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Decrypting the Influence of River Classes on the Effects on the Environment Through Life Cycle Impact Assessment (LCIA) of Water Treatment Processes in Malaysia

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Abstract: Parallel with the city development, industrial and commerce activities increase, river quality started to worsen with the occurrence of erosion, sedimentation and pollution. The scenario in Malaysia shows that the number of rivers in class I and II categories which is of high quality is falling fast but those in class IV and V categories are rising. This development is expected to be in line with the rapid progress experienced by this country along with the lack of awareness of the community in the efforts of preservation and conservation of the environment. The goal of this study is to see the extent of environmental impact form the water treatment processes which uses chemicals and electricity in varying quantum due to varying quality of the source water resulted from anthropogenic activities. To get the depiction of the damages, LCA method is used. Three different river classes is chosen, namely class I, class II and class III, as classified by Department of Environment, Malaysia. This study uses the ISO standards and Ecoindicator 99. In Ecoindicator 99, environmental damages are categorized into 3 types, namely, damage to Human Health, Ecosystem Quality and resources. This study is a streamlined LCA where only foreground data is needed namely the quantity of chemicals used during water treatment and electricity consumption. While the background data for the chemicals and electricity is acquired from Simapro and Jemai-LCA Pro software databases. LCI methodology was used for quantification of the impacts of portable water production at the different river classes. The data inventory is then classified and characterized with Ecoindicator 99 to identify the weaknesses of the system. Treatment of class III rivers contribute higher impact to the environment followed by class II rivers and the lowest impact is from class I river. The use of high quantity of chlorine was identified as the contributor to environmental impact. Weighting analysis shows that three main impact categories identified was respiratory inorganics, acidification/eutrophication and fossil fuels. The major chemical substance to respiratory inorganics and acidification/eutrophication impact categories are nitrogen oxides and sulphur oxides. Both substances are released during the production of Polyaluminium chloride (PAC) use as coagulant. While the material that contributes to fossil fuels impact are natural gas used for the generation of electricity.

Keywords: Life Cycle Impact Assessment (LCIA). Potable water. River Class. River Pollution. Ecoindicator 99. Aluminium Sulphate (Alum). Polyaluminium chloride (PAC).

1. Background, Aim, and Scope:

Rapid development has created a gap for controlling river pollution in areas with high density population to a point that rivers are open sewage dump. The decline of river quality has been rampant since the start of Industrial Revolution in 18th century. River pollution has been identified to be caused by erosion, siltation and contamination. The decreasing river quality has been identified to be caused by human attitude that takes rivers as a convenient way to get rid of garbage and leftovers. Water pollution also affects water supply, human health and also killing aquatic life.

Water quality in Malaysian rivers is increasingly threatened by pollution. In general, rivers in this country are categorized in five classes (Department of Environment, 2005), namely:

- Class I – water supply I – practically no treatment necessary
- Class II – water supply II – conventional treatment required
- Class III – water supply III – extensive treatment before suitable before drinking
- Class IV – can only be used for irrigation
- Class V – extremely polluted and cannot be used for any purposes

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The calculation of water quality index involves six parameters; pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), ammonia-nitrogen (NH_3-N) and Total Suspended Solid (TSS) (see Table 1). Current scenario in Malaysia shows the number of rivers in Class I and Class II categories are diminishing and Class IV and Class V categories are increasing (see table 2). This is expected, in-line with rapid development experienced by the country apart from generally lack of awareness among community in the effort of conservation and restoration of the environment.

Table. 1: Classification of water quality (Department of Enviroment, 1999)

Parameter		River Classification				
	unit	I	II	III	IV	V
pH		6.5-8.5	6-9	5-9	5-9	-
DO	mg/L	7	5-7	3-5	<3	<1
BOD	mg/L	1	3	6	12	>12
COD	mg/L	10	25	50	100	>100
TSS	mg/L	25	50	150	300	300
Ammonia	mg/L N	0.1	0.3	0.9	2.7	>2.7

The Environmental report circa 1997 and the Department of Environment has shown that the number of rivers categorized as clean has reduced as much as 43% from 1996 to 1997. In the same period, the number of polluted river has increased to almost double from 13 to 25 rivers in 1997. In 1999, monitoring effort on the 900 station involving 120 rivers has shown that the number of rivers starting to get polluted and getting more polluted are on the rise.

Table. 2: Quality for chosen rivers in Malaysia (1995 and 1999) (Rahman, 2007)

Category	1995		1999	
	No	%	No	%
Very polluted	14	12.2	13	10.8
Polluted	53	46.1	75	62.5
Clean	48	41.7	32	26.7
Numbers of rivers monitored	115	100.0	120	100.0

The national budget in 8th and 9th Malaysian Plan is also showing an increased budget for cleaning and beautification project on rivers from USD70 million in 8th Malaysian Plan (Economic Planning Unit, 2001) increasing one fold to USD140 million in 9th Malaysian Plan (Malaysia Plan is a five years economic development plan implemented by the government of Malaysia)(Economic Planning Unit, 2006). These numbers depicts to us how critical the river pollution issues in this country and that prompt action should be taken to save the rivers. This situation might get much more serious and the cost could sky-rocketed to billions of dollar if action is not taken immediately.

As we all know, rivers are one of the sources for raw water to produce drinking water. Contaminated water resource would need a more intensive treatment to ensure water is safe for drinking and is at the required standard. Chemicals used would also increase in treating contaminated water. Realizing this fact, an environmental impact comparison between the different chemical usage during water treatment using life cycle assessment (LCA) to depict the impact that is happening in the different river classes is conducted. River pollution issue does not only focuses on the supply cut-off to consumers, affecting human health or threatening aquatic life, but it is a more widespread and long term issues including damage to environmental quality, human health and natural resources.

By using LCA method, weaknesses in a product or service could be identified and corrective measures could be taken to improve it. Weaknesses can only be identified from its assessed or analyzed "life". Each product has its "life" where it starts from product design followed by resource extraction, production (production of materials, as well as manufacturing/provision of the product), use/consumption, and finally end-of-life activities (collection/sorting, reuse, recycling, waste disposal)(Rebitzer et al., 2004). To date there are several LCA studies conducted on water treatment process (Barios, Siebel, Helm, Bosklopper, & Gijzen, 2008; Friedrich, 2001; Landu, 2005; Lundie, Peters, & Beavis, 2004; Raluy, Serra, & Uche, 2005; Raluy, Serra, Uche, & Valero, 2005; Vince, Aoustin, Bréant, & Marechal, 2008) but do not compare the impact produced from the various river classes.

This study is mainly to compare the environmental impacts that exist in the range of three classes of water sources for the production of potable water. The chemical and electrical contents are differing and they are depended on the water quality factor. However, the water quality is not the main cause of the impact directly but the imaginary impact is originated from the release of waste that generated by the life cycle of potable water production.

2. Methodology of LCA:

This study is using the procedure suggested by the International Organization of Standardization (ISO) under environmental management namely ISO 14040 series. There are four main phases in the suggested 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)

2.1. 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.

2.1.1. 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 of the source water resulted from anthropogenic activities. 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 chemical substances and energy flows of the potable water production system from the natural environment back to the natural environment over the product's whole life.

2.1.2. Functional Unit:

The functional unit is the performance of a product system for use as a reference unit in a life cycle assessment study (ISO14000, 2000). Functional unit for this study is the production of $1m^3$ of treated water that fits the standard quality set by Ministry of Health, Malaysia.

2.1.3. 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 go through several phases before drinking water that fits the set standard is produced. Raw water extracted from rivers will go through the following processes in the water treatment plant (Sastry, 1996):

- 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.
- Settling, Aggregated flocs settle on the base of the settler. The accumulation of floc settlement is called settling sludge.
- Filtration, part of the suspended matter that did not settle goes through filtration. Water passing through filtration consisting of sand layers and activated carbon or anthracite coal.
- Disinfection process is needed to eliminate the pathogen organisms that remain after filtration. Among the chemicals used for the disinfection are chlorine, chloramines, chlorine dioxide, ozone, and UV radiation.

Figure 1 shows the system boundary of the study.

2.2. Life Cycle Inventory (LCI):

The inventory of the studied LCA system includes information on the input and output (environmental exchanges) for all the processes within the boundaries of the product system. The 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 (Guinée, 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: (see table 3)

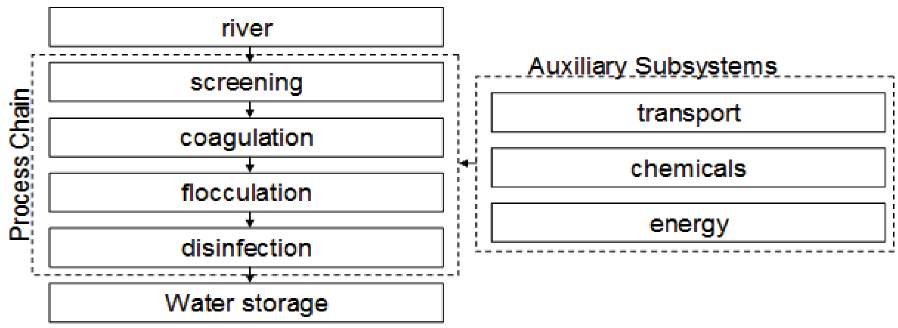

Fig. 1: System boundaries and process under study

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

Filtration material (activated carbon and anthracite) and coagulant (ferrochloride) are not included in this study because all the water treatment plants in Malaysia are not using all these materials.

Foreground data mentioned above was compiled from two separate treatment plants. The treatment plants provide data for three types of river quality:

- Raw water source at Class I, (average chemical and electricity usage is used to represent one day operation for Class I river),
- Raw water source at Class II (average chemical and electricity usage is used to represent one day operation for Class II), and
- Raw water source at Class III (data on certain dates that experience sudden quality increase from Class II to Class III. Records was checked and validated as correct by the water treatment plant operator)

Note:

Data from river Class II and III are taken from the same water treatment plant. The river was classified as Class III due to pollution incident for a period of time.

Table. 3: Foreground data for chemical substances and electrical consumption to produce 1m^3 treated water

	River Class I	River Class II	River Class III
Electrical consumption (Kw/H)	21.35	397.28	381.46
Aluminium sulphate (kg)	2.46	22.55	21.65
Polyaluminium chloride (PAC) (kg)	-	16.85	24.90
Chlorine (kg)	3.39	3.65	9.42
Calcium hydroxide (kg)	4.66	11.12	7.15

2.3. Life Cycle Impact Assessment (LCIA):

The purpose of the life cycle impact assessment is to convert the LCI into its potential impacts on the areas of protection (i.e. the entities that the use of the LCA shall help protect): Human Health, Ecosystem Quality, and Natural Resources (Goedkoop & Spriensma, 2001). The impacts on these areas of protection are quantified by Eco-indicator 99 using the units as shown in table 4.

Generally there are 3 steps in LCIA:

1.3.1 Classification and Characterization
1.3.2 Normalization, and
1.3.3 Weighting

Table. 4: Damage Assessment and Impact According to Eco-Indicator 99 (Goedkoop & 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)

2.3.1. 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 & Gallardo, 2006). Grouping to impact categories is according to their ability to contribute to different environmental problems. While characterization is 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.

To compare the three situations (river Class I, Class II and Class III), outputs (waste and emissions) from life cycle of potable water production system were classified and characterized according to Eco-Indicator 99. Figure 2 shows characterization of waste and emissions from the potable water production system.

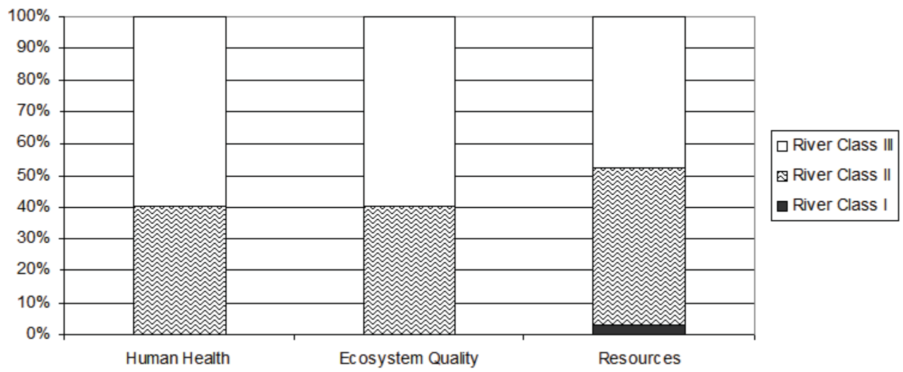

Fig. 2: Characterization According to 3 Protection Areas

Damage to human health is significantly contributed from Class III river at about 60% (0.032 DALY) while Class II river contributes about 40% (0.022 DALY). A more significant damage to human health is contributed by impact categories of respiratory inorganic, respiratory inorganics and ozone depletion in Class III rivers compared to Class II rivers. However the difference is not significant which is about 35% (respiratory organics (18% difference), respiratory inorganics (34% difference) and ozone depletion (17% difference) (see table 4). However, Class II rivers contributed high in impacts such as carcinogen (only about 2% difference compared to Class III rivers), climate change (difference about 6% compared to Class II rivers) and radiation (37% difference compared to Class II rivers). Unlike river Class II and III, analysis of damage to human health shows that Class I river does not contribute any impact to this category. The result of the analysis conducted shows that chemicals contributing to damage to human health category are from the inorganic respiratory impact category. This is possible due to the release of nitrogen oxides and sulphur oxides gases from the production of coagulant product, polyaluminium chloride (PAC).

Table. 5: Characterization to Impact Category for Different River Classification

Impact category	Unit	River Class I	River Class II	River Class III
Carcinogens	DALY	6.78E-07	6.4E-06	6.36E-06
Resp. organics	DALY	2.3E-08	1.01E-07	1.25E-07
Resp. inorganics	DALY	1.21E-05	0.02182	0.032208
Climate change	DALY	5.72E-06	7.2E-05	7E-05
Radiation	DALY	4.9E-09	1.17E-08	7.52E-09
Ozone layer	DALY	1.28E-09	4.2E-09	4.99E-09
Ecotoxicity	PAF*m^2yr	1.552198	18.51406	18.13526
Acidification/Eutrophication	PDF*m^2yr	0.453933	1028.461	1517.911
Land use	PDF*m^2yr	0.015236	0.036363	0.023385
Minerals	MJ surplus	0.003472	0.008192	0.0054
Fossil fuels	MJ surplus	33.44558	521.4128	505.7706

Turning to the ecosystem quality damage analysis, it has shown that Class III rivers contributes higher than Class II rivers with the difference of 35%.. Class III rivers contributes the highest in acidification/eutrophication impact category at 1.52E3 PDF*m^2yr and 1.03E3 PDF*m^2yr for Class II (35% difference). Meanwhile Class

II rivers contributed higher in ecotoxicity impact category (3% difference compared to Class III rivers) and land use (36% difference compared to Class III). Damage to ecosystem quality is contributed by major substances such as nitrogen oxides (over 80%) and sulphur oxides (about 20%) produced during PAC production. Nickel (over 80%) and land use category II-III, II-IV and III-IV on the other hand is produced during electricity generation using natural gas.

Analysis of damage to natural resources depletion concludes that Class II rivers contributes higher that Class III rivers. Contributing factor to this damage is electricity generation using fossil fuel namely natural gas. Reduction of electricity usage in Class III rivers were identified to be caused by the shutdown of several pumps to reduce contaminated water intake to the treatment plant. This situation causes a sudden reduction in electricity usage. But there are no significant difference between Class II and Class III rivers having difference of about 4%. However, Class I rivers contribute only 5% compared to Class II and Class III rivers.

Although rivers in Class II and Class III are seen to be contributor to damage categories, damages are actually from the waste and emissions from the life cycle of potable water production system which the raw water extracted from different river quality.

2.3.2. 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 followings the result of the normalization analysis for the impact category obtained.

Table. 6: Normalisation to Impact Category for Different River Classification

Impact category	River Class I	River Class II	River Class III
Carcinogens	4.41E-05	0.000417	0.000414
Resp. organics	1.5E-06	6.6E-06	8.13E-06
Resp. inorganics	0.000791	1.420503	2.096752
Climate change	0.000373	0.004689	0.004556
Radiation	3.19E-07	7.61E-07	4.9E-07
Ozone layer	8.36E-08	2.73E-07	3.25E-07
Ecotoxicity	3.03E-05	0.000361	0.000354
Acidification/Eutrophication	8.85E-05	0.20055	0.295993
Land use	2.97E-06	7.09E-06	4.56E-06
Minerals	4.13E-07	9.75E-07	6.43E-07
Fossil fuels	0.00398	0.062048	0.060187

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 Class III rivers are given the highest value at 2.1 points where else Class II rivers at 1.42 points. In the damage to environmental quality category, Class III river contributed 0.3 points while Class II rivers contributed 0.2 points. The impact category that contributed this damage is acidification/eutrophication. The value for Class III rivers is still high compared to Class II rivers with a difference of 0.095 points (at 0.296 and 0.201 points respectively).

2.3.3. 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 (Pennington et al., 2004; Soares, Toffoletto, & Deschenes, 2006). 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.

The weighting analysis shows that damage to human health quality category given first place in ranking. This is followed by damage to environmental quality and natural resources depletion category. Impact category that contributes to human health damage is respiratory inorganic. The value for Class III rivers is the highest with the difference between of Class III compared with Class II at 203 points (626 points and 426 points respectively). Acidification/eutrophication impact category (in damage to environmental quality) is placed second in ranking

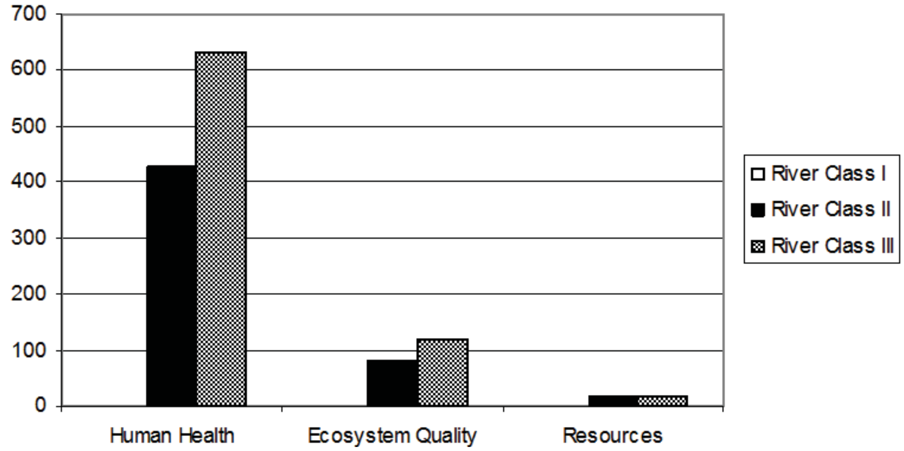

Fig. 3: Weighting in Damage Assessment for 3 Different River Classification

where the values of Class III and II rivers are both below 120 points (118 points and 80.2 points respectively). Both impact categories contributed from the release of main chemical substances of nitrogen oxides and sulphur oxides from PAC production. However third place ranking with value of about 19 points (18.6 points for Class III and 18.1 points for Class II) falls to the damage to natural resources depletion impact. The main natural resource that has high potential of depletion is natural gas. Natural gas is the substance used in generating electricity used for water treatment process. Only three impact categories are seen as significant while other categories are not given much attention as the value contributed is below 1 point.

2.4. 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 (like economic and social aspects) (Hauschild, Jeswiet, & Alting, 2005).

2.4.1. Improvement Assessment:

From the analysis done, there are two weaknesses detected:

- Production of PAC: Contributed to the damage to human health quality and damage to ecosystem quality. The process in producing this chemical releases two other toxic chemicals; nitrogen oxides and sulphur oxides.
- 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 (Ivanov, Ivanova, Kondrat'ev, & Polinkovskii, 1991; Peña, Medina, Anaya-Lara, & McDonald, 2009). 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

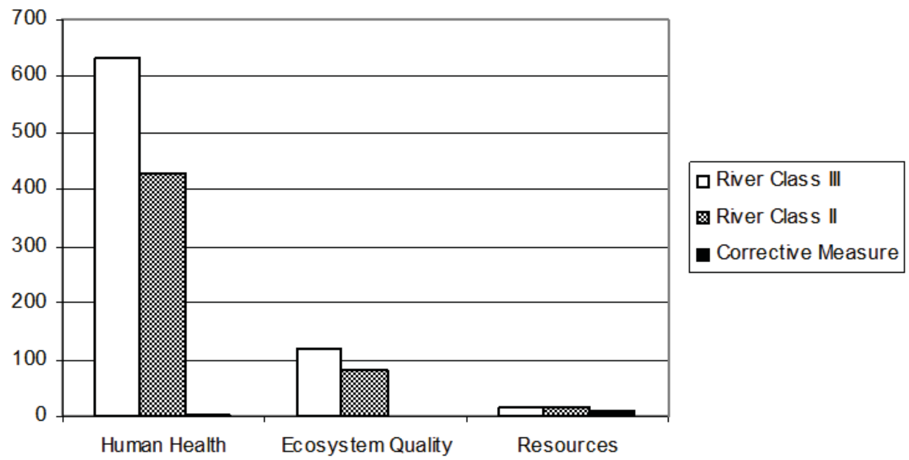

Fig. 4: Weighting analysis with corrective measure to overcome damage to human health, damage to ecosystem quality and damage to resources

From the analysis conducted, damage to the human health quality can be drastically reduced by solely using Alum. The 631 points and 428 points value for both Class III and II rivers respectively is reduced to only 2.65 points. The damage to human health quality is reduced significantly more than 80%. However in the damage to ecosystem quality, the replacement using Alum is seen as a good alternative as the value is reduced to less than 0.5 points from its original value of 119 points for Class III rivers and 80.4 points for Class II rivers.

However the use of hybrid electric only brought a reduction of about 40% of the original value; 18.1 points and 18.6 points (Class III and Class II respectively) to a mere 10.3 points.

3. Conclusion:

The goal of this study is to obtain different impact scenario happens in the life cycle of water treatment process for three different river classes; Class I, II and III. Overall, Class I rivers give the minimum impact while Class III rivers gives impact to damage to ecosystem and human health quality. However the difference in both these impacts is not significant. This situation happens when the change from Class II to Class III has increase the quantity of chemicals used. The chemical that was identified to contribute to these damages are PAC. The production of this chemical releases two dangerous 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 harnessed to generate electric. Hybrid electric could reduce the complete dependence on fossil fuel natural gas in water treatment plant.

The advantage of LCA method is proven to give a clear picture of damages from 3 areas namely damage to ecosystem quality, damage to human health and damage to resources. Without LCA analysis such as the one conducted in this study, we can only evaluate the river quality based on several parameters set such as the physical and chemical quality of water. In line with the increasing number of polluted rivers, impact to damage to ecosystem, damage to human health quality and damage to natural resources depletion is also increasing. The development of rapid growth must go hand in hand with better awareness on conservation of rivers. The importance of river conservation not only capable of reducing all three mentioned damages but also produces quality drinking water that fits the set standard.

The study is to know the relationship of water pollution in river that will become the potable drinking water to the damage that will be undergone by environment. The environmental damages that were mentioned before are the indirect impacts and not directly affected from the water pollution but, the main cause from life cycle of potable water production system that utilize chemical quantity and electrical power higher than clean river.

4. Future Outlook:

Even though the replacement of PAC with the more ecosystems friendly Alum could reduce the damage to ecosystem quality and human health quality, the weakness of Alum use is 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 40 -50%. However, if this effort is put into action, it would at least reduce the use of fossil fuel natural gas.

Apart from the 11 listed impacts, we must add another impact that can be considered as essential that is water resource depletion. It was because; the environment performance and condition will be critical and more degraded when there is a lot of water pollution in the addition of the lack of water resources. In addition, there are some of water treatment plants in Malaysia which are still disposed sludge directly into the river and therefore in LCA study, sludge also needs to include and categorized as a waste to be considered as one of the impacts to the environment.

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