Uncovering the Relation Between the Environmental Damage and the Rate of Rainfall Received Through Life Cycle Assessment (LCA) Study on Potable Water Production in Malaysia.

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Abstract: The world climate change is a phenomenon that is widely discussed in recent times. It causes a huge impact to the population of the world. Global warming causes the world's rainfall pattern to change including Malaysia. Today wet and dry season is very hard to be accurately predicted. Rainy season is getting more frequent and causing destruction to properties and halting economic growth of a nation. Evidence shows that climate change and global warming is caused by human's own lifestyle and activities. Man's savage way is the main caused for global climate change. Life Cycle Assessment (LCA) is a tool that could be used to assess a product or service from cradle-to-grave. This tool is capable of proving that every human invention has weaknesses and is threatening human life. In water treatment process, chemicals and electricity is needed. A sudden increase in water level in river caused by heavy rain resulted in higher usage of chemicals to treat water. Life Cycle Impact Assessment (LCIA) which uses ecoindicator 99 evaluation method to assess the chemicals and electricity, shows that the production of Polyaluminium chloride (PAC) causes damage to human health (respiratory inorganic) while electricity generation is fast depleting the natural resource of fossil fuel such as natural gas. These situation show that the irregular rate of rainfall resulted from the world's climate change not only affect human (eg. Inorganic respitory) but also indirectly causing destruction to the environment (depletion of natural gas) during the treatment of water. To overcome this problem the use of PAC as coagulant can be substituted with Alum. From the impact analysis, it is found that by replacing PAC with Alum, damage is reduced to more than 90% in damage to human health and ecosystem quality. This the same if electricity generation using natural gas is replaced with the combination of natural gas and renewable energy technologies such as solar panels and hydroelectric. Impact analysis also shows that there is 50% reduction in damage to resources when 50% natural gas and 50% renewable energy (solar panel and hydroelectric) without affecting human health and the environment.

Key word: World climate change, rainfall pattern, Life Cycle Assessment (LCA), Polyaluminium Chloride (PAC), Natural Gas

INTRODUCTION

Global climate change is a threat that people are not aware or are not given enough attention to. In Malaysia, there are people who take this problem very lightly. Global climate change is usually linked to the increase in the world temperature that involves; complex processes and would take a long time to take effect. However, the impact from global climate change is getting more apparent and can be felt by people of the world resulted from the increase in world temperature. The increase in world temperature or better known as global warming is a new threat to people's and the nation's safety and could be even worse than weapon of destruction. It is due to the fact that global warming does not discriminate against skin color and boundaries of a nation. In Malaysia, signs of climate changes due to global warming can be seen through various disasters and symptoms affecting several areas throughout the country such as increasing sea level, haze, flood and water shortage. Climate change does not only involves Malaysia but is a global problem that must be dealt with cooperatively by every nations in the world.

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What is Global Climate Change?

Global climate change is usually associated with the increase of world temperature or better known as global warming. Global warming is an indication or a symptom that there is an increase in surface temperature both on land, in the ocean or the combination of both in vast scale. Global warming is caused by burning of fossil fuel such as coal, oil and gas resulting in the increase of green house gases such as carbon dioxide, methane and chlorofluorocarbon (CFC) in the atmosphere. The accumulated green house gases trapped in the atmosphere causes the earth to become warmer.

The real cause and factor contributing to the climate change and global warming is still being debated by various parties. But the fact is, evidence shows that climate change and global warming is caused by human activities and lifestyle. Development, deforestation, industries, factories and transportation are among the activities that contribute to worldwide climate change. Global climate change occurs as an effect from the increase of green house gas in the atmosphere generated by the rapid development in production industries, timber processing, agriculture, transportation and other industries in the world that is tipping the balance with nature. This inadvertently contributes to the increase of these gases, indirectly increasing the earth's temperature.

Increased carbon dioxide gas in the atmosphere is generated from the burning of fossil fuel such as petrol, coal and natural gas. According to the 4th Assessment Report (2007 Climate Change) Inter-Governmental Panel of Climate Change (IPCC), 98% of the temperature increase on earth is caused by the release of carbon dioxide gas. Carbon dioxide concentration in the atmosphere increases from 280ppm recorded in the 18th century (prior to the industrial revolution era) to 379 ppm in 2005. In 2099, if human maintain current momentum of fossil fuel use as it is right now, the concentration of carbon dioxide in the atmosphere is predicted to increase by 700ppm. This situation would render the environment of the earth no longer suitable for human inhabitation. Relatively, green house gas emission by Malaysia is still small compared to other countries in this world(see Table 1). Nevertheless, a control system is needed to reduce the emission of green house gas into the atmosphere.

Table 1: Green house emission by chosen countries (Minister of Science, 2000)

Country	Year	Green house emission (million tan)
Malaysia	1990	138.0
	1994	144.0
Thailand	1990	225.0
Australia	1990	572.0
Japan	1990	1,215.9
	1994	1,276.1
USA	1990	5,895.9
	1994	6130.0

The Impact of World Climate Change to the Country:

Climate change is believed to have speed up the weather process causing sudden changes within a period of time. It is threatening human and nation's safety from the physical and psychological aspects. The combination of both would create crisis to peoples' lives, public safety/order, political stability and economic integrity if not managed properly. Among the physical effects of climate change to the country are as follows:

Natural Disaster:

The change of monsoon wind direction, rising sea level, irregular rainfall are among the result of climate change. The increasing earth temperature will create a huge threat to human life resulted from increased frequency of natural disaster occurrence over time. Typhoon, floods, draught and plague of diseases related to the environment are among the natural disasters that would follow the unpredictable climate change. With 9% of land area in Malaysia (29,000 sq.km) exposed to flooding, 2.7 million people in this country might be the victims. The ever-changing weather causes the country to face possibility of natural disaster situation. As an example, in 2006 and 2007, the state of Johor experiences the worst flooding affecting 109, 831 victims to be evacuated (Bakar *et al.,* 2007). Other states experiencing similar situation during that time were Melaka, Pahang, Kelantan and Negeri Sembilan. A total of 344 flood evacuation centre was set up. It was reported that 17 lives were lost in this extreme flooding disaster (BBC News, 2007). The flood was linked to Hurricane Utor (The Star, 2006). In October 2008, flash flood happened in northern state of peninsular Malaysia like Kedah and Perak due to the hotter sea surface in the region (Bernama, 2008).

Water Source:

Rapid development in urbanization process and industries increases the demand for water especially in the sectors of industrial, agricultural and also domestic use. Climate change can cause two possibility of occurrence; Malaysia experiencing increase or decrease of rainfall. Increase rainfall would mean that Malaysia would be exposed to flooding causing destruction to infrastructure, properties and lost of life. Meanwhile, a decrease in rainfall would cause reduction in clean water source for domestic use, agricultural and industrial. During the 1977 - 78 periods drought devastated paddy production in most of the irrigation schemes in Northwest Peninsular Malaysia (Azizan and Sootyanarayana, 2008). In 1982 and 1991, droughts were responsible for the critical drop of water levels in in the state of Kedah, resulting in cancellation of the off - season crop production (Azizan and Sootyanarayana, 2008). In 1991, the state of Melaka faced critical water problems with water levels falling below critical levels, thereby forcing severe water rationing for months in the state (Climate Ark, 2002). In 1998, the El Nino related drought caused severe water stress in the states of Kedah, Penang and Selangor. The state of Selangor was forced to impose severe water rationing in Kuala Lumpur and Petaling Jaya for many months (Angela, 2002). According to the Seventh Malaysia Plan reports, several countries experience water shortages after the year 2000, including Kedah, Pulau Pinang, Selangor (Rahman, 2007).

World Climate Change and the Need for Sustainable Development:

Development can increase the quality of human life. This can be felt from the increasing quality of products, services, health, social and culture. Development is endless and will keep expanding to fulfill the changing human vision and mission. But development process usually has a negative effects to the environment, thus demanding a more environmentally sound development. Unplanned and unsustainable development has placed great pressure in every dimension of the environment (air, water, soil, health, etc.) that ultimately causes problem that not only involves local but global such as global warming. Sustainable development is the need of the hour; it can only be achieved through effective environmental management (Khan *et al.,* 2002). Effective environmental management can be achieved through the various environmental assessment tools including life cycle assessment (LCA).

Methodology of LCA:

There are four main phases in LCA as suggested in ISO 14040 series:
Goal and scope definition (ISO 14040)
Life cycle inventory (LCI) (ISO 14041)
Life cycle impact assessment (LCIA) (ISO 14042)
Life cycle assessment and interpretation (LCAI) (ISO 14043)

Goal and Scope Definition:

In goal definition and scoping, the use of the results is identified, the scope of the study is stated, the functional unit is defined, and a strategy and procedures for data collection and data quality assurance are established.

Objectives:

The goal of this study is to see the extent of environmental impact from the water treatment process which uses chemicals and electricity in varying quantum due to the varying quality and quantity of the water source resulted from two extreme weather conditions; wet and dry seasons. Apart from that, this study also tries to identify the weaknesses that exists in the drinking water treatment process life cycle as we follows all the material and energy flows of the product system from the natural environment back to the natural environment over the product's whole life.

Functional unit:

Functional unit is quantified performance of a product system for use as a reference unit in a life cycle assessment study (ISO, 2000). A constant value must be created to make the comparison (Miettinen and Hamalainen, 1997). Functional unit for this study is the production of $1m^3$ of treated water a day that fits the standard quality set by Ministry of Health, Malaysia.

Description of the System under Study:

To define the system boundaries for a product, it is essential to understand how a product is manufactured. In producing treated water, raw water goes through several phases before drinking water that fits the set standard is produced. Raw water extracted from rivers will go through the following process in the water treatment plant:

- **Screening**, to remove floating big sized rubbish on the surface of the water.
- **Coagulation and flocculation**, coagulation process is a process of forming particles called floc. Coagulant need to be added to form floc. The coagulants that are normally use includes Aluminium sulphate, Ferric sulphate and Ferric chloride. Tiny flocs will in turn attract each other while at the same time pulling the dissolved organic material and particulate to combine, forming a big flocculant particle. This process is called flocculation.

- **Sedimentation**, Floc produced will settle on the base of the sedimentation basin. The accumulation of floc settlement is called sludge.
- **Filtration,** part of the floc which does not settle in the sedimentation basin will go through filtration. Water passing through filtration consisting of sand layers and activated carbon or anthracite coal.
- **Disinfection** process is needed to eliminate pathogen passing through the filters. Among the chemicals used for the disinfection are chlorine, chloramines, chlorine dioxide, ozone, and UV radiation.
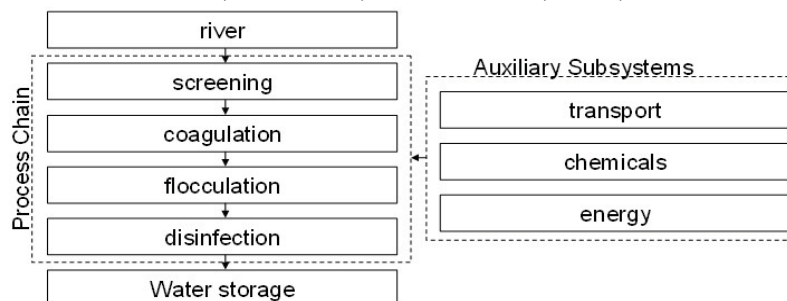

Fig 1: System boundaries and process under study

Life Cycle Inventory (LCI):

After scoping the product system, the inventory in the system under study is gathered. It includes information on the input and output (environmental exchanges) for all the process within the boundaries of the product system (see fig. 1). The result of an inventory is a long list of material and energy requirements, products and co-products as well as wastes. This list is referred to as the material and energy balance, the inventory table, or the eco-balance of the product (Guinee, 2002). This LCA study is a streamlined LCA where background data for electricity, chemicals and transport using database contained in the Jemaipro and Simapro 7 software. Foreground data collected from the treatment plant are:

- Electricity usage, and
- Chemicals such as Aluminium sulphate (alum), Polyaluminium chloride (PAC), Chlorine, and Calcium hydroxide (lime)

Foreground data mentioned above was compiled from selected treatment plant. The treatment plant provides data for three different weather conditions:

- Data for normal day. Chemical and electricity usage data for rivers that does not experience any increase nor decrease in water level. The river water is identified as river category of Class II. The average chemical and electricity consumption is used to represent daily data.
- Data for rainy season. Records for sudden increase in water level in the river is identified. The average chemical and electricity consumption is used to represent data of days that experience sudden increase in water level in the river.
- Data for dry season. Records of water suddenly dipping below minimum level is obtained. The average chemical and electricity consumption is used to represent daily data of days that experience sudden decrease in water level in the river.

Life Cycle Impact Assessment (LCIA):

The purpose of the life cycle impact assessment is to interpret the inventory results into their potential impacts on the areas of protection of the LCA (Hauschild and Why, 2007). i.e in Eco-indicator 99 (see table 3), the entities that the use of the LCA shall help protect:

Areas of protection for LCIA:

• Human Health

• Ecosystem Quality

• Natural Resources

Table 2: Damage Assessment and Impact According to Eco-Indicator 99 Evaluation Method (Goedkoop and Spriensma, 2001)

Damage Assessment	Unit	Impact
Human Health	DALY	Carcinogen, radiation, respiratory organic and inorganic, climate change and ozone layer
Ecosystem Quality	PDF*m^{2}yr	Land use and acidification/eutrophication,
	PAF*m^{2}yr	Ecotoxicity
Resources	MJ surplus	Minerals and fossil fuels
DALY		Disability Adjusted Life Years (Years of disabled living or years of life lost due to the impacts)
PAF		Potentially Affected Fraction (Animals affected by the impacts)
PDF		Potentially Disappeared Fraction (Plant species disappeared as result of the impacts)
SE		Surplus Energy (MJ) (Extra energy that future generations must use to excavate scarce resources)

Generally there are 3 steps in LCIA:

2.3.1   Classification and Characterization

2.3.2   Normalization, and

2.3.3   Weighting

Classification and Characterization:

Classification is the step in which the data from the inventory analysis (the substance emissions) are grouped together into a number of impact categories (Bovea and Gallardo, 2003). Grouping to impact categories is according to their ability to contribute to different environmental problems. While characterization are the effect of each item on each impact category is quantified. A typical way is to use equivalency factors, in some instances also called potentials. For example, global warming potential for a substance indicates its relative potential to increase the global warming effect compared to CO_2, whose GWP is set to one. In ISO 14040 series classification and characterization are two basic mandatory elements. Below is the result of the analysis done in this study (see Fig 2).
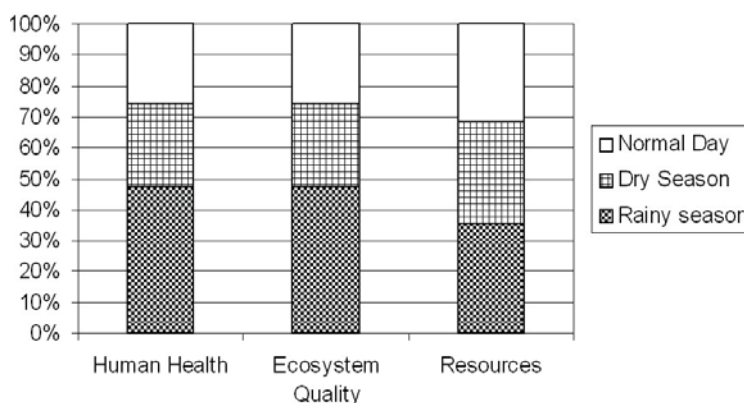

Fig. 2: Characterization According to 3 Protection Areas

Analysis is focused on three damage categories namely damage to human health, damage to ecosystem quality and damage to resource depletion. Analysis found that during rainy season, the situation has the potential to cause higher damage to human health (0.0407 DALY) and ecosystem quality (1.92E3 PDF*m2yr) at about 46% each compared to dry season and normal day. However, during the dry season, eventhough the value is much lower than rainy season, it is still higher than normal day but the difference is not too big (difference in value of 0.0014 DALY in Human Health damage and 0.07E3 PDF*m2yr in Ecosystem Quality

damage). In damage to resources, rainy season is still higher compared to dry season and normal day. But the contribution does not exceed 40%. Meanwhile, dry season still contributes higher compared to normal day. Values for rainy season, dry season and normal day is 578, 536 and 521 MJ surplus respectively. Analysis shows that two main substances contribute to these three damage categories. The substances are polyaluminium chloride (PAC) and natural gas. The PAC chemical production process releases sulphur oxides and nitrogen oxides that contributes to Human Health and Ecosystem Quality damages, while electricity generation contributes to natural resources depletion damage.

Table 3: Characterization to Impact Category for Different Situation

Impact category	Unit	Rainy season	Dry season	Normal Day
Carcinogens	DALY	7.16E-06	6.62E-06	6.4E-06
Resp. organics	DALY	1.17E-07	1.06E-07	1.01E-07
Resp. inorganics	DALY	0.040633	0.023199	0.02182
Climate change	DALY	8.06E-05	7.5E-05	7.2E-05
Radiation	DALY	1.71E-08	1.85E-08	1.17E-08
Ozone layer	DALY	4.79E-09	4.27E-09	4.2E-09
Ecotoxicity	PDF*m2yr	2.036848	1.871666	1.851406
Acidification/ Eutrophication	PDF*m2yr	1915.167	1093.544	1028.461
Land use	PDF*m2yr	0.053107	0.057419	0.036363
Minerals	MJ surplus	0.011961	0.01291	0.008192
Fossil fuels	MJ surplus	577.824	535.6501	521.4128

From impact analysis (refer Table 4), rainy season succeeded other categories in all impact categories (carcinogens, respiratory organics, respiratory inorganics, climate change, and ozone layer) in human health damage except for radiation impact category. For radiation impact category, rainy season falls to second place followed by normal day. In the rest of the categories included in the damage to environmental quality category and natural resources depletion, highest impact is contributed most by rainy season (ecotoxicity, acidification/eutrophication, land use, minerals, and fossil fuels.

Normalization:

Normalization expresses the magnitude of the impact scores on a scale which is common to all the categories of impact. Impact scores and resource consumptions from characterization are related to a common reference in order to facilitate comparisons across impact categories (Huijbregts *et al.,* 2003). The impact scores are usually expressed in person equivalents, PE. The PE represents the annual impact from an average person and is useful for bringing the rather diverse environmental impacts on a common scale. Normalization is an optional element in ISO 14040 series. The following are the result of the normalization analysis for the impact category obtained (refer Table 4).

Table 4: Normalisation to Impact Category for Different Situation

Impact category	Rainy season	Dry season	Normal Day
Carcinogens	0.000466	0.000431	0.000417
Resp. organics	7.64E-06	6.92E-06	6.6E-06
Resp. inorganics	2.64518	1.510249	1.420503
Climate change	0.005246	0.004881	0.004689
Radiation	1.11E-06	1.2E-06	7.61E-07
Ozone layer	3.12E-07	2.78E-07	2.73E-07
Ecotoxicity	0.000397	0.000365	0.000361
Acidification/ Eutrophication	0.373457	0.213241	0.20055
Land use	1.04E-05	1.12E-05	7.09E-06
Minerals	1.42E-06	1.54E-06	9.75E-07
Fossil fuels	0.068761	0.063742	0.062048

Normalization shows the damage to human health quality as the main item. Impact to respiratory inorganic is pointed out as the main cause. The value for this impact category in rainy season, dry season and normal day is 2.65, 1.51 and 6.6E-06 DALY respectively. Meanwhile in damage to ecosystem category acidification/eutrophication is valued at 0.37, 0.21 and 0.20 for rainy season, dry season and normal day respectively. However, damage to ecosystem quality is in second place after damage to human health. Resource category is last in ranking as the impact contribution is the lowest among all the impact categories. For this damage, the fossil fuels impact category is higher compared to minerals. The contribution value for rainy season, dry season and normal day is 0.07, 0.063 and 0.062. Rainy day remains the highest contributor for this impact category.

Weighting:

Weighting is also known as valuation. Weighting is the last step in LCIA where a ranking is performed of the different environmental impact categories and resources consumptions reflecting the relative importance they are assigned in the study (Soares *et al.,* 2006; Pennington *et al.,* 2004). The aim of this step is to arrive at a further interpretation and aggregation of the data of the impact assessment. The importance of the impact categories in relation to each other is a value-bound procedure based on an assessment of the relative environmental harm. This assessment will therefore reflect social values and preferences (Consoli *et al.,* 1993). Weighting is another optional element.
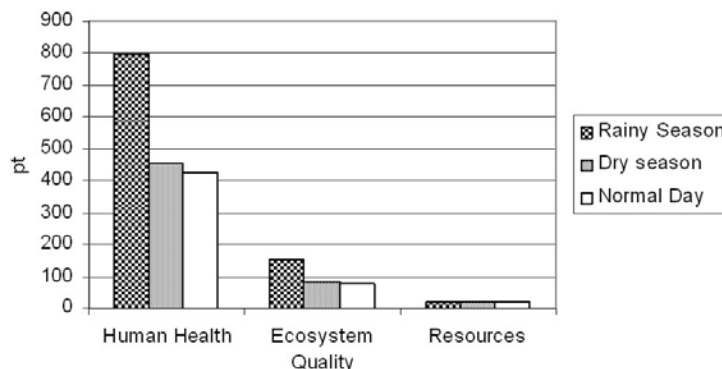

Fig. 3: Weighting in Damage Assessment for 3 Different Situation

Weighting analysis shows a result similar to normalization analysis where the first ranking remain with damage to human health followed by damage to ecosystem quality and damage to resources (refer Fig 3). Values for Damage to Human Health are 795, 455 and 428 Pt for rainy season, dry season and normal day. Damage to Ecosystem Quality is at second place with a difference between 340 Pt (Rainy season), 369.4Pt (Dry season) and 408 Pt (normal day) compared to damage to human health category. Damage to resources category is in the last place indicating that this category is seen as contributing the least impact compared to damage to human health and ecosystem quality. Values for the three situations are 20.6 Pt (Rainy season), 19.1 Pt (Dry season) and 18.6 Pt (Normal Day).

Life Cycle Assessment Interpretation (LCAI):

Interpretation is the phase of the LCA where the results of the other phase are interpreted according to the goal of the study using sensitivity and uncertainty analysis. The outcome of the interpretation may be a conclusion serving as a recommendation to the decision makers, who will normally consider the environmental and resource impacts together with other decision criteria (such as economic and social aspects) (Hauschild *et al.,* 2005).

Improvement Assessment:

From the Analysis Conducted, There Are Two Weaknesses Identified:

1. Production of PAC: Contributed to damage to human health quality and damage to ecosystem quality. The process in producing this chemical releases two other dangerous chemicals; nitrogen oxides and sulphur oxides.
2. Depletion of fossil fuel namely natural gas: Natural gas is used in electricity generation.

These weaknesses could be overcome using more environmental friendly alternatives such as:

*   Replacing PAC with Alum. PAC is a coagulant that could be replaced with other chemical substance such as Alum. In this case, the water treatment plant uses both coagulants in similar quantities. Thus the suggestion is for the complete PAC replacement with Alum to depict the impact of the replacement.
*   Natural resource depletion; natural gas: The existing advantages that water treatment plants have must be given attention should complete dependence in natural gas as fuels of electricity generation are to be avoided. The main advantage is the constant flow of water in water treatment plant that could be used to generate electric. Other than that, the location of the water treatment plant that is usually exposed to solar radiation is also an advantage that should not be taken lightly. The use of solar panels could assist in getting alternative electricity source from this existing advantage. Thus a suggestion made to reduce the

damage to natural resources depletion is the use of hybrid electric generation combining three type of electric generation namely solar panels (25%), hydro electric (25%) and natural gas (50%). This situation tries to get the effects in the reduction of the main substance used in electricity generation; natural gas. Background data for solar panels and hydro electric in Simapro 7 software is used to compare the actual result (natural gas usage) with the suggested corrective measure using the combination electricity generation process.

The result of the weighting analysis for corrective suggestions is shown in fig. 4.
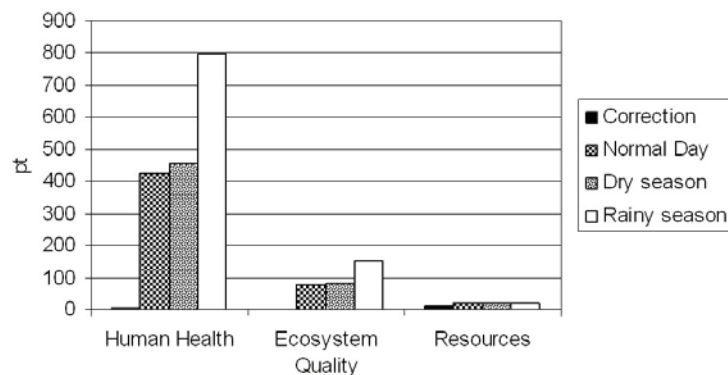

Fig. 4: Weighting analysis with corrective measure to overcome damage to human health, damage to ecosystem quality and damage to resources

From the analysis conducted, both damage to human health and ecosystem quality can be reduced to more than 90%. For example, in the damage to human health category, the original value for rainy season (795 Pt), dry season (455 Pt) and normal day (428 Pt) can be reduced to 2.65 Pt only. This is the same with damage to ecosystem quality, the original value for rainy season (150 Pt), dry season (85.4 Pt) and normal day (80.4 Pt) can be reduced to a mere 0.48 Pt only. However, the used of hybrid technology in electricity generation can reduce 50% of damage to resources. The analysis also found that the use of hybrid technology does not gives impact to damage to human health and ecosystem quality.

Conclusion:

The goal of this study is to analyse the damages that would happen from the use of chemical use dan electricity generation from two extreme climate condition in this country; rainy season and dry season. Both this climate conditions is also linked to the world climate change which; a hot current topic nowadays. Based on the analysis of environment impact using ecoindicator 99 evalution method, it is found that rainy season and dry season contributes higher to environmental damage namely damage to human health, damage to ecosystem quality and damage to resources if compared to normal days. The rainy season is found to contribute much higher impact compared to dry season and normal day. The dry season still contributes impact to the environmental but with insignificant difference than normal days. The consumption of Alum, PAC and Chlorine would increase during the rainy season. This situation is used to ensure that treated water fits the standard set. The increase in these chemicals has the potential to cause environmental damage. The chemical that was identified to contribute to these damages are PAC. The production of this chemical releases two hazardous by product chemicals namely nitrogen oxides and sulphur oxides. Nevertheless, both damages could be reduced by completely replacing the coagulant with a more environmentally friendly coagulant such as Alum. After the replacement of the chemical, the burden on ecosystem quality and human health could be reduced up to 80% -90%.

Damage to the natural resources depletion is caused by electricity generation using natural gas. Advantages at the water treatment plan could be fully utilized to avoid dependence on natural gas. This includes the running water in the water treatment system and water treatment plant location that is exposed to solar radiation could be harness to generate electric. Hybrid electric could reduce the complete dependence on fossil fuel natural gas in water treatment plant.

Even though the replacement of PAC with the more ecosystems friendly Alum could reduce the damage to ecosystem quality and human health quality, but the disadvantage of Alum use is that it generates a high quantity of sludge. Though there are claims that sludge produced from water treatment plant is not dangerous

compared to sludge produced by wastewater treatment plant but it can give negative effects to the environment especially if this sludge is released directly into rivers as it is still currently practiced by some water treatment plants in this country.

The portion suggested to reduce the dependence on natural gas might be improved further as it is currently only able to reduce it to about 50% only. However, if this effort is put into action, it would at least reduce the use of fossil fuel natural gas.

The world climate change demands a sustainable development practices. Without sustainable development in environmental management, damage to the environment is inevitable. Global warming is a general example caused by anthropogenic activities. The results are disasters such as frequent drought and flood that occurs in this country. This situation not only applies to physical disasters but indirectly causing environmental damage when river water had to be treated with higher chemical dosage during the rainy and dry season. By using LCA as the environmental assessment tool, environmental damage could be foreseen. Among the potential damages from these two extreme climates are damage to human health (especially respiratory inorganic impact), damage to ecosystem quality (especially acidification/eutrophication impact) and damage to resources (especially impact to fossil fuels).

REFERENCES

Bakar, S.A., M.F. Yusof and W.S. Amly, *Johor hampir lumpuh*, in *Utusan Online*. 2007: Johor Baharu.

BBC News, *Malaysia floods test aid efforts*, in *BBC News*. 2007.

The Star, *Typhoon Utor to Blame*, in *The Star*. 2006: Cyber Jaya.

Bernama, *Residents Advised To Be Cautious Of Inter-Monsoon Period*, in *Bernama*. 2008: Kuala Lumpur.

Azizan, A.S. and V. Sootyanarayana (2008) *Possible Impact of Climate Change on Agriculture*, 15.

Climate Ark. *Malaysian state begins water rationing amid dry spell* 2002 [cited 23 July 2008]; Available from: http://www.climateark.org/.

Angela, M., *No Water Rationing in Klang Valley*, in *The Sun*. 2002: Shah Alam.

Rahman, H.A. *A survey on a river pollution in Malaysia*. in *Geographic Conference 2007*. 2007. UPSI: UPSI.

Khan, F.I., V. Raveender and T. Husain, 2002. *Effective Environmental Management Through Life Cycle Assessment*. Journal of Loss Prevention in the Process Industries, 15: 455-466.

ISO14000, *Malaysian standards handbook on environmental management: MS ISO 14000 Series - 2nd Ed*. 2000, Shah Alam, Malaysia: SIRIM.

Miettinen, P. and R.P. Hamalainen, 1997. *How to benefit from decision analysis in environmental life cycle assessment (LCA)*. European Journal of Operational Research, 102: 279-294.

Guinée, J.B., *Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards*. 2002: Springer. 704 pages.

Hauschild, M., *Why LCA?* 2007, Department of Manufacturing Engineering and Management, Denmark Technical University of Denmark.

Bovea, M.D. and A. Gallardo, 2006. *The influence of impact assessment methods on materials selection for eco-design*. Materials and Design, 27: 209-215.

Huijbregts, M.A.J., *et al.,* 2003. Normalisation figures for environmental life-cycle assessment The Netherlands (1997/1998), Western Europe (1995) and the world (1990 and 1995). Journal of Cleaner Production, 11: 737-748.

Soares, S.R., L. Toffoletto, and L. Deschenes, 2006. *Development of weighting factors in the context of LCIA*. Journal of Cleaner Production, 14: 649-660.

Pennington, D.W., *et al.,* 2004. *Life cycle assessment part 2: Current impact assessment practice*. Environment International, 30: 721-739.

Consoli, F., *et al.,* 1993. Guideline for life cycle assessment: A code of practice. Society of Environmental Toxicology and Chemistry workshop report: Sesimbra, Portugal.

Hauschild, M., J. Jeswiet and L. Alting, 2005. *From Life Cycle Assessment to Sustainable Production: Status and Perspective*. Annals of the CIRP, 54/2/2005: 535-555.

Minister of Science Technology, 2000. and the Environment Malaysia, *Malaysia Initial National Communication (INC)*. Minister of Science Technology and the Environment Malaysia: Putra Jaya,. p. 131.

Goedkoop, M. and R. Spriensma, 2001. *The Eco-indicator 99 - A damage oriented method for Life Cycle Assessment Methodology Report*. 3rd ed. BB Amersfoort: Pre Consultants. 132.