipation and abdominal cramps.

The decision-making models used for this case were the normative, prescriptive and descriptive judgments. A decision tree in the form of decision options that was employed in this case addressed the normative model of decision-making, while the algorithm and information processing theory focused on the prescriptive model. Lastly, the intuition that was used in this case concentrated on the descriptive model of decision-making.

An emergency abdominal X-ray was indicated for the patient — a prescriptive decision. Options from decision trees were also practiced. However, the patient was in pain; therefore, she was unable to understand the alternatives that were presented. Hence, this choice was suggested by the author because, by intuition, the expectation was that the patient suffered from acute abdominal crisis.

Key words: Decision-making; case study; abdominal X-ray; A&E Department; West Java, Indonesia

This case study aims to apply the processes of decision-making for a patient requiring radiologic emergency abdominal X-ray examination admitted to the accident and emergency (A&E) department in a government-owned hospital in West Java, Indonesia. It also aims to evaluate the patient who is experiencing abdominal pain that is very unusual accompanied by bloating, vomiting, severe constipation, and abdominal cramps.

The purpose of this case is to allow decision-makers to have a world view on how decisions are made with minimal errors. A sound decision can achieve this, having patients or relatives and others significant who takes part in decision-making (Thompson & Dowding 2002).

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BACKGROUND

Decision-making in Indonesia is already done autonomously with the development of central and local government programme. There are a lot of basic radiologic examinations in major health centers that are nowadays independently decided upon by radiographers to help lessen the workload of physicians-in-charge, and that formal written referrals may not be necessary (Regulation of the Minister of Health No. 290 / Menkes / Per / III / 2008). Large hospitals may also have independent healthcare practitioners who diagnose certain diseases (Decree of the Minister of Health No. 631 / Menkes / SK / IV / 2005).

Also, autonomously deciding on plain radiographic examinations in cases of emergencies in underdeveloped countries are now at large (Regulation of the Minister of Health No. 290 / Menkes / Per / III / 2008). For example, an acute abdominal pain can be decided upon for treatment, care, diagnostic examination, and management by any healthcare professionals.

This is because an acute abdominal pain will more likely lead to chronic cholecystitis, biliary colic, hepatitis, hepatic congestion, peptic ulcer, gastroesophageal reflux disease (GERD), chronic pancreatitis, irritable bowel syndrome, diverticulitis with constipation, ovarian tumors for female, pelvic inflammatory disease (PID), Crohn's disease and mesenteric artery ischemia (McQuaid 2012). *Figure 1* shows the acute abdominal diseases or disorders found in adults.

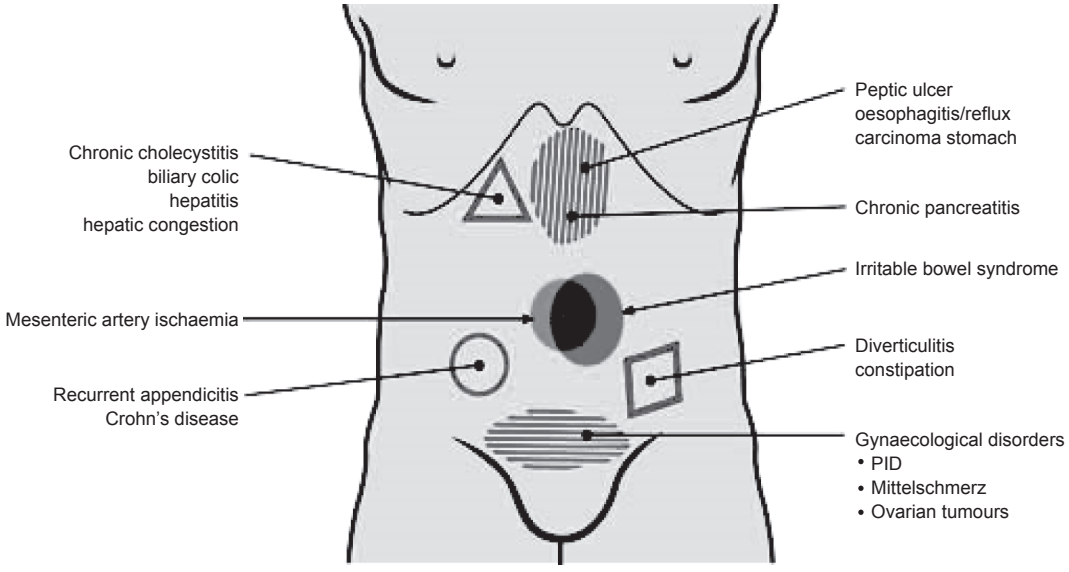

Figure 1. Acute abdominal diseases and disorders.

THE CASE

A 60-year-old female patient with the chief complaint of abdominal pain accompanied by flatulence and abdominal cramps was admitted to the A&E Department. An initial blood investigation was primarily done and is highlighted in *Table 1*.

About the patient's blood investigation result (*Table 1*), there was a drop in the hemoglobin which healthcare professionals should intuitively anticipate for a potential hemorrhage combined with a decreasing level of hematocrit that measures her hydration (Ministry of Health RI 2011). A drop in the patient's lymphocyte count indicates a potential inflammation of the abdomen (Ministry of Health RI 2011).

The inflammatory category of causes might be divided into two subgroups: (1) bacterial; and (2) chemical. Some typical examples

Table 1. Initial blood extraction – highlighted are the abnormal results.

Formed elements	Result	Normal values
• **Hemoglobin**	**11.0 g/dl**	**M : 13 – 16 F : 12 – 14**
• **Hematocrit**	**31%**	**M : 40 – 48 F : 37 – 43**
• **Erythrocytes**	**3.7 million/µl**	**M : 4.5 – 5.5 F : 4.0 – 5.0**
• Platelets	429 000 thousand/µl	150 000 – 450 000
• **Leukocyte**	**11 100 thousand/µl**	**5 000 –10 000**
• Basophil	0%	0 – 1
• Eosinophil	2%	1 – 3
• Trunk	2%	2 – 6
• **Segment**	**80%**	**50 – 70**
• Lymphocyte	13%	20 – 40
• Monocytes	3%	2 – 8
Blood chemistry	Result	Normal values
• Random glucose	118 mg/dl	70 – 140
• Blood urea nitrogen	8 mg/dl	8 – 20 mg/dl
• Creatinine	1 mg/dl	1 – 1.2 mg/dl with two kidneys 1.8 – 1.9 mg/dl with one kidney
• **Sodium**	**156 mEq/l**	**135 – 147**
• Potassium	2.7 mEq/l	3.5 – 5.5

of the bacterial causes will include acute appendicitis, diverticulitis, and some cases of pelvic inflammatory disease (Abdullah & Firmansyah 2012). An abnormal result of the leukocyte, lymphocyte, and segments (*Table 1*), indicates an inflammation that the patient is experiencing (Abdullah & Firmansyah 2012; Eisenberg 2008).

An example of a chemical cause would be a perforation of a peptic ulcer, where spillage of acid gastric contents causes an intense peritoneal reaction (Eisenberg 2008). While an increase in sodium decrease in potassium from the patient's blood investigation (*Table 1*) indicates fluid retention in the peritoneal cavity (McQuaid 2012).

After the algorithm found in *Figure 2* was carried out, the next step was to explicitly decide on the type of abdominal X-ray to be done for cases of acute abdomen pain. There were three different X-rays choosen specifically for patients with severe abdominal pain.

Table 2 enumerates the prescriptive types of abdominal X-rays that have not been indicated by the physician in the A&E Department of the said hospital, hence it was decided upon by the author (the radiographer).

The decision of the author was primarily intuitive based on recognized pattern of same signs and symptoms that were experienced by other patients with similar cases who eventually

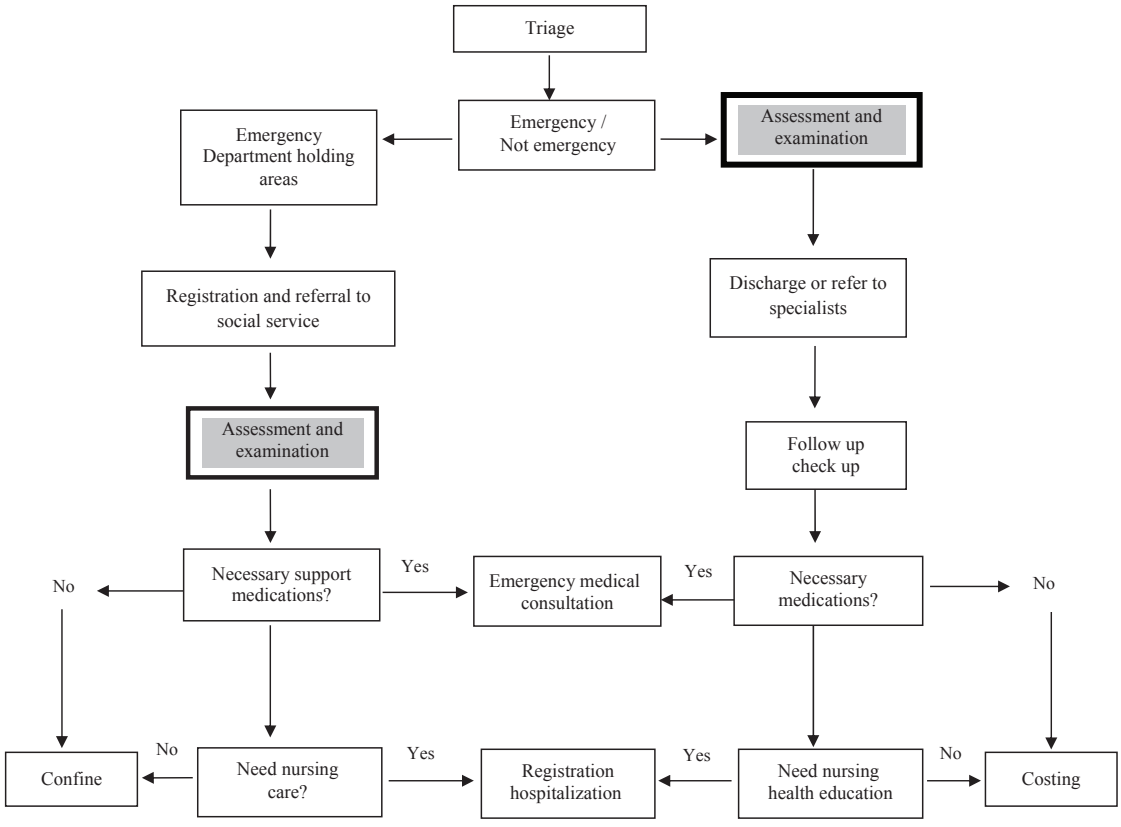

Figure 2. Algorithm for managing, treating and caring for patients in the A&E department of a government-owned hospital in West Java, Indonesia.

Table 2. Clinical guidelines on the types of abdominal X-rays (Bontrager *et al.* 2012).

Type of abdominal X-ray	Indication
Plain	Suspected bowel obstruction/ perforation with dilated loop Suspected intussusception Suspicious abdominal mass
Erect	Suspected bowel obstruction to exclude perforation
Antero-posterior	Foreign body ingestion

required a plain abdominal X-ray. Besides, clinical guideline prescribes plain abdominal X-ray that may help visualize possible suspected bowel obstruction, perforation with dilated intestinal loops, intussusception and abdominal mass (Kellow *et al.* 2008).

Although erect and anterior-posterior abdominal X-ray is also theoretically important to be considered done, it is also by intuition that the patient may not be experiencing foreign body ingestion and more likely having a perforation of the bowels (Balinger 2012).

The main symptom that was experienced by the patient such as prominent sudden severe pain in the abdominal area was confirmed after a physical examination and interpretation of the blood investigation.

Therefore, it was intuitively decided upon by the author that the patient's acute abdomen required a plain abdominal X-ray. Surgery could be decided after a plain abdominal X-ray result was done, to avoid potential delays that could cause complications and result in heightened mortality.

Nevertheless, options were still presented to the patient (*Figure 3*), showing selections whether to perform an emergency abdominal X-ray or delay the procedure and to wait for arrival of the physicians.

The decision tree for decision options are necessary to be considered since the patient is the key decision maker (Sabiston 2004; Dioso 2015).

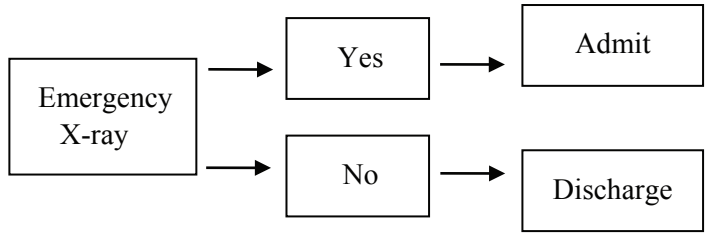

Figure 3. Decision tree as decision options presented to the patient.

The author finally decided that an emergency abdominal X-ray was necessary. *Figure 4* below shows the intra-abdominal X-ray of the patient that was visualized in the right supine position and that can be life threatening if surgical repair was delayed.

METHODOLOGY

The decision-making models used for this case are the normative, prescriptive and descriptive judgements. A decision tree in the form of decision options that was employed in this case addresses the normative model of decision-making, while the algorithm addresses the prescriptive model and lastly, the intuition that was used in this case addresses the descriptive model of decision-making (Thompson & Dowding 2002). *Table 4* below summarizes the decision-making process that was used for this case.

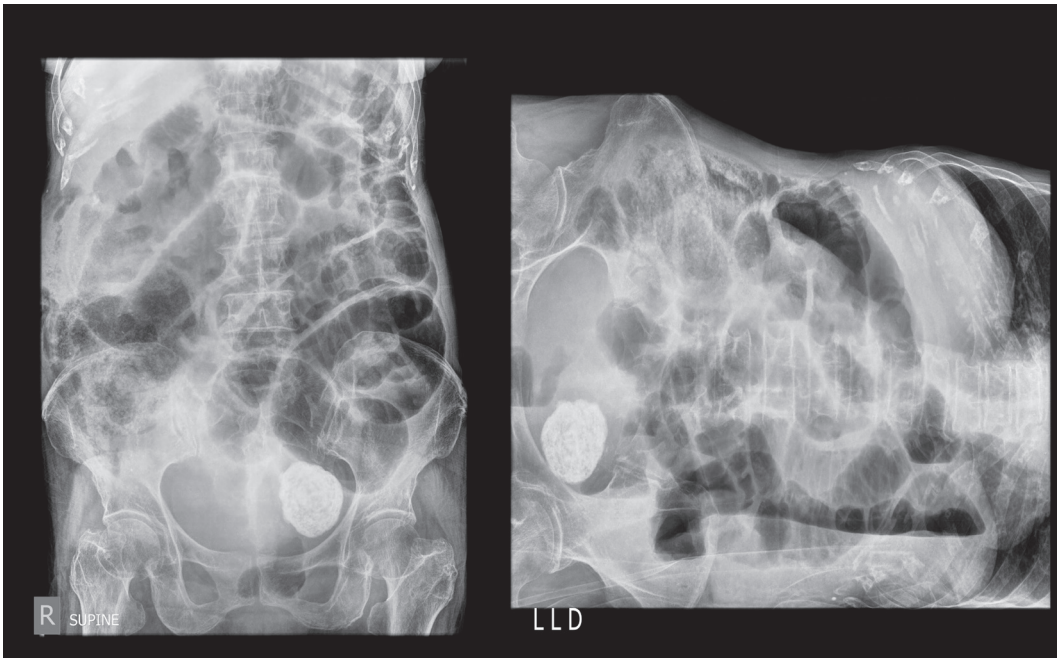

Figure 4. Abdominal X-ray result on right supine and left.

Table 4. Summary of three decision-making models (Dioso 2015).

Item	Normative model
Characteristics	Rational, logical, scientific, evidence-based decisions.
Information sources	Statistical analysis of large-scale experimental and survey research which is representative of a target population where the findings can be applied.
Examples	Decision options
Advantages	Enable decision-makers to predict and explain the outcomes of decisions. Minimize judgment errors from "base rate neglect".
	Prescriptive model
Characteristics	Frameworks or guidelines designed to enhance specific decision tasks.
Information sources	Principles and findings of previous scientific research (associated with normative models).
Examples	Information processing theory.
Advantage	Facilitating more efficient decision-making.
	Descriptive model
Characteristics	Understanding how individuals make judgments and decisions focusing on the actual conditions, contexts, ecologies, and environments in which they are made.
Information sources	Observation, description and analysis of how decisions are made by managers and professionals with their day-to-day responsibilities.
Examples	Intuition
Advantage	Adequacy in supporting assumptions made about decision-making processes with relevant examples from a suitable period of observation.

Prescriptive Decision-making Model

Information processing theory (IPT) used the algorithm and clinical guidelines.

IPT Step One: Cue acquisition

Based on the results of blood tests carried out on the patient, it showed that pain under the left side of the abdomen was acute. Healthcare professionals who took the patient's blood sample which showed that cues acquired such as the serum sodium level was increased, while venous hemoglobin, hematocrit, lymphocyte and erythrocyte and potassium decreased. More importantly, the physical examination done to assess the intensity of the abdominal pain was also used to support the blood investigation results.

IPT Step Two: Hypothesis Generation

Acute abdomen is hypothesized as a condition that occurs suddenly with the main symptoms that arise which are abdominal pain and that is life threatening. It is also hypothesized that 5% – 10% of all emergency visits to the hospital have abdominal pain that is life threatening (Grafft & Robinson 2001; Cordell *et al*. 2002).

The emergency case is any condition that the opinion of the patient, his family, or whoever assumes the responsibility of bringing the patient, is of less priority if immediate medical attention is deemed necessary to save the patients' life (Thompson & Dowding 2002). Emergency resuscitation or diagnostic procedure is hypothesized to be done until clinical experts have made a determinat ion that the patient's life or well-being is not threatened anymore (Domball & Margulies 1996).

IPT Step Three: Interpretation of Cues

From the results of the assessment of the patient, it was interpreted that the impression of the author on the acute abdomen required abdominal examination on three positions which was supine abdominal AP, AP half-sitting and LLD (left lateral decubitus) to assess fluid water level (*Figure 4*). While the results obtained, suggested expertise for radiology doctors to interpret the results.

IPT Step Four: Hypothesis Evaluation

Based on the physical examination, an emergency plain abdominal X-ray was evaluated to be required immediately. The result of the emergency abdominal X-ray on *Figure 4* is shown to have an obstructive ileus with suspected ovarian tumor on the right which was why an emergency plain abdominal X-ray was required.

In patients with acute abdominal examination with plain abdominal radiology, supine and standing positions, as well as thorax images, were used. But if the patient was unable to stand, the testing should use the left lateral decubitus.

Evaluation of the images should remain based on or confirmed by history, physical examination and laboratory obtained previously. A picture of the free air and dilated bowel possibility of intestinal obstruction found in *Figure 4* showed a perforation. The image classification of the biliary system, kidneys and urethra was also a possibility found on the X-ray result of the patient.

It was also hypothesized that free air in the peritoneal cavity showed a perforation of the gastrointestinal tract (*Figure 4*). Lastly, a hydropneumoperitonium extensively appears as a picture of water fluid level that was hypothesized on the X-ray result found in *Figure 4*.

Normative Decision-making Model

Decision options were presented to the ultrasonography. Ultrasound examination is useful in patients with acute abdominal pain because it could provide an evaluation that was fast, safe and cheap. As suggested by the author there was a need to do a CT scan of the abdomen soon to evaluate complaints that did not have clear indications. CT-scan was very useful in identifying intraperitoneal free air of very little time, and location inflammation areas required immediate surgery.

Descriptive Decision-making Model

By intuition, the author intuitively believed that the patient should undergo do the abdominal examination on three positions — anterior-posterior, left a lateral, and right side. Based on the results, expert specialist in radiology to the patient should obtain the following: normal peritoneal fat line; air distribution within the intestine that was not filling the pelvic cavity, did not seem to depict free intraperitoneal air, widening intestines with water fluid level; visible mass hiperdens in the left pelvic cavity; and the bones and soft tissue being normal.

It was important to trust an intuition if it was also based on recognized patterns of previously encountered similar cases. The author being an expert radiographer could intuitively perceive signs of the acute abdomen from the resulting expertise. Therefore trusting the intuition was just the same as looking back at the patterns of previously encountered cases.

However, it is important to be contious using intuition (*Figure 5*; Dioso 2015) during the early part of the consultation. This is because intuition is a substandard way of decision-making that is only characterized by a shallow understanding of actual events and conditions taking place.

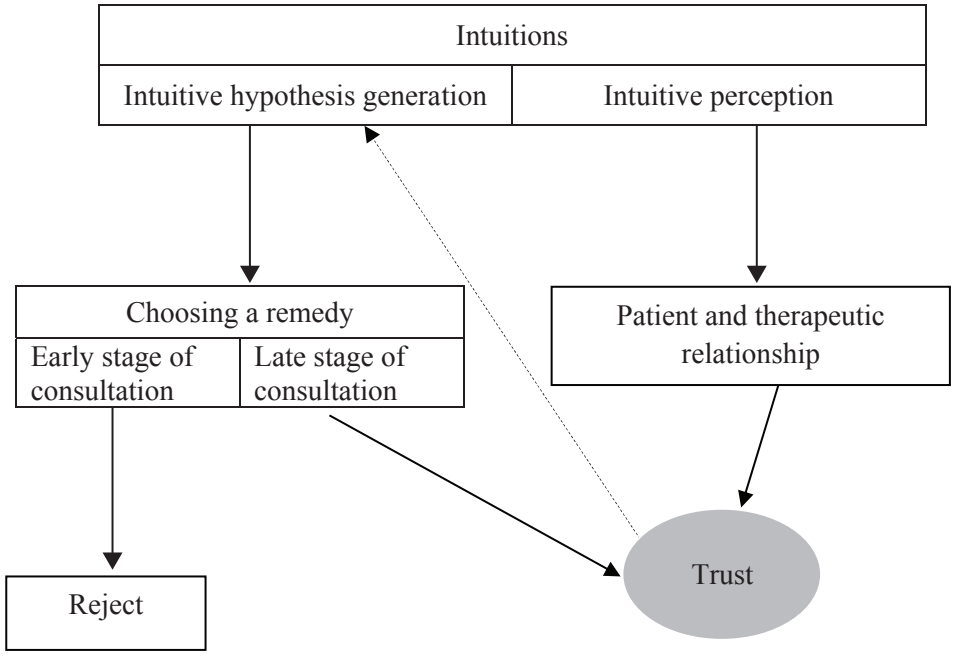

Figure 5. How to trust an intuition (Dioso 2015).

DISCUSSION

The prescriptive decision-making made an impact in this case. The system of independently deciding for emergency abdominal X-ray is practiced already in Indonesia since this decision is more likely to be autonomously done by the radiographers. The Ministry of Health has issued a policy regarding the Standard Emergency Room (ER) Hospital contained in KEPMENKES No. 856 / Menkes / SK / IX / 2009 to regulate the standardization of emergency services at the hospital. To improve the quality of emergency in Indonesia, there needs to be a commitment to help provide socialization to the public in handling emergencies that is often not drawn to more mistakes.

Patients who go to the Emergency Department of a hospital would need help quickly and accurately for standard needs in providing emergency services in accordance with the competition of each hospital to guarantee an emergency care with a response time that is fast and precise in handling, connoting excellent hospital service (KMK 856 on the standardization of the Emergency Department).

Reviewing the case raised by the authors, the decisions that should be done was to provide education to the patient or the patient's family that was normatively done by the radiology services in providing precise information about the flow of patient care. In this case, any measures should include a letter for radiological X-ray request of either the sender doctor for emergency cases or not, only then it would be possible for radiological examinations. Due to the Minister of Health Decree No. 375 of 2007 which is about the professional standard radiography which are related to the code of conduct for radiographers who in this case had an obligation to his profession as "radiographer just doing a job of radiography, imaging and radiotherapy at the request of doctors by not leaving the procedures outlined". This means that the radiographers in Indonesia have full autonomy to decide on the best diagnostic examination that is recommended to the patient in an emergency situation.

According to Eisenberg (2008), in a small group in the USA 25 years ago, the role of examinations for plain radiographers can reduce the risk of further complications up to 50% without loss of clinical findings.

Risks of abdominal pain of moderate to severe, and the obvious clinical symptoms may lead to intestinal obstruction, ureter stones, ischemia, or diseases of the gallbladder (Kellow *et al.* 2008). In a retrospective study it was found that 40% of photo plain radiographs of the abdomen was considered normal had to be followed up with additional advanced checks which discovered the abnormal condition of 72% so the current role of photo plain radiographs of the abdomen benefitted that which was taken over by CT scan and ultrasound.

Field (1998) stated that the examination of plain radiographs remains as the very useful and valuable inspection of the initial investigation and make the clinician decide whether patients with acute abdomen pain requires surgery or not; and if necessary, whether immediate surgery or whether it still can be delayed so that other tests can be done to support the diagnosis.

RECOMMENDATIONS

It was recommended that patients in private hospitals in Indonesia who were not capable of paying their hospital bills should limit the usage of technology such as X-ray machine. Intuitions were recommended especially if the main complaint was recognized to be similar to previously encountered cases. In this way, the impact of decisions gave more benefits than harm to the patient.

It was still however recommended that in a fast paced environment, the use of clinical guidelines should be considered as the safest decision-making process. Explaining to the patient the advantages of each diagnostic examination for the patient to understand clearly the options provided was the better decision-making process.

CONCLUSION

It was therefore concluded that in this case, the decision-making process used the prescriptive model substantiated by intuition. The X-ray examination carried out by plain abdominal anterior-posterior, and lateral view found abnormalities in the abdominal cavity. Options on decision trees were also practiced; however the patient was in pain. Therefore, she was unable to understand the choices that were presented. Hence, the alternatives were suggested by the author. Fast and accurate action was needed for these patients, given the emergency situation. Therefore, decision-makers must always be in psychological and intellectual control to demonstrate sound decision.

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Potential Application of ENR/EPDM Blends in the Dynamic and Endurance Conditions — A Review

B.L. CHAN

Since the process and conversion of natural rubber into epoxidized natural rubber (ENR) was discovered and patented by I. R. Gelling of the Malaysian Rubber Product Research Association (or now known as the Tun Razak laboratory), Brickendonbury, Hertford, in the United Kingdom, there are more than 10 000 technical and technological papers cited in the internet. Information on ENR is available, not only in the the English language but also other languages like Chinese, Malay, French, Thai and even German languages are used.

ENR is the most versatile and reactive rubber/elastomer. It is an advanced natural rubber which could be potentially used as a starting material for the development of other rubbers, modified elastomers, for grafting, plastic-based materials and also thermoplastic rubbers. Its reactivity is dependent on its epoxy groups, the opening of its ring structure, and also the subsequent structures of carboxylic groups and the *in-situ* side-chains "carbon – carbon" double bonds (> C = C <). In some instances, up to 65% epoxidation of NR is possible and achieved for more oil resistance. For these reasons, there are many new and advanced materials which have been formed and developed in the last two decades.

Among them, some of the recent research work is listed here. Apart from studies of compounding the ENR itself and its potential uses, there are many rubber-rubber blends and ENR rubber-plastics blends, some of the studies cited are "uses of new and advanced chemicals" and synthetic rubbers: ENR/NBR, ENR/PVC, ENR/polylactic acid blends, ENR/copolyester blends, ENR/Copolyamide Blends, ENR/poly (vinylidene fluoride) blends, ENR/Carbon Nanotubes with co-agent Trimethylol Propane Triacrylate, ENR /recycled silicon materials, and ENR/copolymer of *n*-butyl acrylate/butyl methacrylate "grafted". Each of these blends has its own characteristics in terms of processing, enhancement of processing like safety, scorch, oil and water resistance properties, or some in the development of potential thermoplastic rubber and its thermoplastic vulcanizates.

In this paper, the author would like to share some findings of the ENR/EPDM blends that have good flex and dynamic properties, relatively low compression set, and tolerant tensile properties that satisfy most rubber products that are required for and used in the industrial, mechanical, and even automotive parts. More importantly, the sliding skid resistance/frictional property and wear resistance of the blends are also examined. In some blends, the thermal dynamic behaviour is also measured over a temperature range depicting the low-temperature stability, its temperature of transition and the dynamic factor like tangent delta (σ). These are the potential factors that could enhance the blend properties that give possible, good high speed and traction, applicable in tyres.

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Key words: Epoxidised NR, ENR/EPDM blends, organo-metallic titanate, maleic anhydride, microscopic topography, flex and endurance, wear resistance, sliding skid test; friction resistance, thermal dynamic properties; transition temperature; tangent delta

The uniqueness of the epoxidised natural rubber (ENR) is that it is very reactive in terms of both nucleophilic substitution and free radical reactions, depending on the condition of a chemical reaction. Either it is its form or chemical modified, it is easy to process, and most of the common rubber chemicals can be used to plasticize and cure the rubber, and most of the rubber processing machine can be used. If it is thermoplastic form, then the common thermoplastic machines can be used too. In a more advanced state of the modified / grafted ENR, its surface can be cured or hardened by UV irradiation. This gives rise to the surface coating required for the protection of surfaces and also possibly used in the seal sector of the industry. At the low molecular level where the molecular weight is between 10 000 to 20 000 levels, it is used as a sealant and also used as a seal in the laminates.

In this paper, the author describes the results of the R&D in the ENR and ENR/ ethylene propylene diene monomer (EPDM) blends, especially at the 50:50 level, that has the potential applications in various industries. The vulcanization system is a mixture of low accelerated sulphur plus catalytic peroxide system that cure these blends, with the condensation reaction between the polymeric fractions with the *in situ* reactive chemical like organo-metallic titanate as reactant and compatibilizer that would assist in the incorporation of the non-carbon black fillers in the blends, and also enhances the grafting reaction of maleic anhydride onto the epoxides (in this case, the epoxidized NR). This uniqueness of this dual vulcanization system plus the coupling agent like organo-metallic titanate with the incorporation of silica in the blends gives rise to a more holistic physical and thermal dynamic properties of the blended rubbers. This *in-situ* or in-process reaction, and sometimes, vulcanization, would result in developing strong bonds in the vulcanized modified blends.

The R&D work also describes how conventional tools like the resilient apparatus, pendulum slip and skid apparatus and phase control microscopic observation would be used to assess physical properties like abrasion, skid resistance, and the topological structures (by phase contrast microscopy) related to abrasion and wear surfaces, and the dynamic mechanical thermal analysis (DMTA) method for the study of compatibility and miscibility of the blends. All the methods of determination and testing are according to the testing standards and standard practices.

The epoxidation (Gelling 1984; Gelling & Smith 1979) though increases the polarity of the natural rubber (ENR), it also improves compatibility with the polar polymer. It also improves the properties of air impermeability, and substantially reduces oil-swelling. However, it still has good strength and retains its ability to strain-induced crystallization during stretching. Thus, it still behaves like NR. The ENR can be vulcanized by a typically accelerated sulphur curing systems. The epoxidation raises the glass transition temperature, thus reducing gas permeability and decreasing the low-temperature resilience, leading to increased damping and making ENR-50 a highly damped rubber. However, at even higher temperatures

the high resilience of NR is maintained. Briefly, 25 and 50 mol% epoxidised natural rubber are produced and, which are marketed as ENR-25 and ENR-50. Despite the modification, ENR is still a strain-crystallizing rubber with high strength up to about 50% epoxidation.

In this paper, only the 50 mole% of the epoxidation on NR or known as ENR50 is used in the study. The epoxide groups are randomly distributed along the natural rubber molecule as shown below (*Figure 1*).

3. The use of the compatibilizer, organo-metallic titanate,and maleic anhydride in the final development of the blends in the dynamic and flex properties.

The physical properties of the blends tested were a tensile strength, Dunlop resilience, abrasion, the slide test, crescent tear, and dynamic flex.

In one series of the blends with and without fillers, the thermal dynamic mechanical properties of the blends were determined and

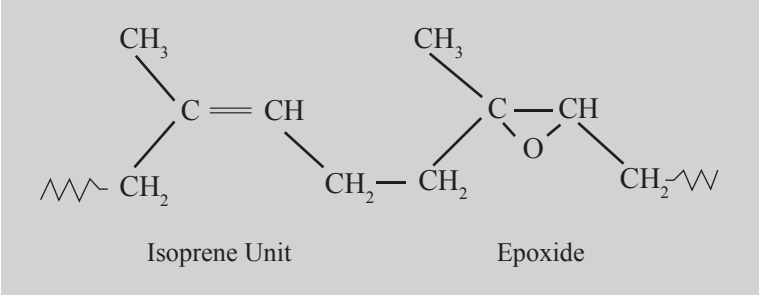


Figure 1. Epoxidized natural Rubber.

MATERIALS AND METHODS

Preparation of the Blended Material and Testing

The blends of the ENR and EPDM in various ratios were mixed using a laboratory OOC Banbury, an intermixing of two litres, and then finally compounded on a two-roll mill, and cured to the optimum plus 2 min, after the test and assessment of the rheometer.

The series of development includes:

1. The unfilled and filled blends with calcium carbonate, silica and carbon black/silica

2. To determine the compatibility and miscibility of blends by DMTA method; and

their glass transition behaviour and their relative tangent delta. The basic recipe and composition of the blends are recorded in the Figures or Tables in the results.

The Dynamic Mechanical Thermal Analysis Properties of the Blends

The compatibility and miscibility of two rubbers in a blend are complex. Many methods are used to study these properties. One of the latest methods is the DMTA (*ASTM* 5992; *ASTM* E 1640) which measures thermal behaviour and stability of nature in the blends, especially the inter-physical morphologic structures and compatibility of the rubber phases in the blends could be studied. The study was carried over a range of temperature, and they were

subjected to typical dynamic vibration of 10 Hz from –50°C to 100°C, the temperature shift, the glass-transition temperature (*T*g) and the temperature peak of tangent delta (tan σ pk.) were measured). In this case, the properties of the blends (ENR 50/EPDM) with and without the fillers were studied.

DMTA Properties of the Filled Compounds in ENR 50/EPDM Blends at 10 Hertz

The DMTA spectrum had two distinct regions /phase: the ENR 50 in the sub-zero phase, and EPDM phase at the higher temperature range. There were two glass transition temperatures; one in the ENR 50 phase and another in the EPDM phase, each with a maximum tangent delta. The results were of these blends, unfilled and filled with 40 phr calcium carbonate, and 40 phr silica. The results are shown in *Tables 1* (unfilled, gum-vulcanizates of blends; *Table 2* for the vulcanizates filled with $CaCO_3$; and *Table 3* for the vulcanizates filled with silica.

Except for the blends of the calcium carbonate filled for the EPDM phase, all the glass-transition temperatures, *T*g, at each level of EPDM/ENR 50 ratio is similar, and independent of the type and nature of the fillers. For example, at the ratio of blend, EPDM 50% : ENR 50 50%, the Tg of the EPDM phase is 14.3°C for the gum-vulcanizate; 16.0°C for the silica filled; and in the ENR 50 rubber phase, the *T*g is –34.9°C for the gum, and –32.3 for the calcium carbonate filled, and –33.5°C for the silica filled respectively. It is interesting to note that the rest of the blends of the gum-vulcanizate and filled vulcanizates show similar trends at each ratio. This thermal, mechanical dynamic behaviour of the blends, that is, *T*g, observed could be independent of the filler.

Table 1. The DMTA properties of unfilled.

ENR 50	100	75	50	30	0
EPDM	0	25	50	70	100
Gum-vulcanized rubber blends					
Hardness	43	43	46	47	52
Dunlop resilience	24	28	32	38	63
*T*g°C	14.0	14.3	16.1	21.3	–
*T*g°C	–	–35.8	–34.9	–30.7	–27.0
Tan σ pk (25°C)	1.903	1.421	1.036	0.478	–
Tan σ pk (25°C)	–	0.071	0.147	0.391	1.139
Tan σ pk (80°C)	0.081	0.078	0.097	0.119	0.10
Accelerated sulphur cured blends					

Table 2. The DMTA properties of $CaCO_3$-filled.

$CaCO_3$ filled					
ENR 50	100	75	50	30	0
EPDM	0	25	50	70	100
Hardness	60	62	62	65	59
Dunlop resilience	17	21	26	32	49
*T*g°C	7.6	6.9	5.6	4.6	–
*T*g°C	–	–35.2	–32.2	–30.0	–28
Tan σ (25°C)	1.0	0.733	0.575	0.416	–
Tan σ (25°C)	–	0.085	0.168	0.270	0.693
Tan σ pk (80°C)	0.081	0.078	0.097	0.119	0.100
Accelerated sulphur cured blends					

Table 3. The DMTA properties of silica filled.

Silica filled					
ENR 50	100	75	50	30	0
EPDM	0	25	50	70	100
Hardness	70	75	76	72	67
Dunlop resilience	20	24	29	34	56
*T*g°C	13.2	13.33	16.0	21.1	–
*T*g°C	–	– 34.6	– 33.5	– 32.3	–29.5
Tan σ pk (25°C)	0.752	0.565	0.429	0.311	–
Tan σ pk (25°C)	–	0.091	0.171	0.247	0.552
Tan σ peak (80°C)	0.082	0.115	0.144	0.10	0.115
Accelerated sulphur cured blends					

Table 4. Portable skid resistance and friction.

Portable Skid resistance tester results						
ENR 50%	0	20	35	50	80	100
Dry terrazzo						
Skid No.	95	93	93	92	85	84
Wet terrazzo						
Skid No.	19	20.2	21.0	22.0	23.5	25.0
Oil terrazzo						
Skid No.	7	8	8.5	9	10	10.5

However, the filler influenced the thermodynamic behaviour of the blend, especially the elastic moduli and the loss tangent (tan σ peak). The tan σ peak inclined to decrease as the amount of ENR 50 in the blends decreased, while at the same time, tan σ peak of the EPDM phase increased, as shown in *Tables 1* (gum-vulcanizate), *2* (calcium carbonate filled), and *3* (silica filled). Then the DMTA was carried out at the temperature of 80°C, allowing the equilibrium period of 5 min, the scenarios changed. All the *T*g's of the two phases collapsed and merged into a single phase, and only a single tan σ peak was observed. These tan σ peak values observed were much reduced in the range of 0.081 to 0.115. The silica series had marginally higher values at each level of blends. Though the ENR 50 is more polar than natural rubber, it was not as compatible as it is was shown in the blends, and at 80°C, the thermodynamics of each blend was more homogeneous, and no double tangent delta peaks were observed.

The Physical Properties of the Blends

The tensile properties like strength (TS) and the elongation-at-break (EB) were affected by the blend ratios and, they are within the range of 15.7 to 19.2 MPa for the TS, and 530% to 610% for the EB respectively, and these data were within the specification and performance of most rubber products. The results are shown in *Figure 2*.

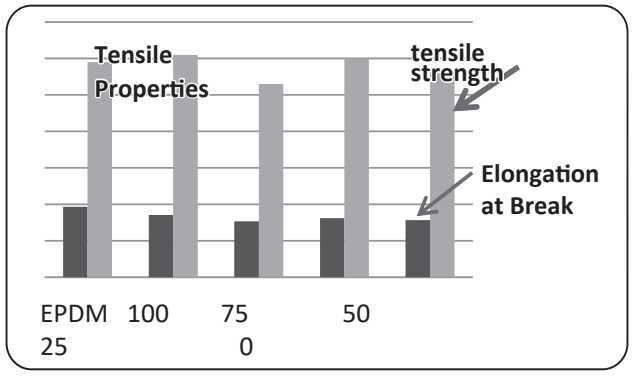


Figure 2. Tensile properties.

The other properties of the blends were also determined. They are the abrasion resistance in ml/per run of the Din abrasion tester and crescent tear in Newton/mm strip. These results are shown in *Figure 3*. The tear resistance as indicated by crescent type increased from 13.8 Newton/mm (100% EPDM) to 14.5 Newton/mm at the 50% blend ratio, and decreased as the addition of ENR 50 to 7.4 Newton/mm in 100% ENR 50. Thus, the addition of the EDPM in the blends improves the abrasion resistance of the blend. The abrasion loss decreased as the addition of the ENR 50 in the blends. It decreased from 0.30 cc for the 100% EPDM, through 0.28 cc in the 50:50 ratio of the blend, to the lowest 0.23 cc in the 100% ENR 5, which correlated well with the tear behaviour of the blends. The abraded surfaces of these blends were examined under microscopy, and the results of the micro-structures and possible voids are shown in the next few Figures.

Skid Resistance and Equivalent Friction of the Blends

The contact behaviour like skid resistance of a rubber surface is complex and hard to determine. One of the methods used is the portal skid resistance tester that is established in Britain, and commonly used to test road surfaces for the assessment of risk at the site where accidents frequently occurred (*ASTM* E 303-1974). The tester was used to assess the skid resistance of a series of blends using a non-bitumen tar surface, such as terrazzo which had more control over the surface nature. The dry, wet and oily surfaces were tested, and the relative skid resistance number were recorded, the equivalent fraction resistance was also computed, and the results are reported in *Table 4*. At the dry condition of the terrazzo, the difference in the skid resistance in the blends was marginal and small. The skid number recorded was relatively high even when they were determined using the dry, smooth terrazzo. As indicated by Giles *et al.* (1965) any skid number above 65 is considered 'good' fulfilling the traffic requirement of the road surface. However, for the wet condition, or the oily surface, the addition of the ENR 50 improves moderately in the wet skid resistance or its skid numbers are within the range of 19 to 25, which is classified as 'unsatisfactory', and similar range was reported by Sabey & Lupton (1964) for their work on wet smooth highly polished surface. Even more so in the oily surfaces, that is, from skid number 7 for the 100% ENR 50. The addition of the ENR 50 could generally improve the skid resistance on both wet and oily surfaces.

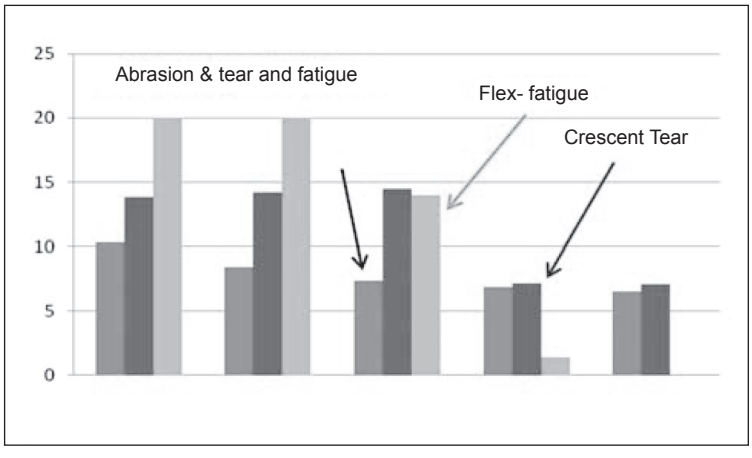


Figure 3. Abrasion, tear and flex.

Abraded Surface of the Blends

The abraded surfaces of each blend was examined using a simple light microscopy and with a suitable range of magnification, the micro-structures of the surfaces was examined and photographed. The photographic images are shown in *Figures 4 – 9*. From the topographic images, there were voids or empty inter-phase spaces observed, and the spatial area increased as the ENR 50 decreased. The ridges (Bhomwick 1964), and depth of the voids were measured and average values computed, and the final equivalent volume of voids were plotted as shown in *Figure 10*. The volume of the void in the blends of various ratios increased as the percentage of ENR 50 increased. The volume and its distribution would affect the physical property, especially the abrasion, or even tear resistance. The occurrence of the voids is also observed by Loh and See Toh (1985) in their work on the electron microscopic study of the epoxidation of NR latex particles.

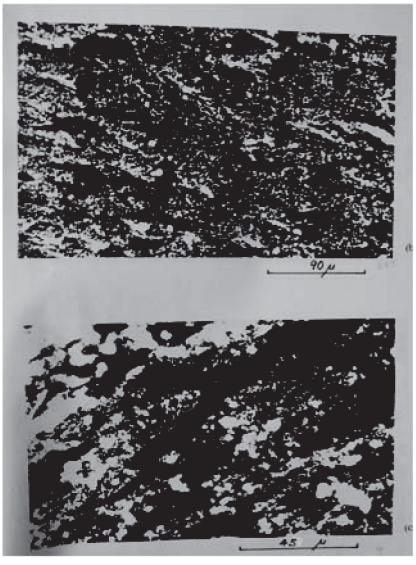


Figure 4. Topography of 1000% EPDM.

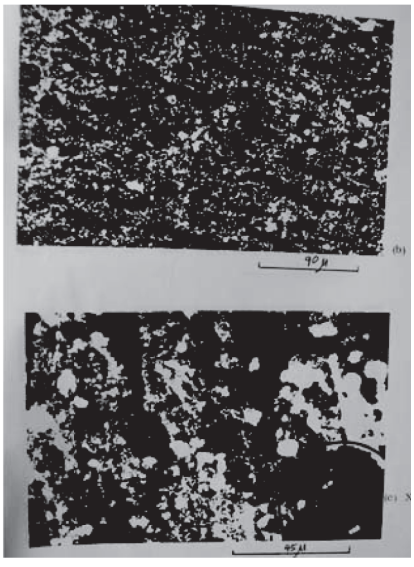


Figure 5. Topography of 80% EPDM.

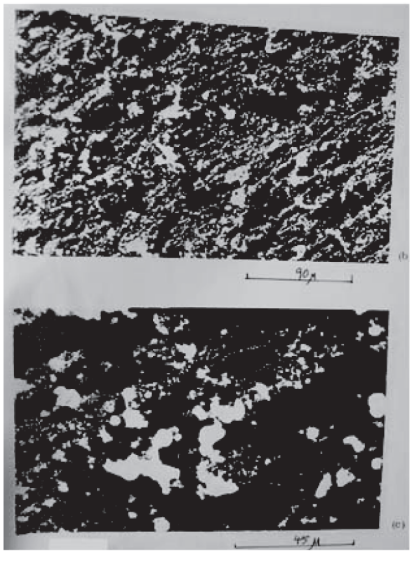


Figure 6. Topography of 65% EPDM.

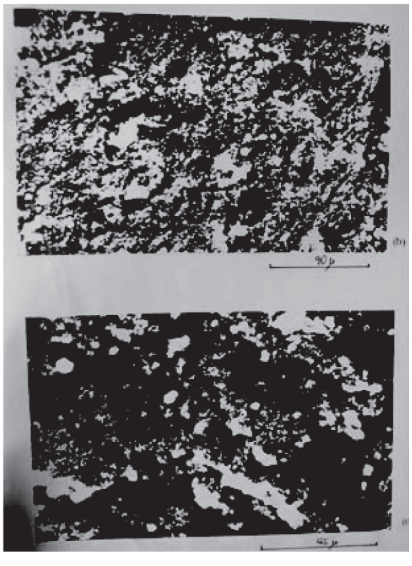


Figure 7. Topography of 50% EPDM.

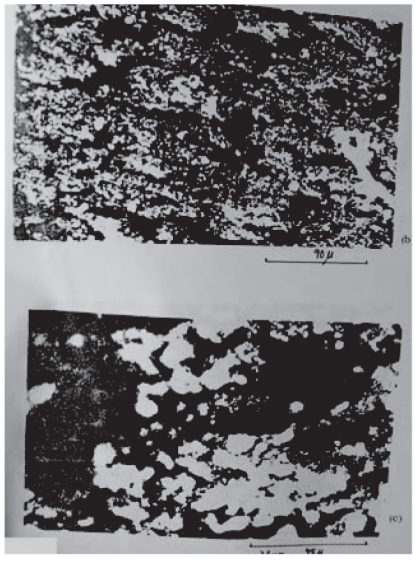


Figure 8. Topography of 20% EPDM.

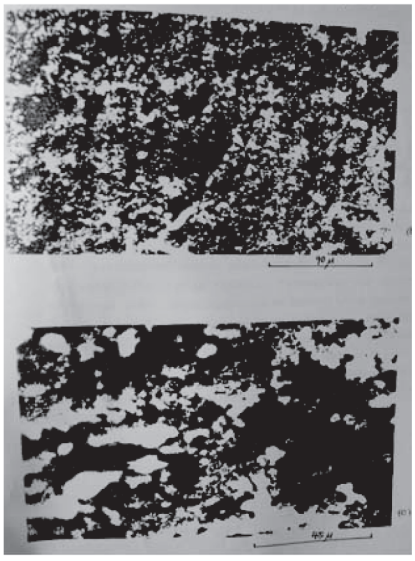


Figure 9. Topography of 0% EPDM.

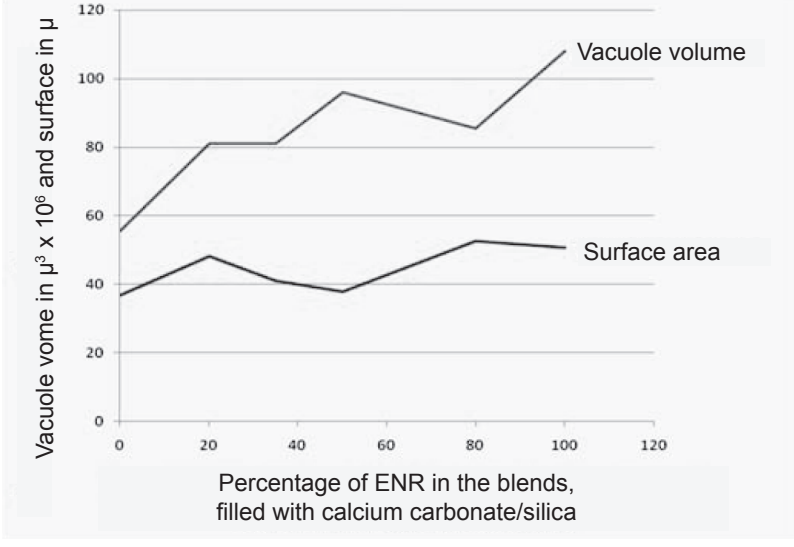


Figure 10. Void volume and surface area of abraded surface of the EPDM/ENR 50 blends.

Improvement in the Morphology of Blends and in the Homogeneity of the Fillers in the Rubber Matrice

The above results and observations showed some discrepancies in the physical properties due to the heterogeneity of the blends. Of course, it was possible to have a better and more homogeneity of the blends, that is, to extend the time of mixing, time of incorporation of fillers and finally extending to the final homogenization, or to increase the temperature of mixing process. These either conditions would affect the flow and scorch behaviour of the final blend compounds, and also finally their physical properties and performance. To overcome these conditions, the organo-metallic titanates, and zirconates which are reactants and compatibilizers are sought, and they are widely used in the rubber compounds of chloroprene (neoprene), nitrile, butyl, hypalon, and others especially with non-black fillers. They are also effective for the dispersion and incorporation of non-black fillers; they are also effective for the dispersion and incorporation of non-black fillers, like silica, lead oxides, and talc.

In this case, LICA38 (Monte *et al.* 1990), a neoalkoxy titanate in liquid form, is used for easy incorporation in the blends. It helps to not only compatibilize the rubber phases of the ENR 50 and EPDM, and also to assist in the homogeneous incorporation of silica in the rubber matrix. In this series, a combined carbon black and silica is used with a low sulphur semi-efficient sulphur vulcanization system chosen, and be combined with a peroxide and maleic anhydride. They were mixed, compounded in the usual method using the Banbury where the maleic anhydride was added, and the active accelerators, sulphur, peroxide and titanate were added as usual on the mill. They were cured to the optimum, plus 3 min at 160°C.

The results in *Table 5* showed a great duel of improvement in terms of tensile properties. The abrasion and especially the compression

Table 5. Effects of organ-metallic and maleic Anhydride.

Black/silica filled–Fatigue/flex property of blends					
ENR 50	0	70	50	25	100
EPDM	100	25	50	75	0
Hardness	69	65	77	69	63
Dunlop resilience	64	45.7	36.7	29.0	28
TS, MPa	28.2	18.9	17.2	16.8	15.3
EB, %	680	590	580	530	510
Compression set					
22 h/70°C	24.3	28	27.5	25.6	28
22 h/100°C	37.6	41.7	43.1	46.7	60.1
Abrasion	52.3	74.4	83.3	92.0	101.0
Crescent tear,					
N/mm	41.8	46.8	35.6	27.5	16.2
De Matia flex					
Kilocycle × 10^6	**2.0**	**2.00**	**1.30**	**0.38**	**0.18**

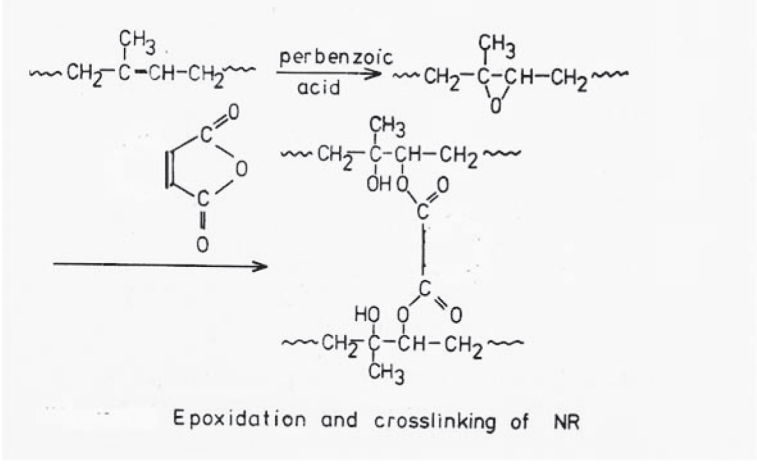
ENR 50	0	70	50	25	100
EPDM	100	25	50	75	0
Hardness	69	65	77	69	62
Dunlop resilience	64	45.7	36.7	29.0	28.0
40°C	64.5	47.6	42.3	35.3	36.0
60°C	60.5	57.1	50.7	44.8	45.7
80°C	62.4	59.3	52.7	48.5	48.5
Aged properties					
70 h/100°C					
TS ret. %	93	90	90	86	76
EB, ret %	83	85	71	69	67
70 h/125°C					
TS ret. %	82	80	79	83	71
EB ret. %	81	76	49	25	28

set, even at 10°C, was still within 60%, and the retention of the tensile properties were relatively, at the conditions of 70 h/125°C. The high level of ENR 50 in the blends had lower tensile and abrasion resistance properties. The resilience property related to the hysteresis of the blends measured at 40°C, 60°C, and even 80°C were high, indicating possibly that the rolling resistance which should be possibly and relatively high too. The results of dynamic flex properties determined by de Matia flexing machine were very high, in terms of more million kilocycles. Normal natural rubber compound would have 150–300 kilocycles. The overall observations in this final series of blends were that the addition and incorporation of the maleic anhydride in the polymer phase during mixing and the titanate as the compatibilizer and coupling agent in these blends enhanced the physical properties, abrasion and tear resistances, and compression set plus the endurance/flex properties. This improvement in the blends, especially at the levels of 25% or 50% of ENR 50 in the EPDM compounds will be ideal for high endurance and performance applications such as in tyre, and for the lower end-applications, the non-slide shoe soles application on wet ship decks, and the semi-niche market applications in the high speed cycle tyres as discussed by Loh and See Toh (1988) on the ENR in tubeless inner liners.

Chemical Reaction Mechanism that Possibly Enhances the Properties of Vulcanizates of the Blends

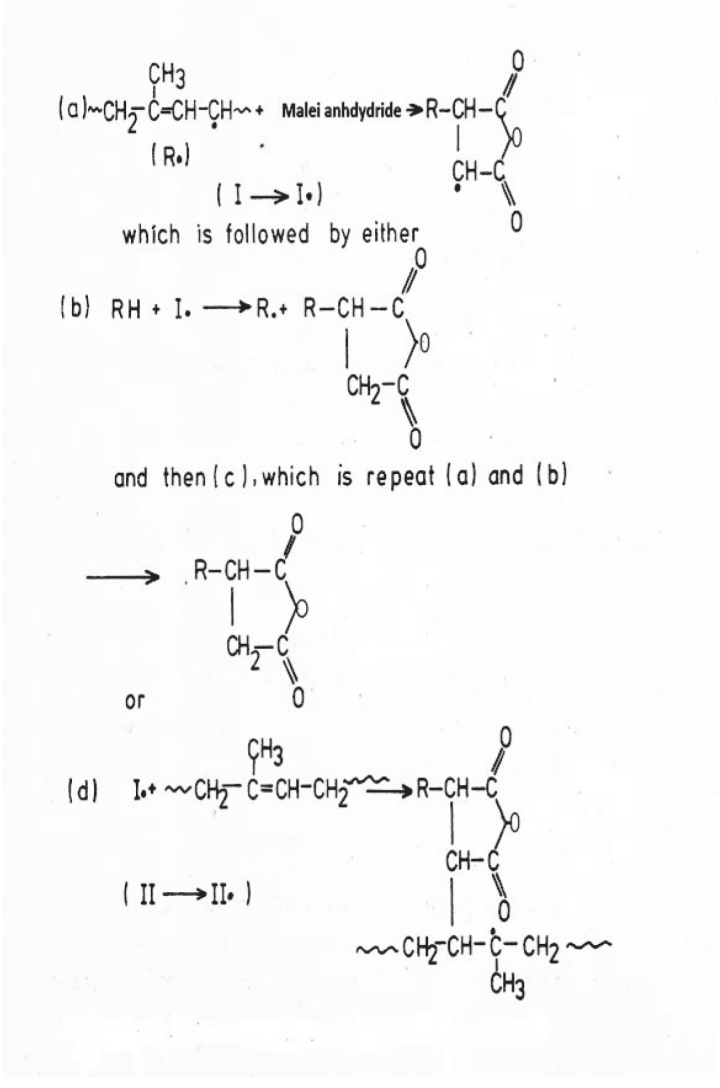
The possibility of chemical mechanism that leads to the overall balanced and enhancement of the physical, dynamic and abrasion properties is the participation of the maleic anhydride in the vulcanisation and also *in situ* dynamic situation. Though the maleic anhydride is purported and mechanistically favoured an Diels-Alder reaction (Alder *et al.* 1943) in the methylene/allylic double carbon bonds (> C = C <) as reported in the classical chemical reactions (Baraboim & Popov 1963), and also by Pinazzi (Pinazzi *et al.* 1963), and Farmer (1942)in natural rubber, while Loo (1985) reported that it is possible that the dibasic acids could be used to open the epoxide ring and also used as crosslink sites, or the dibasic acids used to crosslink in the non-sulphur accelerated curing system.

In this present scenario, apart from the chemical reaction in the methylene/allylic sites, it was possible that the chemical reaction mechanism could occur where the maleic anhydride reactd with the epoxy group to form a carboxylic group and reacted with another to form an effective crosslink (*Scheme 1*), both



Scheme 1. Reaction by substituting.

through the normal substituting reaction, or the free radical reaction in the presence of a peroxide as proposed below (*Scheme 2*). These "maleic anhydride crosslinks" being more flexible than the normal sulphide crosslinks (mono- and di-sulphides types) and would enhance dynamic property like flexing and endurance. Coupled with the low sulphur accelerator curing system, the vulcanized blends could have achieved its ultimate and optimal properties, and the performance using this type of curing system would enhance the overall physical, abrasion resistance and dynamic performance.



Scheme 2. Possible reaction of maleic anhydride in a free radical reaction mechanism.

SUMMARY

The physical properties due the heterogeneity of the blends of the ENR 50 and EPDM were in question, even though the ENR was more polar than normal NR. Of course, it was possible to have a better, and more homogeneity at each of the blends was to extend the time of mixing, time of incorporation of fillers and finally extending to the final homogenization, or to increase the temperature of the mixing process. Either of the conditions would affect the flow behaviour and scorch of the final blend compounds, and also finally, in turn, affect their physical properties and performance. To overcome these conditions, the LICA38 (Monte 1999), a neoalkoxy titanate in liquid form is used in the blends. It enhanced compatibilization of the rubber phases of the ENR 50 and EPDM, and also to assist in the most homogeneous incorporation of silica in the rubber matrix and rubber phases. The dispersion of the combined carbon black and silica was more homogeneous as shown by the results. With a low sulphur accelerated semi-efficient vulcanization system chosen, plus a combination with peroxide and maleic anhydride the crosslinked blended through the epoxide groups and showed excellent physical and performance properties like abrasion and tear resistance. The dispersion of the combined carbon black and silica was more homogeneous as shown by the results. With a low sulphur accelerated semi-efficient vulcanization system chosen, plus a combination with peroxide and maleic anhydride the crosslinked blends showed excellent physical and performance properties like abrasion and tear resistance.

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APPENDIX

For *Figures 1 – 10*:

ENR 50, EPDM (Exxon7000), Stearic acid 2, Sulphur 1.5, CBS 1.0, TMTD 0.1, TMQ 1.2, $CaCO_3$ 30 phr , silica 25 phr filled blends, DEG 5.

For *Table 1*:

ENR 50, EPDM (#4050), ZnO 5.0, Stearic acid 2.0, Sulphur 1.5, CBS 1.0, TMDT 0.5, TMQ 1.2

For *Table 2*:

EPDM (#4050), ZnO 5.0, Stearic acid 2.0, Sulphur 1,5. CBS 1.0, TMDT 0.5, TMQ 1.2, $CaCO_3$ (30 phr) filled blends, blends.

For *Table 3*:

EPDM (#4050), ZnO 5.0, Stearic acid 2.0, Sulphur 1.5, CBS 1.0, TMDT 0.5, TMQ 1.2, silica (30 phr) filled blends, DEG 1.2.

For *Table 4*:

ENR 50, EPDM (#4050), Stearic acid 2, Sulphur 1.5, CBS 1.0, TMTD 0.1, TMQ 1.2, $CaCO_3$ 30 phr, silica 25 phr filled blends, DEG 5.

For *Table 5*:

ENR 50, EPDM (Exxon 7000), Stearic acid 2, Sulphur 1.5, CBS 1.0, TMTD 0.1, TMQ 1.2, carbon

black 20 phr, silica 35 phr filled blends, DEG 5, LICA38, anhydride 0.25 and DiCup® R 1.0 and ZMB2 1.0

CBS N-cyclohexyl 2-benzothiazyl suplhenamide

TMTD Tetramethyl thiuram tetrasuphide

TMQ polymerised 2.2.4–trimethyl1, 2 hydoquiline

DE G diethylene glycol

LICA 38 neoalkoxy titanate, patents, Kenrich Group

ENR 50 Guthrie's Group of Company / RRIM

Exxon 7000 Exxon Goup

EPDM from Japan

Dicup® R, dicumyl peroxide

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