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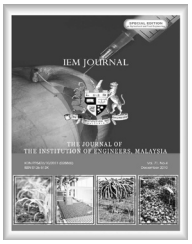
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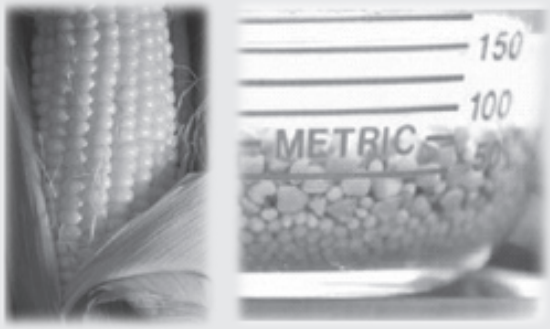
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PREFACE FOR THE SPECIAL EDITION ON AGRICULTURAL AND FOOD ENGINEERING

The Agricultural and Food Engineering Technical Division (AFETD) has decided to champion an issue to address the importance and sustainability of agricultural and food sectors for Malaysian economy in this Special Editions of IEM Journal. A call for papers for this special edition was announced in January 2010 and dateline for manuscript submission was in April 2010. A total of 10 manuscripts were received and finally 7 manuscripts were selected for publication after a peer-evaluation process.

SUMMARY OF PAPERS

The subjects of these papers are on researches conducted in the main agricultural and food sector in Malaysia. There are three papers on paddy and they are closely related to water and irrigation. All the papers on paddy are case studies, one concerning the determination of water requirement in a paddy field in Seberang Perai, one is on the Seberang Perai irrigation water quality and the third is on the nitrate-nitrogen concentration variation in ground water flow of a paddy field in Kota Bahru. The paper on oil palm is on utilisation of palm oil mill by-products into compost through the production of non-shredded empty fruit bunch semi-compost. The fifth paper is a case study on runoff quality index for area under maize cultivation. There is a paper on impact of commercial enzymes on pitaya fruit juice and the last paper is on fouling deposits and cleaning studies of pink guava pasteurisation process.



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As guest editors by invitation, we would like to express our gratitude to the IEM Standing Committee on Information and Publications and the Agricultural and Food Engineering Technical Division for their support in making this special edition possible. Assistance given by the publication Secretariat, Puan Nurul Aida Mustafa and AFETD Secretariat, Encik Ahmad Tarmizi Abu Ariffin is deeply appreciated. We would also like to express thanks to the following reviewers for willingness to provide good reviews and comments.

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NITRATE-NITROGEN CONCENTRATION VARIATION IN GROUNDWATER FLOW IN A PADDY FIELD

(Date received: 1.12.2009/ Date approved: 20.8.2010)

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ABSTRACT

This study was carried out to evaluate the influence of groundwater on nitrate-nitrogen concentration in a paddy field. Fertiliser if applied excessively can cause leaching into the soil and will penetrate deep into the soil and eventually contaminate the groundwater. Nitrates in groundwater is soluble hazardous to users. This work was carried out at Ladang Merdeka Ismail Mulong, Kota Bharu, Kelantan to determine groundwater and nitrate-nitrogen flow using ArcGIS in a Geographical Information System (GIS) environment to produce groundwater level and nitrate concentration variation maps. All data were obtained from field measurements. The results showed that the average nitrate level was 4.81 mg/l with a maximum value of 17.16 mg/l. The groundwater levels in this area ranged from 3.75 to 6.52 meters above mean sea level with an average of 5.65 meters. Three dimensional images of ground surface and groundwater levels variation were also produced to study the relationship between groundwater and nitrate movement. From the analysis, it can be deduced that the groundwater and nitrate generally flows from the South-West to the North-East direction following the ground surface gradient.

Keywords: *GIS, Groundwater, Nitrate-nitrogen, Paddy Field*

1.0 INTRODUCTION

Many regions around the world are dependent on groundwater resources for their various uses especially in rural areas. Major threats to groundwater quality are from point sources and non-point sources. These could be due to urbanisation (septic tanks, sewer and detergent), industrial wastewaters and agricultural activities (fertilisers and pesticides). Contamination of groundwater can result in poor drinking water quality. Many studies have reported growing incidences of nitrate pollution and increase of nitrate concentration in groundwater in intensive farming areas. The main source of nitrate contamination is nitrogen rich fertilisers [1], [2], [3].

In Kelantan, Malaysia, groundwater plays a very important role in the public water supply system. About 70% of the total water supply in the state is derived from groundwater [4]. The shallow aquifer system in the Kelantan river delta constitutes an important source of water not only for public water supply, but also for domestic and agricultural purposes [4]. Being shallow and relatively unprotected, the aquifer is generally exposed to higher risk of contamination due to anthropogenic activities at the surface.

In a study conducted by Abdul Rashid [5], the result showed that 35 percent of the areas around the Kelantan River Valley included Kota Bharu, Bachok, Tumpat and Pasir Mas district have nitrate levels exceeding the threshold value, 10 mg/L while 2 percent exceeds 45mg/L or the permissible World Health Organisation (WHO) value. Generally, groundwater with elevated nitrate content appears to be related to areas with cultivation [5].

The large transmissivity value of about 2,000 to 24,000 m^2/day and permeability value of about 700 to 2,200 m/day can easily cause the surface pollutants to infiltrate into the shallow aquifers through precipitation, infiltration, stream infiltration or waste drainage system at the surface or from the water supply leakage [4]. In Kelantan, the climate changes are obvious and produce significant impacts on groundwater levels which also contribute towards the contamination of groundwater in the shallow aquifers [4].

Apart from the climatic changes, pumping activities for supplying groundwater can also contribute to the movement of groundwater. In a populated area where the demand for groundwater is high, extensive pumping will cause the water level to decline lower than the surrounding area. The differences in the water table will eventually cause the movement of groundwater. The groundwater movement would contribute to the variation of the contaminant. A study in France showed that changes in the physical-chemical groundwater quality occurred at an hour-scale in deep sediments due to flooding and pumping [6].

Nitrate, being one of the major contaminants in groundwater may be hazardous when it is consumed excessively. Studies have shown that high nitrate levels are associated with diseases such as methemoglobinemia, gastric cancer, non-Hodgkin's lymphoma and diarrhea [7-9].

In this study, satellite images and groundwater data from a paddy field at Ladang Merdeka Ismail Mulong, Kelantan were assembled in a GIS environment to achieve three main objectives as follows:

(i) to evaluate the groundwater level variation
(ii) to determine the general groundwater flow and
(iii) to evaluate the concentration and the variation of nitrates in groundwater.

2.0 MATERIALS AND METHODS

2.1 The Study Area

Kota Bharu is a district in Kelantan, consisting of a total area of about 14,922 square kilometers. It is the state's administration and commercial centre. Kelantan's climate is tropical monsoon, with stable temperatures ranging from 21°C to 32°C. Dry and warm weather with consistently high humidity on the lowlands ranging from 82% to 86% are seen through January to April. It has an average yearly rainfall of 2,540 mm, with the wettest months being from November through January

The study site is known as the Ladang Merdeka Ismail Mulong. It is situated in Kampung Mulong Lating, Kota Bharu. The approximate longitude and latitude of the study area is 668000N to 671000N and 472000E to 473000E. Ladang Merdeka Ismail Mulong is currently the largest in the Kemubu Agricultural Development Authority (KADA) area. It is a result of a systematic management of paddy fields introduced by KADA by combining smaller paddy lots into one large and uniformly distributed paddy field.

2.2 Field Measurements

All the data required were obtained from field measurements. The field measurements include sampling, analyzing, leveling, and GPS readings. Geographic locations or the coordinates of the wells were obtained using E-Trex Garmin hand-held Global Positioning System (GPS). The GPS uses the World Geodetic System of 1984 (WGS 84) reference system which provided the coordinates of the wells in the form of degrees, minutes and seconds (d.m.s). These d.m.s coordinates were converted into meters East and North because the image provided by Malaysian Centre for Remote Sensing (MACRES) uses the RSO coordinate system. This conversion was done using the GPS Pathfinder software which automatically calculate and convert the d.m.s coordinates into meters East and North.

Leveling was carried out to obtain the surface level of the study area above mean sea level (a.m.s.l). The leveling process includes all the monitoring wells and also the production wells. The measurements of the surface levels of monitoring wells in the paddy fields were taken from inside of the paddy plots and for the production wells, measurements were taken from the ground surface.

Groundwater levels in the wells were obtained by using the combination procedures of leveling and water level measurement from the ground surface with a water level indicator. The water samples were analysed within 48 hours for nitrate-nitrogen using a spectrophotometer (DR 2500, Hach Co.) after reduction with cadmium [10].

2.3 GIS Data and Analysis

The raster image obtained from MACRES was a multispectral image with resolution of 10 meters taken with Spot 5 satellite. The raster image was used as the base map in GIS analysis using ArcGIS. The image was already georeferenced with Rectified Skew Orthomorphic (RSO) coordinate system. RSO is a local plane projection system frequently used in Malaysia because it provides the geographic location in the form of meters of Easting and Northing. Since the map has been georeferenced, it was digitized on-screen to create point, segment, and polygon maps of the different geographical entities. The locations of the monitoring wells were digitised as points and linked to an attribute table, including all the water levels and chemical data (nitrate-nitrogen levels). The entities that were digitised include the paddy field, main canal, sub canals and the nearest populated site around the paddy field. To investigate the spatial extent of groundwater level and nitrate concentration level, a groundwater variation map and a nitrate concentration map were constructed from the point data using Kriging interpolation [3].

In Kriging, a weighted averaging on point values were performed where the output estimates equal the sum of product of point values and weights divided by the sum of weights [3]. The weight factors in Kriging were determined by using a user-defined semi-variogram model based on the output of a spatial correlation operation and the distribution of inputs points [3]. These values that are needed to perform the Kriging analysis can be obtained by using the GS+ software. The output raster map that was obtained from the Kriging analysis showed the estimation of groundwater levels and nitrate concentration in the study area. From these maps, the groundwater flow behavior can be determined.

Three dimensional images analysis of ground surface level variation and groundwater level variation were compared to investigate the relationship between groundwater and nitrate-nitrogen movement.

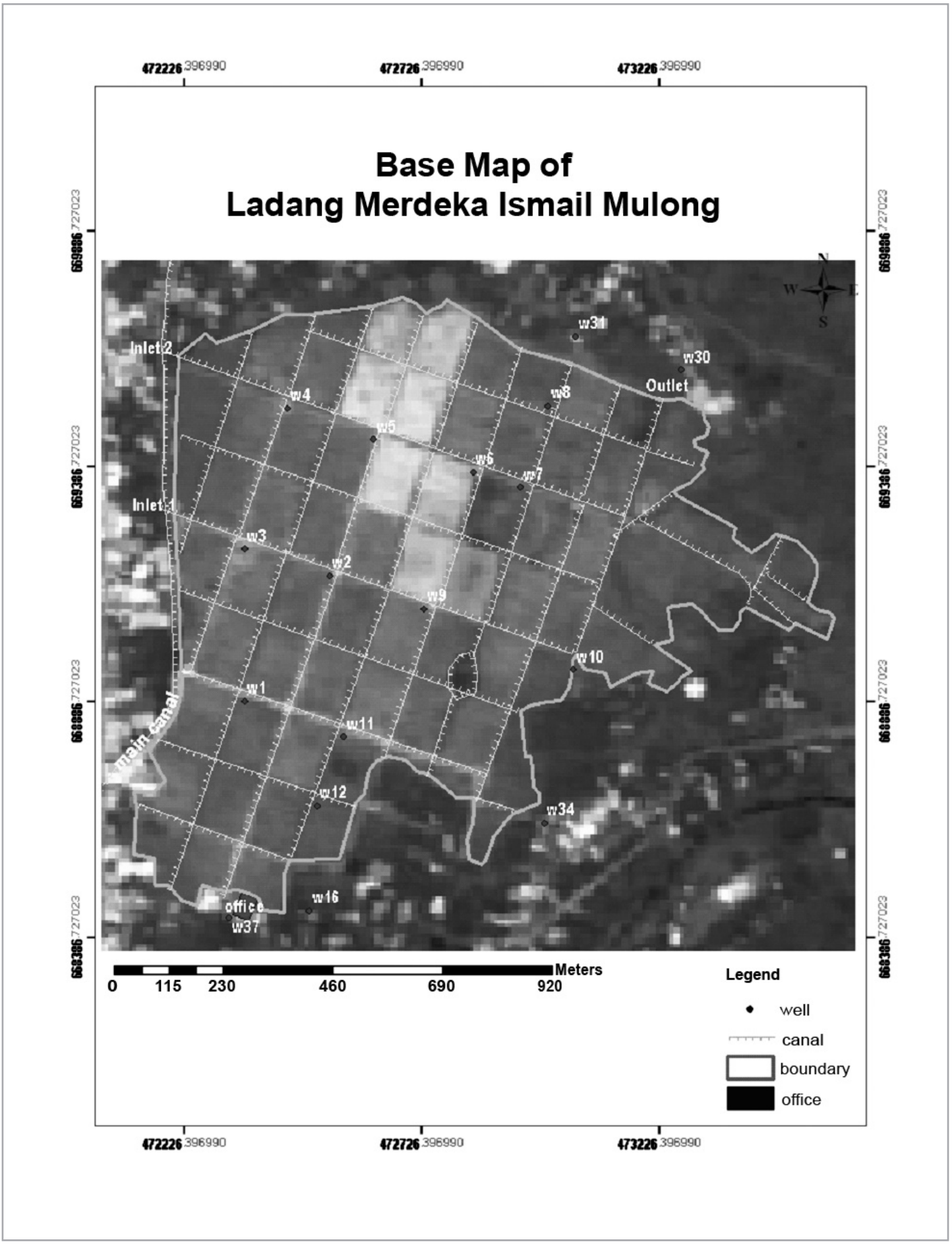


Figure 1: Base Map of Ladang Merdeka Ismail Mulong

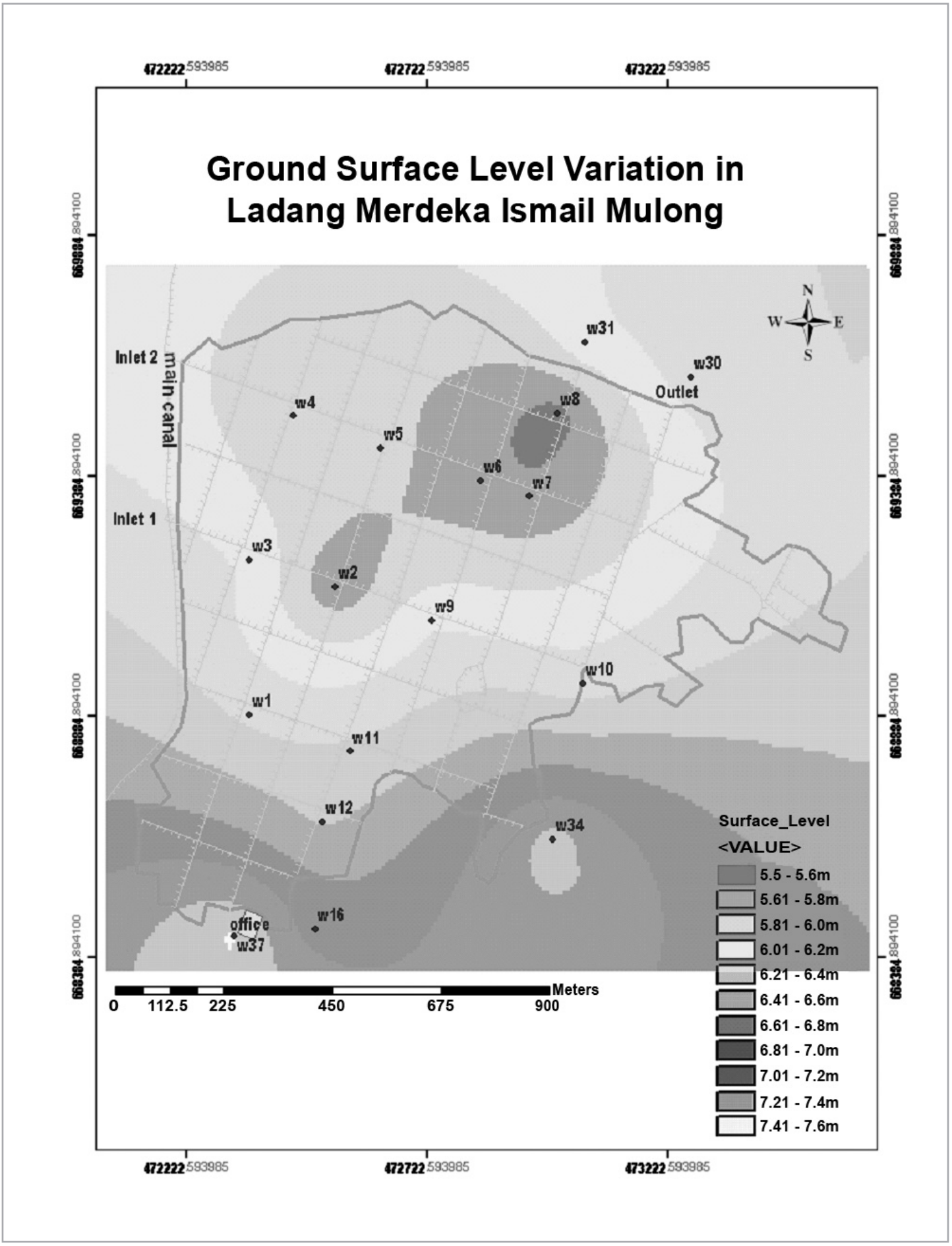


Figure 2: Ground Surface Level Variation in Ladang Merdeka Ismail Mulong

3.0 RESULTS AND DISCUSSION

3.1 Base Map of Ladang Merdeka Ismail Mulong

The base map in Figure 1 shows the location of the monitoring wells, the paddy field boundary, the field's office and also the main canal and sub canals of the study area. There were a total of twelve monitoring wells in the paddy field and four production wells in the population area around the paddy field. The four production wells represented two villages around the paddy field. W37 and W34 in the South East represent Kampung Lanting and W30 and W31 in the North-East represents Kampung Tunjung Dalam. The map also indicates the inlets and outlet of the surface water. There are two inlets from the main canal into the paddy field and an outlet from the paddy field. The flow of the surface water in the paddy field is from the North-West to the North-East direction.

3.2 Ground Surface Level Variation in Ladang Merdeka Ismail Mulong

From the ground surface level variation, it can be observed that the area around W37 in Kampung Lanting at the South East of the study area had the highest ground surface level, which was 7.41 to 7.60 meters above mean sea level (Figure 2). The ground surface levels decreases in the North -East direction and towards the confines of the paddy field. The lowest value of 5.50 to 5.60 meters above mean sea level was observed around W8 in the paddy field. The areas outside the paddy field have a higher ground surface level compared to the area inside the paddy field. This could be explained because the measurement of the surface level in the paddy field was referenced from within the paddy plot.

Figure 3 represents the three dimensional image of ground surface level variation with the brighter areas indicative a higher surface level while the darker areas are the lower surface levels. W37 and W34 in Kampung Lanting have the highest surface levels and W2 and W8 in the paddy field were areas with the lowest surface levels. W30 and W31 in Kampung Tunjung Dalam are having relatively low surface level.

3.3 Groundwater Level Variation in Ladang Merdeka Ismail Mulong

The map in Figure 4 shows the groundwater level variation in Ladang Merdeka Ismail Mulong. Areas around W37 and W16 (Kampung Lanting) are the areas with the highest groundwater level, which was 6.41 to 6.60 meters above mean sea level. The groundwater levels decrease towards the North East, similar to the ground surface levels. The groundwater flows from the paddy field to Kampung Tunjung Dalam because of the hydraulic gradient which decreases towards the village. Kampung Tunjung Dalam had the lowest groundwater level of 3.70 to 3.80 meters above mean sea level. Thus the general direction of groundwater flow was from the South- West to the North- East.

The arrows in the three dimensional image of groundwater level variation (Figure 5) shows the general direction of groundwater flow. From the image, it can be clearly seen that the groundwater decreases from W37 and W16 in Kampung Lanting towards W30 and W31 in Kampung Tunjung Dalam. The groundwater flows from Kampung Lanting through the paddy field towards Kampung Tunjung Dalam.

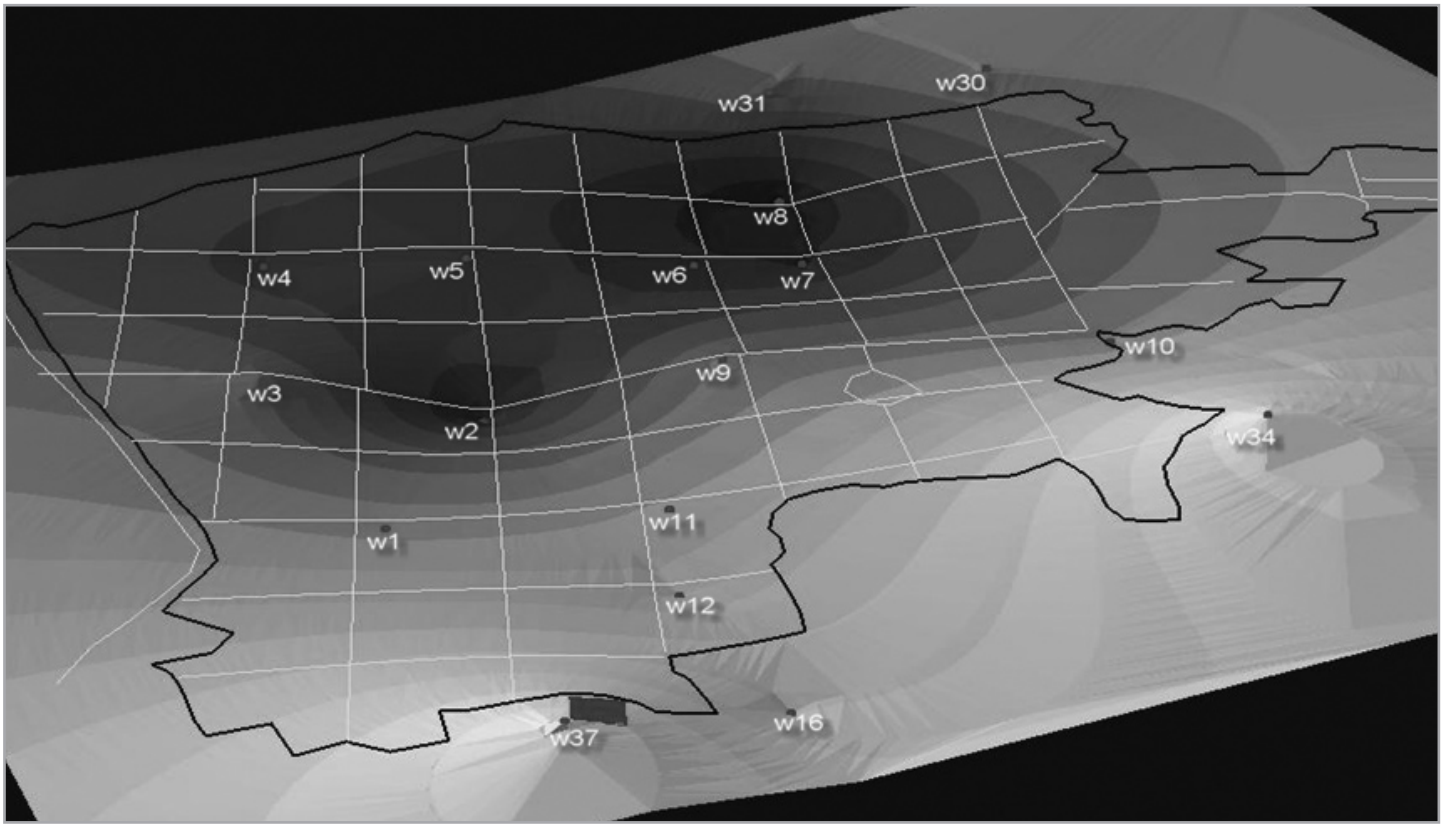


Figure 3: 3D Image of Ground Surface Level Variation

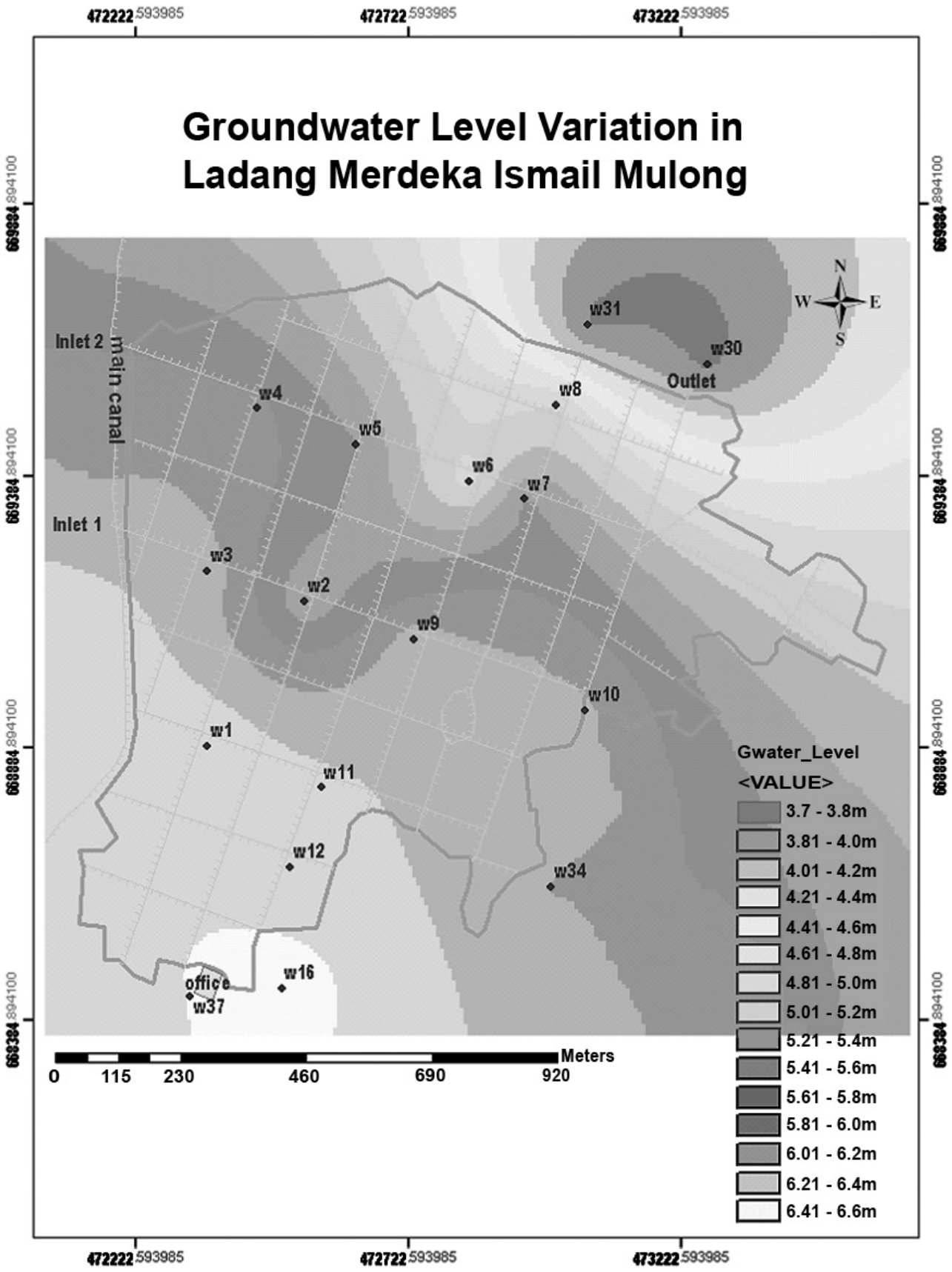


Figure 4: Groundwater Level Variation in Ladang Merdeka Ismail Mulong

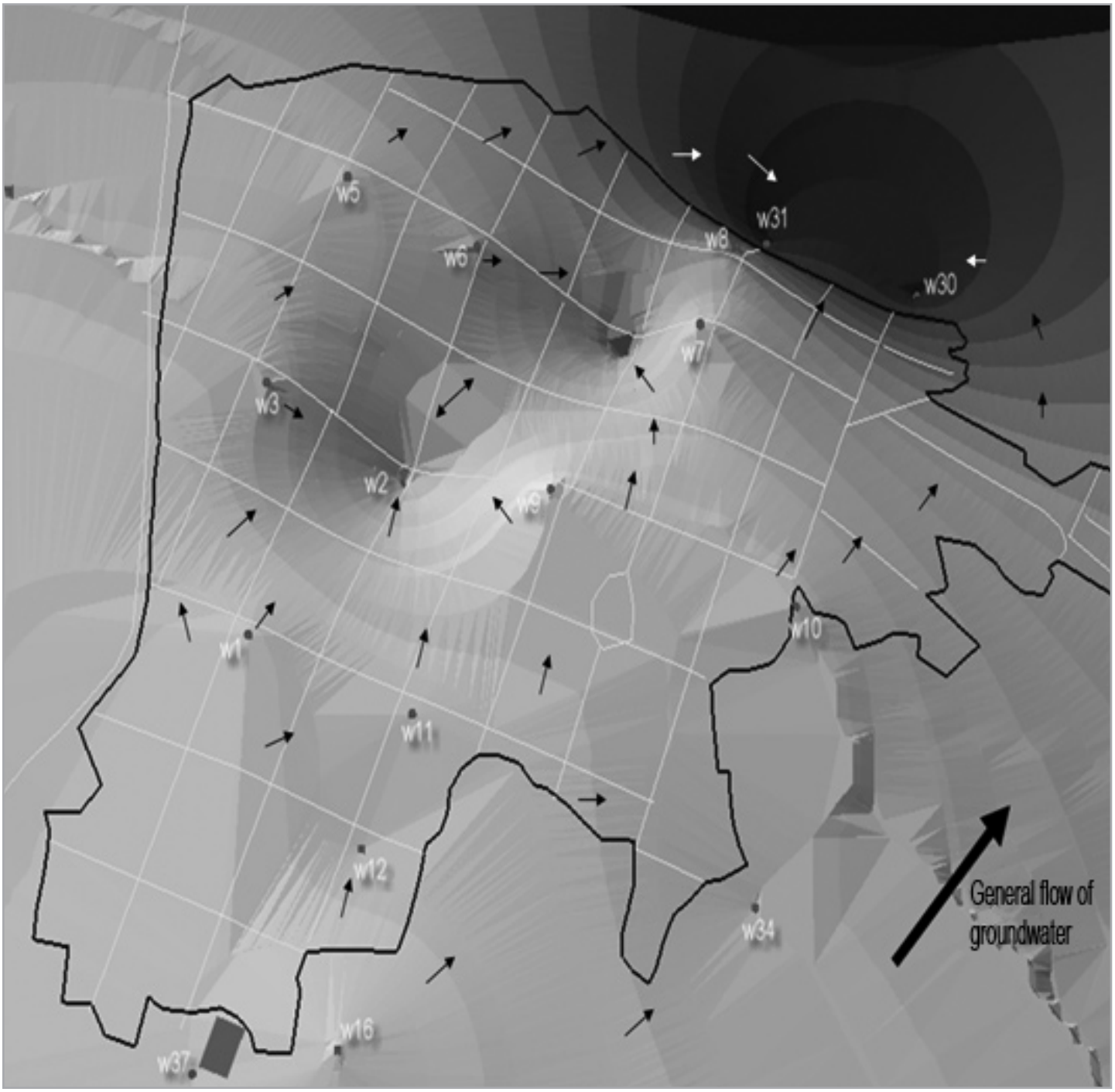


Figure 5: 3D Image of Groundwater Level Variation

3.4 Nitrate Level Variation in Ladang Merdeka Ismail Mulong

Examination of the pattern of nitrate concentration clearly showed that it was similar to the direction of the groundwater flow (Figure 6). Thus, since the groundwater level in Kampung Lanting is high and its movement is towards the paddy field, the nitrate level inside the paddy field turns out to be higher than in the Kampung Lanting. The highest nitrate level was around W12 with a value of 17.16 mg per liter.

The abrupt increase of nitrate concentration around W12 may indicate an introduction of nitrate from other sources. It could be associated with leakage of fertilisers stored at the KADA office located in the South East which percolates into the soil and later into the groundwater. However, the increase of nitrate concentration may also be contributed from septic tanks, sewage wastes, animal wastes and organic matters from the village in Kampung Lanting. This matter has to be further investigated.

The groundwater level in Kampung Tunjung Dalam was lower than inside the paddy field. This relates well with the areas around this village having a considerable high nitrate concentration which is 13.64mg/L. The groundwater flows from higher to lower areas carrying the contaminants which accumulate around these areas. The nitrate contamination most likely could have come from the nitrogen fertilisers applied to the rice crop.

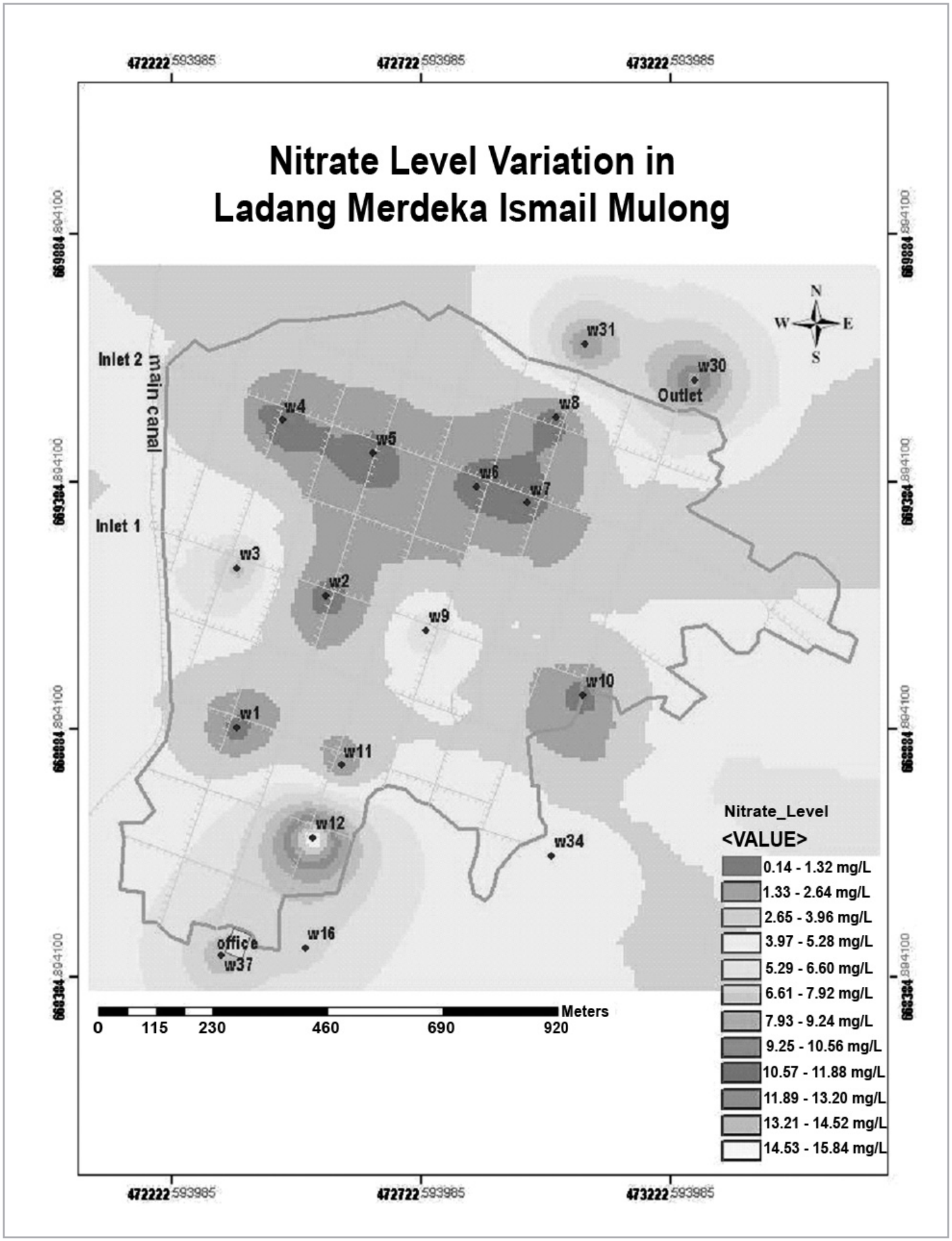


Figure 6: Nitrate Level Variation in Ladang Merdeka Ismail Mulong

In the paddy field, the nitrate levels variation was non uniform. In general, the nitrate levels in the paddy field were quite low. Time could be the factor because at the time of samplingthe nitrogen from the fertiliser has not percolated into the groundwater yet.

3.5 Correlation between Groundwater and Nitrate Flow

The nitrate level variation showed a similar pattern to the direction of groundwater flow which was from the South-West to the North-East. However, this observation does not apply to the inside of the paddy field because the nitrate concentration variation was not uniform.

4.0 CONCLUSION

The variation of groundwater level and the nitrate concentration in groundwater was successfully shown through the maps produced by using ArcGIS and Kriging interpolation. The flow of groundwater and nitrate-nitrogen in groundwater were determined by analysis of these maps. The results suggested that nitrate concentration variation corresponds to the groundwater flow, that is, from higher surface level to lower surface level in the direction from the South-West to the North-East. ■

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PROFILES



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PRODUCTION OF NON SHREDDED EMPTY FRUIT BUNCH SEMI-COMPOST

(Date received: 30.7.2010/ Date approved: 19.8.2010)

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ABSTRACT

Composting of the empty fruit bunch (EFB) with the palm oil mill effluent (POME) could simultaneously treat the solid and liquid waste from palm oil mill. With the aim to reduce the composting yard area, production of ***semi-compost*** *in industrial scale windrow was studied. Total composting time including preparation of the windrow was about 40-45 days and the windrow was turned every ten days. Compost* ***quality; moisture*** *content, pH, nitrogen and other nutrients, was evaluated during six months operations, and it was found that the nutrient in compost is acceptable for soil conditioner.*

Keywords: *Compost, Empty Fruit Bunch, Palm Oil Mill Effluent, Windrow*

1.0 INTRODUCTION

Palm oil industry significantly contributes to the economic growth in Malaysia. However, the palm oil mill produces a high amount of solid and liquid waste such as the empty fruit bunch, kernel, and POME (*palm oil mill effluent*) that requires treatment and disposal [1]. Composting is regarded as sustainable technology for processing solid and liquid waste from the palm oil mill [1-2]. Composting is a controlled biological process that can accelerate the conversion of organic matter to humic substances known as compost. The compost can be applied as a soil amendment or mulching [2]. The quality of compost depends on the raw material, process system, process parameter *i.e.* carbon to nitrogen ratio (C/N), moisture, turning frequency, *etc.* [2] as well as weather/season [3].

Several studies have been conducted for the *empty fruit bunch* (EFB). Enhancement of the composting process can be achieved by adding amendment material(s) such as animal waste [4-5] and palm oil mill effluent [3]. Applying POME as amendment material can be considered advantageous because it can reduce the total flow of POME to the wastewater treatment plant.

Effective EFB composting could reduce approximately 50% of the volume and hence the transportation cost [1]. However, lengthy period for composting of EFB poses problems in the industrial scale composting due to high land area needed. It is reported that the composting system take about 50-90 days to mature depending on the raw compost mixture, system used and composting environment [3-6].

In conventional method, the purpose of shredding EFB is to increase the rate of biodegradation [3-5]. However, the shredding process is time consuming, use high electricity [4] and the important nutrient might be loss during the process. Moreover, it has been reported that the addition of POME onto the shredded EFB is troublesome because the liquid waste can easily leached from the heap [4]. The conventional process flow is shown in Figure 1.

Thus, with the aim to reduce the time of composting, the large scale production of semi-compost from non shredded EFB and fresh POME were introduced at the Merotai Composting Plant by Prestige Central Management Sdn Bhd since July 2009. Semi-compost means that the final compost would be further stabilised after being applied to the soil. Evaluation of physicochemical parameters is important to determine the effectiveness of the process. Therefore, in this study, temperature and oxygen content evolution, pH and nutrients analysis was assessed during the composting period from August 2009 to December 2009.

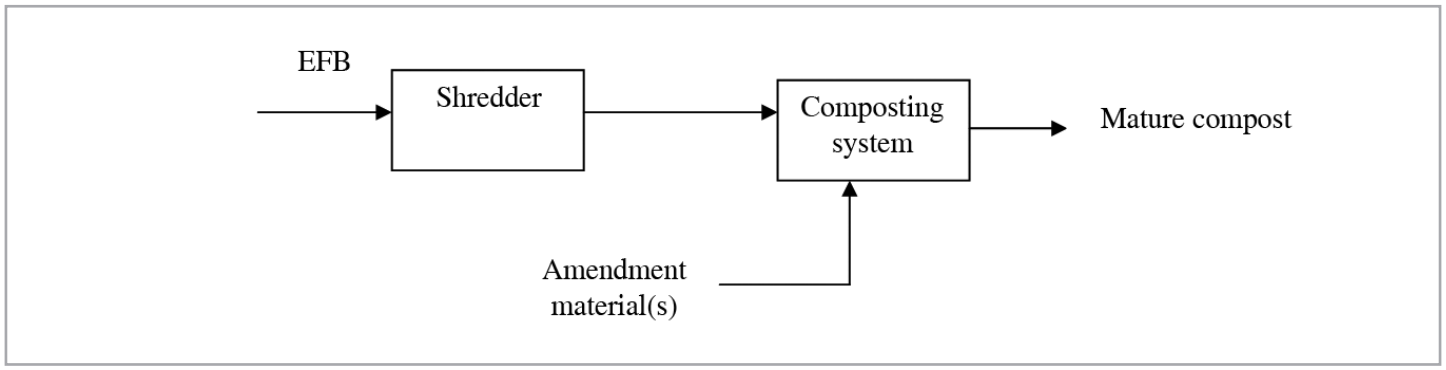


Figure 1: Conventional empty fruit bunch (EFB) composting

2.0 METHODOLOGY

2.1 Production of compost at the Merotai Composting Plant

Merotai Composting Plant is located at Tawau, Sabah, Malaysia and operating since April 2006. The plant was designed to process about 340 000 metric ton POME/year (60% from total POME) and 78 000 metric ton empty fruit bunch/ year.

The plant consists of a composting yard (4.0 hectares), palm oil mill effluent (POME) holding pond (1.8 hectares) and environmental pond (0.85 hectares). The system employed here is open turned windrow with size of 4 m length, 1.5 m height, and width 40 m. Each windrow contains about 120 metric ton of EFB and 324 metric ton POME respectively.

After the inoculation with the bacteria, the fresh EFB then was sprayed with POME (Figure 2). Then the composting



Figure 2: POME spraying into the empty fruit bunch
(Courtesy of Prestige Central Management Sdn. Bhd.)



Figure 3: Empty fruit bunch-POME compost turning using tractor with macerator
(Courtesy of Prestige Central Management Sdn. Bhd.)

Table 1: Typical nutrients analysis of EFB and POME

	Moisture, %	% on dry			
		N	P_2O_5	K_2O	MgO
EFB	58-65	1.1-1.2	0.05-2.6	2.4-2.7	0.4-0.5
POME	96	0.08	0.08	1.2	1.5

process commenced and the compost windrow was turned using the macerator to homogenise the compost as well as to enhance the aeration (Figure 3). The turning process takes place at day 10, 20, 30 and 40. Total composting process including windrow building and curing takes about 40-45 days. The compost then was applied at the palm oil plantation as soil amendment. The application rate is approximately 12 metric ton/hectares.

Sampling was taken in nine various points at each windrow and sent to the lab for analysis. Data on the composting temperature, moisture content, and nutrient analysis was generously given by the Prestige Central Management Sdn. Bhd.. Typical characteristic of empty fruit bunch (EFB) and POME are shown in the Table 1.

3.0 RESULTS AND DISCUSSIONS

Typical temperature and oxygen content were shown in Figures 4 and 5 respectively. Temperature in the windrow rose immediately (>53 ºC) during two days of composting (Figure 4) and then drop to temperature below 50 ºC. Turning process then increase the temperature back to greater than 50 ºC (~60 ºC) at day 11. Temperature approximately 50 ºC is essential to maximise biodegradation but temperature above 60 ºC has been reported to reduce the microbial activity [2]. From day 10 to day 25, the temperature was maintained at about 45 to 55 ºC with the aids of turning at the day 20. After the temperature starts to decrease, turning at day 30 again increase the temperature to ~50 ºC. However, at day 40, turning did not increase the temperature.

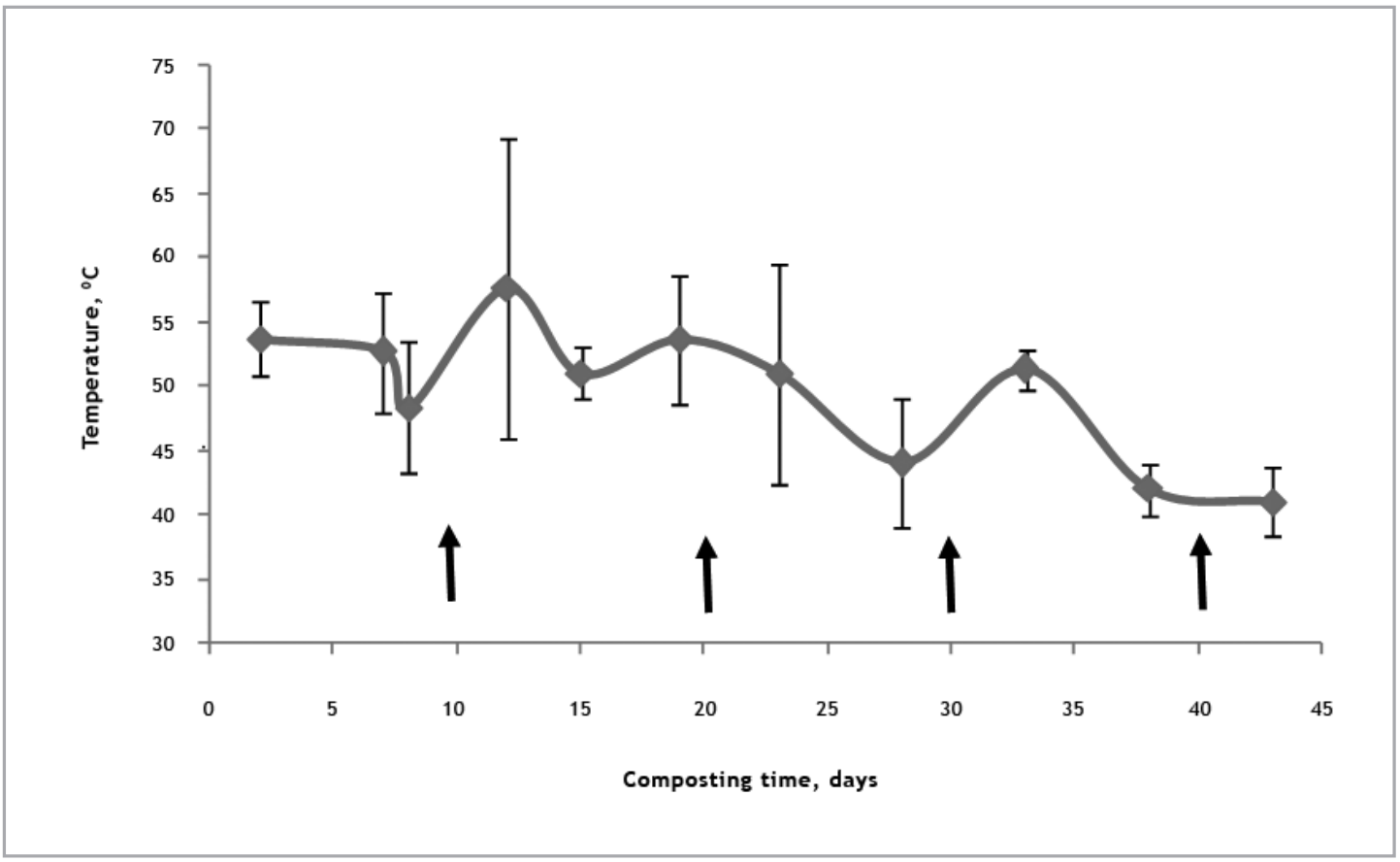


Figure 4: Typical temperature evolution for EFB-POME composting. Arrow indicates turning. Ambient temperature: 32 °C. The bars on the figure refer to standard deviation. (Average data on three windrows)

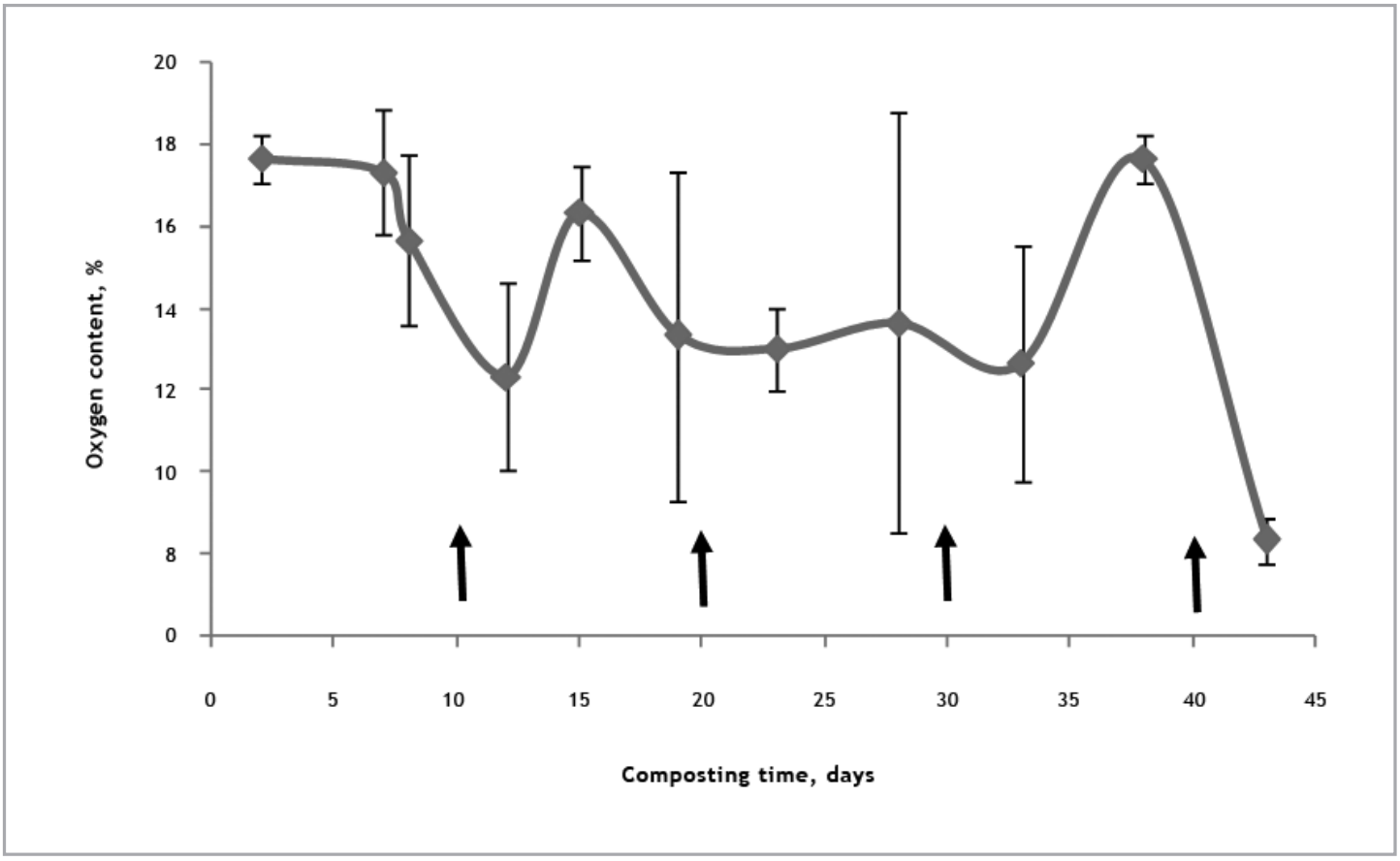


Figure 5: Typical oxygen content evolution for EFB-POME composting. The bars on the figure refer to standard deviation. Arrow indicates turning. (Average data on three windrows)

Table 2: EFB-POME compost quality

Month	pH	N, %	P_2O_5, %	K_2O, %	MgO, %	C/N
August	8.2	1.7	0.5	1.7	0.8	20
September	7.8	2.1	0.7	1.4	1.0	15
October	7.7	2.0	0.6	1.3	0.9	18
November	7.7	1.8	0.7	3.4	0.6	24
December	8.0	1.9	0.8	2.0	0.8	23
Average	**7.9**	**1.9**	**0.6**	**2.0**	**0.8**	**20**
Standard deviation	0.2	0.2	0.1	0.8	0.1	3.6

This is due to lack of carbon that has been fully utilised by the microorganisms and consequently, reduce the metabolism [2].

Oxygen is used as terminal electron acceptor for aerobic respiration and also in the oxidation of organic substance *i.e.* protein, cellulose, oil, lignin, *etc*. in the compost windrow. Therefore, the oxygen content is a critical variable to be controlled. In windrow composting, turning frequency is also an important factor for controlling the oxygen content. From Figure 5, the oxygen content is maintained above 10%, which is necessary for maximum biodegradation [3] although 5% oxygen content is reported to be sufficient for windrow composting [7]. At the later stage, lower oxygen content was observed. This incident might be due to the inefficient mixing. In general, this study shows that turning frequency for every ten days is adequate to supply enough oxygen for the EFB-POME compost pile. It has been reported that an optimum turning frequency was important in order to maintain the high temperature, minimise the nutrient losses/ pathogen and control the odour from the composting process [2, 7].

The turning frequency is different from one system to another depending on the substrate(s). Turning frequency of three days during composting POME-shredded EFB was reported by Baharuddin *et al*. [3]. However, too much turning frequent also will increase the operational cost [2]. According to Tirado [7], the turning every three days increase operational cost up to 1.15 times than turning for every ten days. Tirado [7] also suggested that turning is conducted every ten days for composting of dairy manure with sawdust.

Table 2 shows the quality of compost from August 2009 to December 2009 and the average nutrient contents is shows in Table 3. From Table 2, it can be seen that the average pH of the compost is 7.9, and it might be beneficial for acidic soil because it can be used as liming agent. The pH value obtained in this study is within others finding *i.e.* pH 5.6-8.5.

Application of inorganic fertiliser is costly and could turn the soil to be more acidic. The compost nutrient content *i.e*. N, P, K, and Mg (Table 2) are considered in the acceptable range and could help the farmers to reduce the reliance on the inorganic fertiliser and simultaneously improved the soil condition.

It has been shown that the composting time for compost is shorter than other methods. The composting time for conventional compost is 60-90 days. From Table 3, the moisture content for compost is slightly lower from other compost. The final compost should have moisture content about 40-55% if the problem of fungi to be avoided [9]. Too high moisture content for final compost is also not preferable because it can enhance anaerobic biodegradation, which will produce a bad smell and hence reduce the quality of compost [9].

Although in this study, the compost produced is just semi-compost, the C/N about 20 is lower than EFB compost without any amendment (Table 3) and slightly same with EFB with POME-wheat flour compost (Table 3). It should be noted that, the further stabilisation will occurred after application to the soil. It was reported that the C/N approximately 20 is reported to be phytotoxic-free although the compost is considered as immature [8].

4.0 CONCLUSION

The evolution of temperature, oxygen content and nutrient for five months productions of semi-compost has been presented in this paper. Based on the temperature profile, the maximum biodegradation had been achieved due to the sufficient oxygen content. The nutrient for compost is comparable with other

Table 3: Nutrients content for various EFB compost

Amendment (s) material	Composting time, days	Moisture content, %	pH	C/N	N, %	P, %	K, %	Ref.
Fresh POME	40-45	55	7.9	20	1.9	0.6	2.0	This study
Partially treated POME	60	61	8.1	12.7	2.2	1.3	2.8	[3]
POME + Wheat flour	60	ND	5.6	20	ND	ND	ND	[8]
Without any amendment material	60	65	8.5	24	1.7	ND	ND	[5]
Goat dung	60	65	8.5	14	2.5	ND	ND	[5]
Cow dung	60	65	8.5	18	1.9	ND	ND	[5]
Chicken manure	60	65	8.5	12	2.0	ND	ND	[5]
Sewage sludge + oil palm trunk, frond	90	60	6.2	19	2.1	0.6	1.4	[6]

**ND = Not determined*

studies. However, further research should be done to investigate the effect of compost during long term application. In-vessel system such as rotating drum composter for faster degradation of EFB-POME could be an interesting subject in the future studies.

5.0 ACKNOWLEDGEMENT

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PROFILES



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RUNOFF QUALITY INDEX FOR AREA UNDER MAIZE CULTIVATION

(Date received: 24.11.2009/ Date approved: 20.8.2010)

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ABSTRACT

Land development activities contribute to water quality impairment. The resulting runoff from rainfall from different land use areas carries a wide range of pollutants that find their ways to the surface and ground waters. The use of models plays an important role in the assessment of diffuse pollution sources and their delivery to the receiving water bodies. The current Water Quality Index (WQI) used by the Department of Environmental (DOE) Malaysia has limitations when applied to agricultural areas. The important parameters do not include those pollutants particular to agricultural areas. This research project was carried out on sandy clay loam soil grown with maize (Zea Mays). The experimental plot was isolated from the surrounding areas with perimeter bunds to protect from runoff from adjacent areas. Thirty seven rainfall events in three seasons were monitored to evaluate the parameters that contributed most to the Non-point Source (NPS) pollution. A Runoff Quality Index (RQI) was proposed to assess runoff quality. The quality parameters include Total Kjeldhal Nitrogen (TKN) and Total Phosphorous (TP). It must be mentioned that the results of this experimental study is limited specifically to an agricultural area that was cultivated in maize only.

Keywords: *Agricultural Pollution, Diffuse Pollution, Runoff Quality Index (RQI)*

1.0 INTRODUCTION

The environmental sustainability of agricultural systems has been discussed worldwide and the degradation of water is among the main environmental concerns related to agriculture. High risk of flooding, dead fish, and contamination by pesticides and nutrients in surface and groundwater are considered the main impacts of agriculture. The quality and quantity of water resources decrease over time. The degradation of water resources is caused by a lot of activities such as land conversion from forest to farmland, shifting cultivation, plantation, residential and industrial development. Those activities involving earthworks cause soil erosion, sedimentation of rivers and consequently flooding that threatens human beings and properties.

Water resources are degraded due to addition of pollutants from the point and non-point sources (NPS). Point source pollution are usually noticeable, confined and is comparatively easy to estimate its pollutant loads into the rivers and other water bodies. On the contrary, non-point sources pollution is not confined and therefore is difficult to be estimated and to be captured to reduce water pollution problems. Non-point source pollution is directly governed by storm runoff. Runoff from agricultural areas is the main conveyance of non-point sources pollution to the downstream river system.

Malaysia receives an annual average rainfall that varies from 1700 to 4000 mm depending on location. The resulting runoff can be substantial and can carry a wide range of pollutants from different land uses that find their ways to the surface and ground waters. The runoff may contribute as high as 60% of the total pollutants coming into the rivers [7]. Malaysia covers an area of about 32.86 million hectares, consisting of Peninsular Malaysia and the states of Sabah and Sarawak and the island Federal Territory of Labuan in northern Borneo Island. Over 10 million hectares, or 31% of Malaysia's total land area, is considered suitable for agricultural practices. Of this, some 5.4 million hectares have been cultivated, constituting a very large potential area to generate NPS pollution.

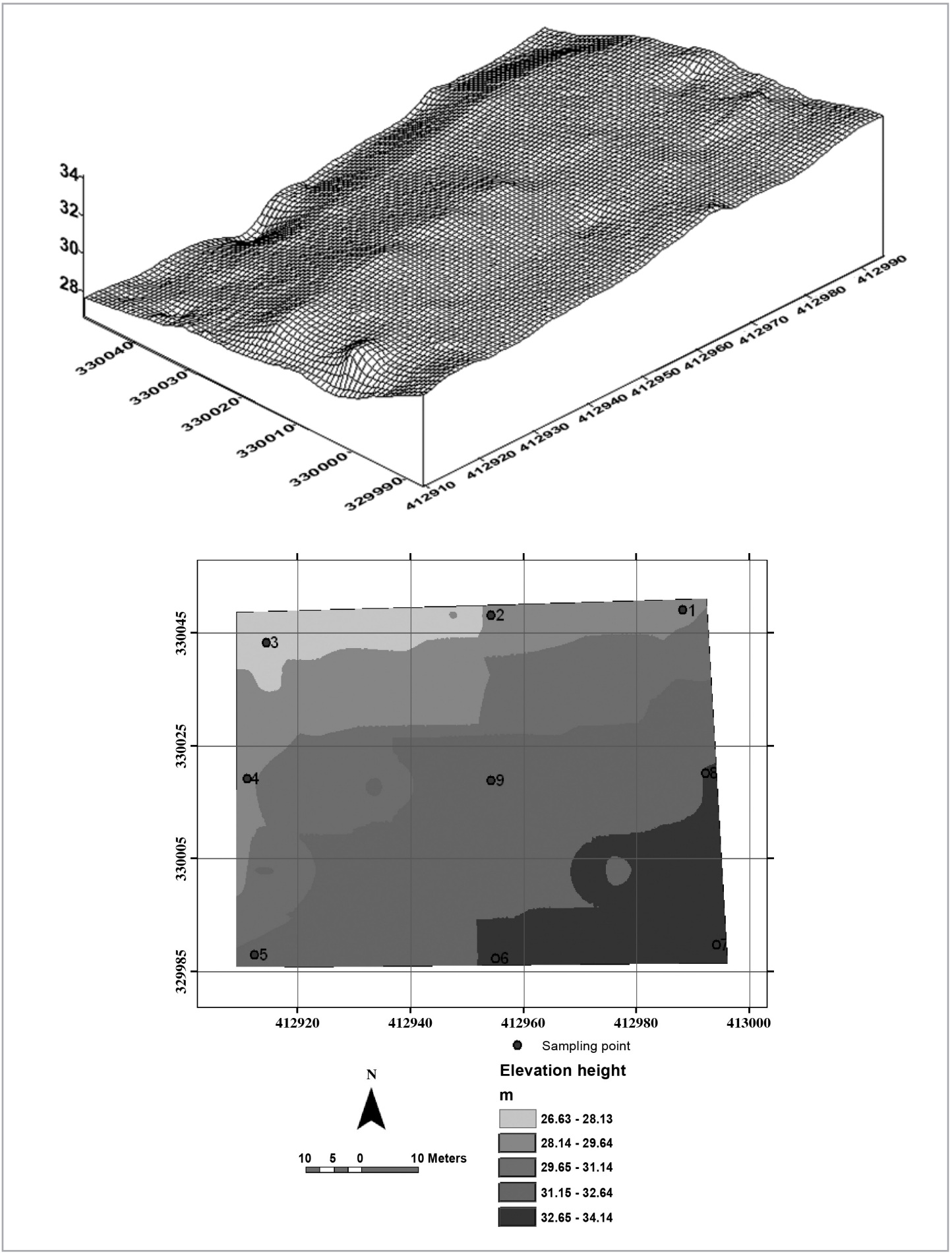


Figure 1: Elevation Height of the Study Area above Mean Sea Level (MSL)

The existing Water Quality Index (WQI) proposed by the Department of Environmental (DOE) Malaysia was reviewed and found to have limitations when applied to agricultural areas. In view of the issues and problems discussed above, the objective of the study was to develop a Runoff Quality Index (RQI) based on the dominant pollutants in runoff specifically from a tropical cultivated agricultural area.

2.0 METHODOLOGY

2.1 The Study Area

The research project was carried out at the Precision Agriculture Experimental Plot in Universiti Putra Malaysia (UPM). Maize (Zea Mays variety) was planted in the study area the size of about 0.56 ha located at latitude 3° 02' N and longitude 101° 42' E, at 31 m above mean sea level. The soil in the study area is the Malayan Serdang series. The study plot was isolated from the surrounding areas by building bunds to prevent runoff produced from the adjacent areas. The area has 7 % slope in the direction sloping down from south to north (Figure 1). Water quality study was conducted during three consecutive seasons from March to June2004 (Crop season I), August to October 2005 (Crop Season II) and November 2005 to February 2006 (Crop season III). Normal agricultural practices were implemnented. For each season, fertilisers were spread three times. The first time being 15 days after seeding with Nitrophoska Green, (15% N, 15% P_2O_5 and 15% K_2O). The second and third spreads were done 30 and 45 days after seeding resepctively, using Nitrophoska Blue TE which contains 12% N, 12% P_2O_5, 17% K_2O, and 2% MgO and trace elements: Boron (B), Manganese (Mn), Zinc (Zn) and Iron (Fe). I all a total of twenty rain events in crop season I, nineteen events in crop season II and eight events in crop season II were monitored. It must be mentioned that the results of this experimental study is limited specifically to an area that was cultivated in maize only.

2.2 Collection of Samples

The following equipment and instruments were installed at the site to collect water samples: automatic rain gauge, auto-sampler for water collection [6], automatic water level recorder. Water samples were collected by the auto-sampler (ISCO 6712 Portable Sampler, Teledyne Isco Inc.) with a built-in peristaltic pump following recommended procedures [2].

Table 1: Proposed runoff quality index for the agricultural area (planted in maize)

$$RQI = 0.14SITKN + 0.18SIBOD + 0.18SICOD + + 0.17SINH3\text{-}N + 0.19SITSS + 0.14SITP \quad (1)$$

Where,
RQI= Runoff quality index for agricultural area; SITKN= Sub-index of TKN; SIBOD= Sub-index of BOD;
SIBOD= Sub-index of BOD; SINH3-N= Sub-index of NH3-N; SITSS= Sub-index of TSS and SITP= Sub-index of TP.

Sub-index of TKN for $0.5 \text{ mg/L} \leq TKN \leq 5 \text{ mg/L}$:

$$SITKN = 0.559\,TKN3 - 3.8857\,TKN2 - 14.786\,TKN + 101.83 \quad (2)$$

Sub-index of BOD for $1 \text{ mg/L} \leq BOD \leq 15 \text{ mg/L}$:

$$SIBOD = 0.0063\,BOD3 - 0.2427\,BOD2 - 4.4215\,BOD + 100.32 \quad (3)$$

Sub-index of COD for $10 \text{ mg/L} \leq COD \leq 100 \text{ mg/L}$:

$$SICOD = 2E\text{-}05\,COD3 - 0.0063\,COD2 - 0.6134\,COD + 100.55 \quad (4)$$

Sub-index of NH3-N for $0.20 \text{ mg/L} \leq NH3\text{-}N \leq 1.50 \text{ mg/L}$:

$$SINH3\text{-}N = 24.681\,NH3\text{-}N3 - 50.507\,NH3\text{-}N2 - 46.907\,NH3\text{-}N + 101.42 \quad (5)$$

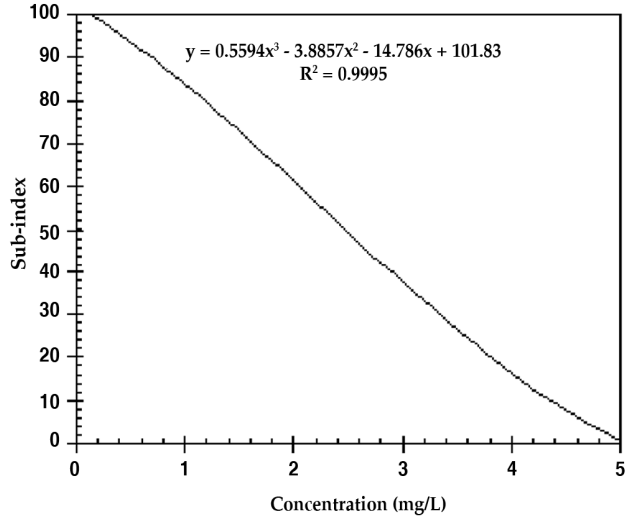
Sub-index of TP for $0.15 \text{ mg/L} \leq TP \leq 1.0 \text{ mg/L}$:

$$SITP = 97.175\,TP3 - 153.8\,TP2 - 42.759\,TP + 100.54 \quad (6)$$

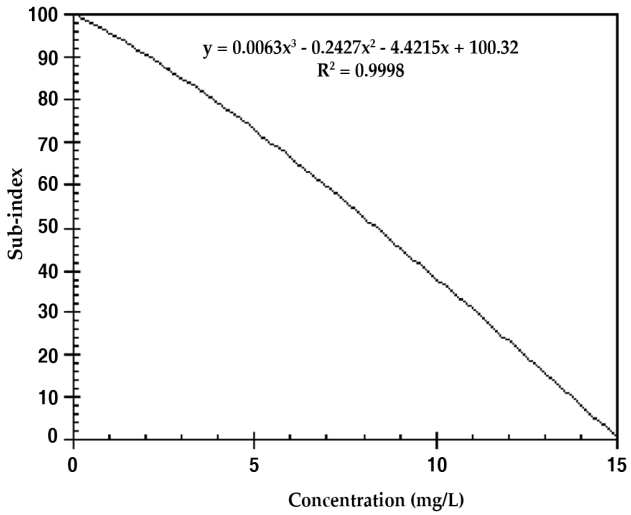
Sub-index of TSS for $25 \text{ mg/L} \leq TSS \leq 500 \text{ mg/L}$:

$$SITSS = 9E\text{-}07\,TSS3 - 0.0007\,TSS2 - 0.0823\,TSS + 98.998 \quad (7)$$

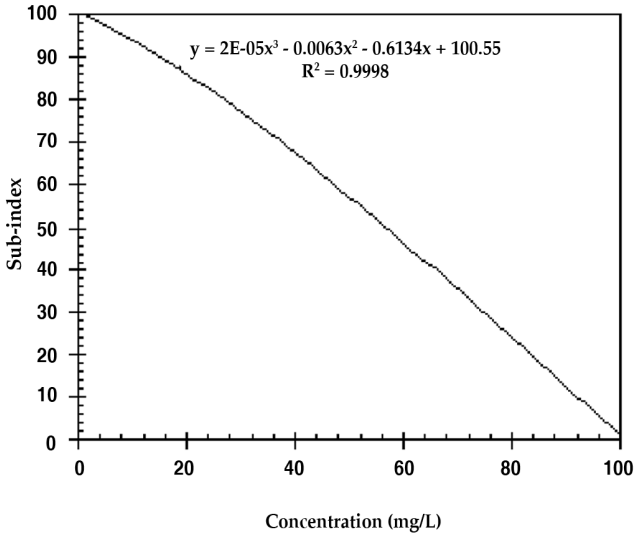
Pollutant concentrations are in mg/L for all parameters. The sub-index value cannot be negative.
These equations (from 1 to 7) are graphically represented in Figure 2.



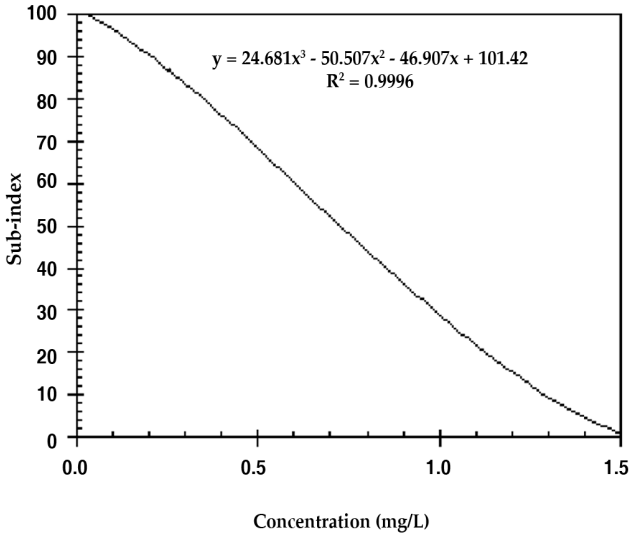
(a) Total Kjeldhal Nitrogen (TKN)



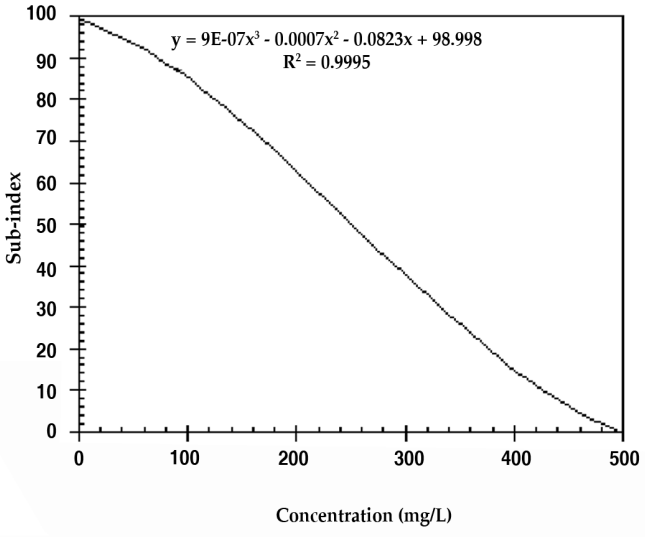
(b) Biochemical Oxygen Demand (BOD)



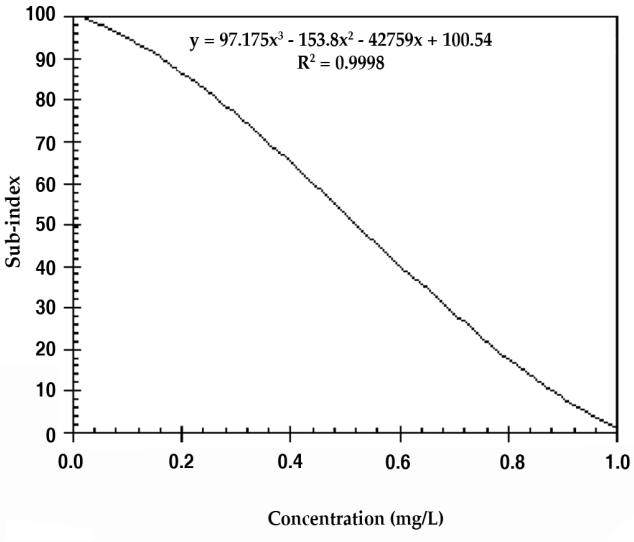
(c) Chemical Oxygen Demand (COD)



(d) Ammoniacal Nitrogen (AN)



(e) Total Suspended Solids (TSS)



(f) Total Phosphorus (TP)

Figure 2: Variation of Sub-indices with Pollutant Concentrations for the Parameters Required for the Proposed RQI

Table 2: Existing water quality index (WQI) and classes

Parameter	Class I	Class II	Class III	Class IV	Class V
Ammoniacal Nitrogen (NH3-N)	< 0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
Biochemical Oxygen Demand (BOD)	< 1	1 - 3	3 - 6	6 - 12	> 12
Chemical Oxygen Demand (COD)	< 10	10 - 25	25 - 50	50 - 100	> 100
Dissolved Oxygen (DO)	< 7	5 - 7	3 - 5	1 - 3	< 1
pH	> 7	6 - 7	5 - 6	< 5	< 5
Suspended Solids (SS)	< 25	25 - 50	50 - 150	150 - 300	> 300
Water Quality Index (WQI)	> 92.7	76.5-92.7	51.9-76.5	31.0-51.9	< 31.0

The sampler had a maximum of 24 bottles of 1 L capacity and the unit was programmed to collect samples at various time intervals. For each storm event, a maximum of 24 samples were collected from the drainage outlet. Non-uniform time intervals of sampling were chosen to plot the runoff hydrographs covering the storm events. For all 3 seasons, the first 10 samples were collected at 2-minute intervals and the other 14 samples at 5-minute intervals making a 90-minute rainfall satisfactorily sampled. Available laboratory facilities were used to analyse the pollutants in the samples collected.

2.3 Laboratory Testing

The most important and sensitive component of water quality study is the method of laboratory testing and analysis. Adequate attention was given to maintain acceptable level of accuracy in laboratory testing. The water quality parameters were tested using standard methods [1], calibrated sensors and instruments, which are accepted and practiced internationally (YSI, HACH, Oreon, *etc*.).

2.4 Pollutants Studied

Initially, the first crop season samples were analysed for eleven parameters that affect water quality. They were pH, Dissolved Oxygen (DO), Temperature, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3-N), Nitrate (NO_3), Total Kjeldhal Nitrogen (TKN), Total Phosphorous (TP), Total Suspended Solid (TSS) and Turbidity. For the second season, however, only parameters that exceeded the limits of Class III water (which is considered suitable for general usage) were analysed. Seven parameters namely BOD, COD, NO_3, TKN, TP. TSS and Turbidity were found to have exceeded those of Class III water. Consequently, only these seven parameters were analyzed during the second and third seasons.

Table 3: Proposed runoff quality index (RQI) and classes

Parameter	Class I	Class II	Class III	Class IV	Class V
Ammoniacal Nitrogen (NH3-N)	< 0.1	0.1 - 0.3	0.3 - 0.5	0.5 - 1.1	1.1 - 1.5
Biochemical Oxygen Demand (BOD)	< 1	1 - 3	3 - 6	6 - 12	12 - 15
Chemical Oxygen Demand (COD)	< 10	10 - 25	25 - 50	50 - 75	75 - 100
Total Kjeldhal Nitrogen (TKN)	< 0.5	0.5 - 1.5	1.5- 2.5	2.5 - 3.5	3.5 - 5.0
Total Phosphorous (TP)	< 0.15	0.15 - 0.3	0.3- 0.5	0.5 - 0.75	0.75 - 1.0
Total Suspended Solids (TSS)	< 25	25 - 50	50 - 150	150 - 300	300 - 500
Runoff Quality Index (RQI)	> 94.6	82.8-94.6	62.1-82.8	26.5-62.1	< 26.5

Table 4: Statistical Summary of the case study WQI and RQI Values Obtained

Parameter	RQI	WQI	RQI - WQI	Class RQI	Class WQI
Mean	32.3	46.3	-14.0	IV	IV
Median	28.6	48.0	-18.0	IV	IV
Minimum	21.9	32.5	-25.7	IV	IV
Maximum	54.2	57.7	5.9	III	III
10%tile	23.6	36.5	-23.3	IV	IV
90%tile	50.0	50.9	2.2	IV	IV

3.0 RESULTS AND DISCUSIONS

Runoff Quality Index (RQI) shown in Table 1 for the agricultural area was proposed based on statistical analysis of primary data collected from the site. The proposed RQI parameters and their rankings were selected to suit the local water quality problems and objectives. The convenience in water quality sampling and testing was another factor considered in selecting the parameters for the proposed RQI of an agricultural area. The RQI is proposed considering the potential important physical, chemical and nutrient parameters from maize cultivation activities.

The proposed RQI given in Equation 1 also consists of six parameters. However, their relative weightage is different from those of the existing WQI equations (DOE). In addition, the pH and DO terms were replaced with Total Kjeldhal Nitrogenand Total Phosphorous. Ammoniacal Nitrogen NH_3-N was included to evaluate the toxicity of the runoff to the aquatic fauna. BOD and COD will represent the biochemically and chemically oxidiseable elements in the runoff from the maize field. There was strong correlation between TSS and turbidity of runoff data. In view of this only TSS was considered in the RQI, which indirectly also represents the clarity of runoff from the study area. The parameters were selected such that the water quality was assessed based on the common and important physical and chemical parameters of surface water. The RQI was also proposed in relation to the five (5) classes of river water as recommended for the existing WQI (Table 2). However, uniformity was maintained in dividing the ranges of water quality classes (from I to V in Table 3), which was not considered in the existing WQI guidelines established for the evaluation of river water quality.

It was observed that the average value of RQI at the site was less by some 14.0 points from the WQI values as shown in in the Table 4. This indicated that the proposed runoff quality index (RQI) was slightly more stringent compared to those derived from the the existing WQI equations. The big difference in WQI values also indicted that the proposed RQI equations are more sensitive to the non-point source pollution, which has been identified as the main source of river pollution in Malaysia [3], [4], [5].

This preliminary RQI for the evaluation of overall water quality discharged from an agricultural area would of course benefit from require further in-depth analyses in different solid types and locality and detailed discussion with the relevant Authorities before implementation in the country. The proposed modifications for the determination of water quality index is necessary to assure good river water quality to enhance the Malaysian government's mission to increase aquatic tourism and river related activities in the country.

4.0 CONCLUSION

The existing Water Quality Index (WQI) guidelines as adopted by the Department of Environmental (DOE) Malaysia was reviewed and found to have a few limitations when applied to Non Point Source pollution common in agricultural practices. It was established that the existing WQI procedure is not suitable for the evaluation of runoff quality from agricultural areas. The main pollutants from the study area were identified and a runoff quality index (RQI) was proposed to assess the runoff quality from the maize field. This modification is necessary to ensure good river water. Further studies on its application throughout the Malaysian agricultural landscape would further enhance is applicability.

5.0 ACKNOWLEDGEMENT

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LIST OF ABBREVIATIONS

RQI	runoff quality index
TKN	total Kjeldhal nitrogen
TP	total phosphorus
BOD	biochemical oxygen demand
COD	chemical oxygen demand
TSS	total suspended solids
NH_3-N	ammonical nitrogen
DO	dissolved oxygen
NO	nitrate
SI	sub-index
WQI	water quality index
DOE	Department of Environment
MOSTI	Ministry of Science Technology and Innovation
IRPA	Intensive Research for Priority Areas
UPM	Universiti Putra Malaysia
MACRES	Malaysia Centre for Remote Sensing

IMPACT OF COMMERCIAL PECTOLYTIC ENZYMES ON SELECTED PROPERTIES OF WHITE DRAGON FRUIT JUICE

(Date received: 22.12.2009/ Date approved: 19.8.2010)

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ABSTRACT

The aim of this work was to observe the effects of commercial enzymes i.e. Pectinex Ultra SP-L and Pectinex CLEAR on the chemical composition, vitamin C and total polyphenols contents of white dragon fruit (Hylocereus undatus) juice. The differences of these properties in fresh fruit pulp and juices produced without enzymatic treatment were also observed. The dragon fruit juice produced after enzymation and pasteurisation has not shown significant changes in most of its major chemical parameters such as moisture, ash, fat, carbohydrate and calorie. However, enzymation using Pectinex CLEAR leads to the juice with higher yield of protein. The protein content after the treatment increased to 0.33% w/w from 0.17% w/w of the fresh juice. Phenolics amounts were slightly higher up to 15% in the enzyme samples which suggest that dragon fruit beverage is rich in antioxidant capacity than in the unprocessed fruit.

Keywords: *Chemical Composition, Commercial Enzyme, Dragon Fruit, Total Polyphenols, Vitamin C*

1.0 INTRODUCTION

Dragon fruit is also called pitahaya, strawberry pear, pitaya (in South East Asia), night-blooming cereus, and paniniokapunahou or papipi pua (in Hawaii). Dragon fruit is known to be highly nutritious. It has been called the most beautiful in the cactus family [1]. The dragon fruit flesh can be white, red or magenta depending on variety. It is rich in potassium, ferum, protein, fiber, vitamin C and minerals which are good for human health. This exotic fruit is now being converted into ready-to-drink beverages, jam and wine. Fruits have always played an important role in human nutrition [2]. The demand for fruit beverages is largely based on their nutritive value, flavour, aroma and colour.

Juice with low viscosity, high clarity and yet high in nutrition is more desirable by consumers. Enzymes can play a key role in improving juice clarity, stability as well as reducing the viscosity. The presence of polysaccharides such as pectin and starch has caused cloudiness in the juice. An effective way to reduce the pectin in the fruit juice is by enzymatic treatment using pectinase because of its ability to hydrolyse pectin and causes pectin-protein complexes to flocculate [3-6]. Pectinases are obtained from plants and fungi. However, the major commercial source of pectinases is *Aspergillus* sp.. Pectinases are used industrially to weaken plant cell walls and enhance extraction of fruit juice. They help to improve juice recovery, decrease viscosity and prevent gelation in the extracts. Easier release of the components contained in cells is due to the degradation of plant cell walls by exogenous enzymatic treatment [7].

In juice processing, enzyme is an essential tool in terms of quality improvement and cost saving [8]. Currently, the production of fruit and vegetable juices is unthinkable without the use of enzymes [9]. The key of producing clear and stable fruit juice is a complete enzymatic breakdown of pectin. Generally, fruit juice extraction involves maceration of the pulp followed by centrifugation and filtration, to separate the juice from the solids. The aim of mash treatment is to increase juice yield and to facilitate the extraction of the soluble substances from the cells [9]. Filtration is employed to remove insoluble plant material from the enzyme-treated juice.

For a few years ago, studies have been done to study on the color pigments of red pitaya [10-13]. Research on the cultivation of pitaya has also become appreciated [1]. However, not many studies have been done on white pitaya or dragon fruit. In this work, the chemical composition, vitamin C and total polyphenols contents of fresh and treated white dragon fruit juices are reported for the first time. The data found in this study are expected to be useful for the optimisation of dragon fruit juice production.

Table 1: Optimum processing condition for enzymatic clarification of white dragon fruit pulp

Types of enzymes	Enzyme concentration (%)	Incubation temperature (°C)	Incubation time (min)
Pectinex Ultra SP-L	0.06	49	40
Pectinex CLEAR	0.10	40	81

2.0 MATERIALS AND METHODS

2.1 Samples

Ripe white-fleshed dragon fruits were obtained from a local farm in Sepang (Selangor, Malaysia). Two commercial pectinase enzymes preparations were used which are Pectinex Ultra SP-L (from *Aspergillus niger*) and Pectinex CLEAR (from *Aspergillus aculeatus* and *Aspergillus niger*) that both obtained from Novo Nordisk Ferment Ltd., Dittigen, Switzerland were used for enzymatic treatment of white dragon fruit juice and stored at 4°C. Pectinex Ultra SP-L and Pectinex CLEAR are commercial enzymes used to clarify the fruit juice. Polygalacturonase, pectinesterase and pectin transeliminase are mainly contains in the commercial enzyme. The activity of Pectinex Ultra SP-L and Pectinex CLEAR enzymes are 26 000 PG per ml (polygalacturonase activity per ml). Such enzymatic preparations rupture the juice retaining particles of the pulp; the effect is due to action of polygalacturonase in splitting the peptic chain and the action of pectinesterase in hydrolysing the methyl ester groups of the pectin molecule [14, 15]. The ideal conditions for fruit processing are when the optimum enzyme reaction conditions are at pH 3.5 – 6.0 and temperature range below 50°C [16].

2.2 Production of Clarified White Dragon Fruit Juice at Laboratory Scale

Dragon fruits were peeled and a juice extractor (Philips Juicer Model: HR 1858155; Royal Philips Electronics, Eindhoven, The Netherlands) were used to extract and remove the seeds and coarse cloud particles. The dragon fruit pulp was added with two commercial enzyme preparations separately for each enzyme. The parameter for the clarification were enzyme concentration, time and temperature of enzymatic treatment for Pectinex Ultra SP-L enzyme and the parameter have been obtained from trials done by Nur 'Aliaa *et al*. [17]. For Pectinex CLEAR, the processing condition data for enzymatic clarification of white dragon fruit juice was also obtained from trials (data not published). Pectinex Ultra SP-L and Pectinex CLEAR were added separately to the pulp for each sample and incubated (Wise Cube Shaking Incubator Model: WIS–S10; DAIHAN Scientific, Co., Ltd., Seoul, Korea) with continuous shaking (250 rpm). The optimum conditions for enzymatic clarification of white dragon fruit pulp using both enzymes shown in Table 1.

Pasteurisation at 90°C for 5 min was done to the treated pulp in a hot waterbath (Laboratory Waterbath Model: LMWB-6PC; PLT Scientific Sdn. Bhd., Selangor, Malaysia) and then circulating waterbath (Model: 71; PolyScience, Illinois, USA) was used to cool it at 2°C. These steps were performed before filtration to inactivate the enzyme action. The treated white dragon fruit juice was centrifuged (Refrigerated Centrifuge 5800; Kubota Corporation, Fujioka, Japan) for 10 minutes at 3000g, and the supernatant was collected. A filter paper (Whatman No.1, Whatman International Ltd., Kent, England)

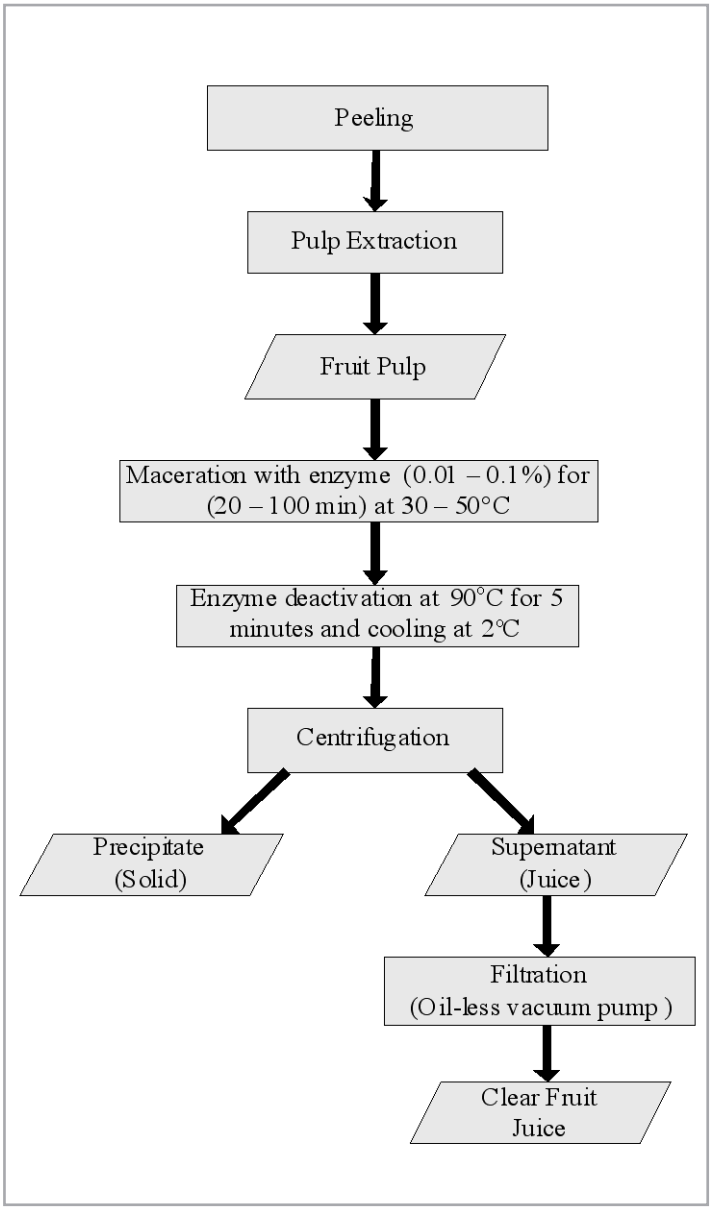


Figure 1: Steps for extraction and subsequent clarification by enzymatic treatment of white dragon fruit juice

Table 2: Chemical composition of white dragon fruit juice

Treatment	Protein (%w/w)	Fat (%w/w)	Moisture (%w/w)	Ash (%w/w)	Carbohydrate[a] (%w/w)	Calorie[b] (Kcal/100g)
Fresh fruit pulp (untreated pulp)	0.17±0.06	0.00	87.73±0.06	0.40±0.00	11.70±0.00	47.67±0.58
Control sample (pasteurized only)	0.23±0.06	0.00	87.33±0.06	0.47±0.06	11.97±0.12	48.67±0.58
Juice treated with Pectinex Ultra SP-L	0.13±0.06	0.00	87.40±0.00	0.40±0.00	12.07±0.06	49.00±0.00
Juice treated with Pectinex CLEAR	0.33±0.06	0.00	87.43±0.06	0.40±0.00	11.83±0.06	48.67±0.58

Values given are the mean of three replicates ± standard deviation

[a] *% Carbohydrate = 100 – (% Protein + % Fat + % Moisture + % Ash)*

[b] *Calorie (Kcal) = 4 (% Carbohydrate) + 4 (% Protein) + 9 (% Fat)*

was used to filter the juice, which has the pore size of 11 μm using oil-less vacuum pump (Model: Rocker 300; Rocker Scientific Co., Ltd., Taipei County, Taiwan). In order to avoids the costly pressing steps, the separation of the pulp from the juice is filter on a rotary vacuum filter and the juice obtained is clear [9]. Figure 1 shows the step for the production of clarified white dragon fruit juice at laboratory scales. A control sample without enzymatic treatment step was produced and pasteurised at 90°C for 5 min followed by cooling at 2°C.

2.3 Determination of Chemical Parameters, Vitamin C and Total Polyphenols Contents of White Dragon Fruit Juice

Protein, fat, carbohydrate, moisture, ash and calorie were determined according to AOAC [18]. Ascorbic acid was determined volumetrically with 2-6 dichlorophenol-indophenol reagent [18]. Total polyphenol was measured by modified Folin-Ciocalteu method using gallic acid as a standard. 5g of juice was extracted with 20ml mixture of methanol-water and with 30ml mixture of acetone-water separately under stirring for 1 hour. Then the supernatant were combined in volumetric flask and made up to 50ml with distilled water and is called extract. 0.5ml of extract is added with 0.5ml Folin-Ciocalteu reagent and allowed to react for 3 min under continuous stirring. After that, 10ml of sodium bicarbonate (75 g L^{-1}) was added and the mixture was diluted to 25ml with distilled water. The solution was kept at room temperature for 2 hour in the dark; the absorbance was then measured at 750nm using UV-Vis Spectrophotometer (Model UV-260; Shimadzu Corporation, Tokyo, Japan). The mean value of total polyphenols was obtained from triplicate experiments.

3.0 RESULTS AND DISCUSSION

A general practice in juice processing is the treatment of fruit pulp with appropriate enzyme preparations [8]. The cloudy appearance of the ripe fruit juice extracted was due to the existing of substantial amount of pectins and starches which can be removed by enzymatic depectinization. Depectinization affected the composition of juice in relation to the type of juice, the type of enzyme and the time considered [19].

In this study, ripe white dragon fruits were selected from a local farm in Malaysia with considerably higher quality which is reflected by the fruit larger size, well-developed colour and very juicy pulp. Ripe fruits lead to juice freshness and quality that is crucial to the quality of the final product. Two pectinase enzymes application (Pectinex Ultra SP-L and Pectinex CLEAR) were used to demonstrate the effects of pectinases on the quality of fruit juice.

3.1 Influence of Enzyme Application on Chemical Composition of White Dragon Fruit Juice

The impact of different enzyme preparations on chemical parameters of white dragon fruit juice is presented in Table 2. By enzymatic treatment, not only the yield of juice increased, but also the macro- and micro-components contents of the product [20]. The white dragon fruit juice produced after enzymation and pasteurisation has not shown marked changes in the most of its major chemical parameters such as moisture, ash, fat, carbohydrate and calorie. From the study done by Ramadan and Moersel [8] on goldenberry juice, they found out that the effect of enzymation on these macro- and micro-constituents seems to be insignificant. It can be seen that fat levels remained zero in fresh pulp and even in pasteurised and enzyme-treated white dragon fruit juices. An

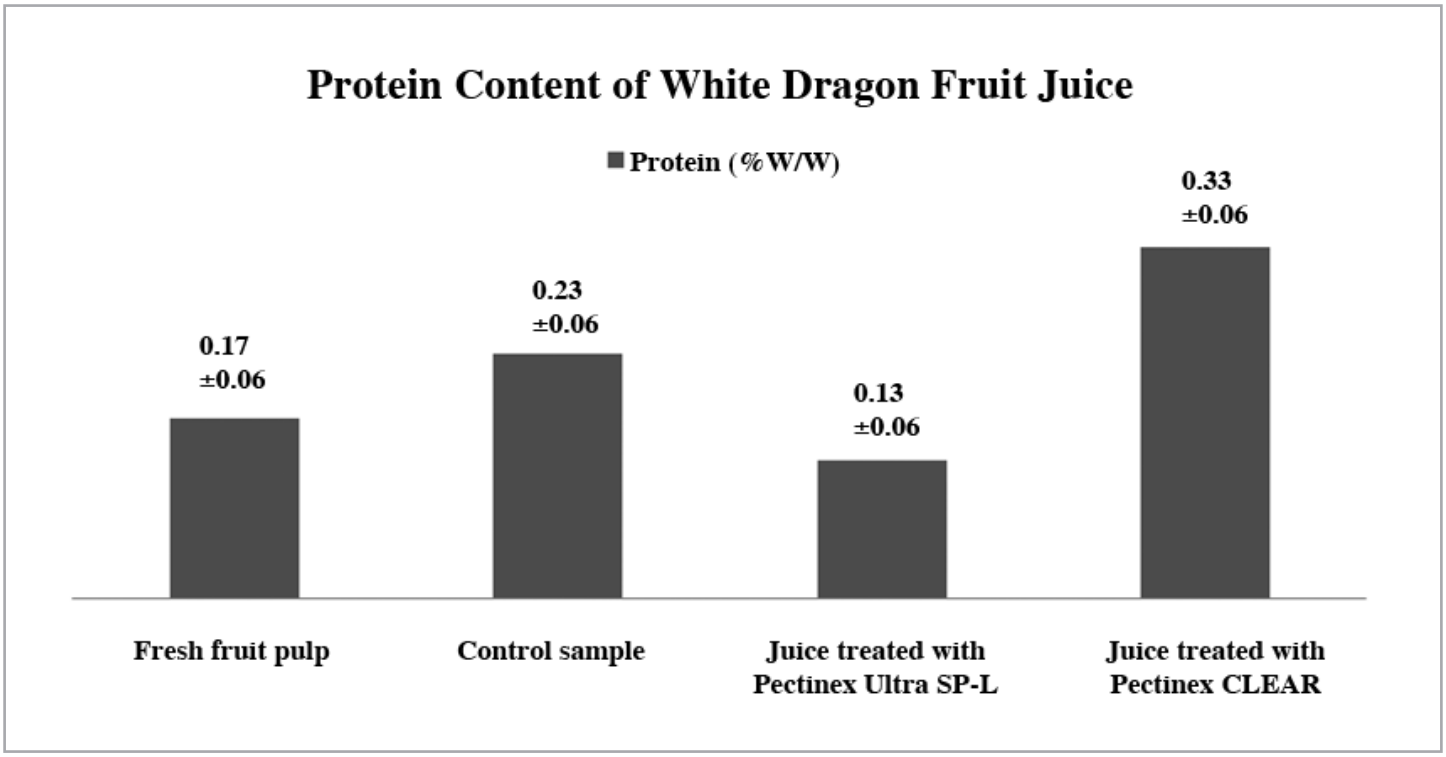


Figure 2: Protein content of white dragon fruit juice

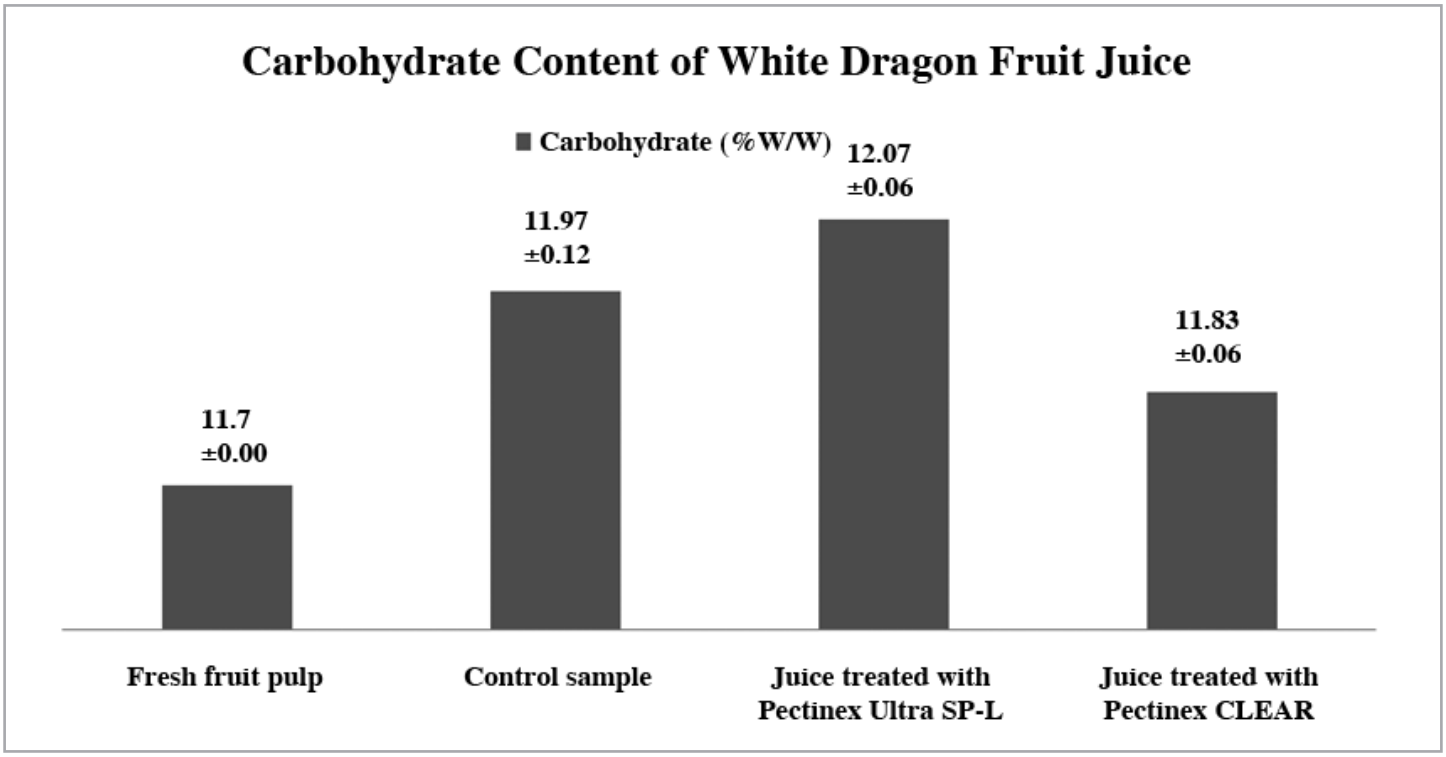


Figure 3: Carbohydrate content of white dragon fruit juice

interesting result is that the juice treated with Pectinex CLEAR enzyme preparation resulted in markedly higher yield of protein as shown by the chart in Figure 2. The same trend was also observed for the protein content in red dragon fruit juice [21].

Carbohydrate contents in enzyme-treated white dragon fruit juice were found to be higher than in the untreated pulp and control samples. Treatment with Pectinex Ultra SP-L increased the level up to 12.07% as shown in Figure 3. The effect of Pectinex Ultra SP-L was different than Pectinex CLEAR because pectinases act in different ways on the pectins. Carbohydrate content in other fruits was reported to be as follows: strawberry and watermelon (3%); apricot, guava, lemon, orange, papaya, peach and plum (6%); apple, grape, mango and pineapple (15%); and banana and puree (20+%) [22]. Since the range of carbohydrate content in

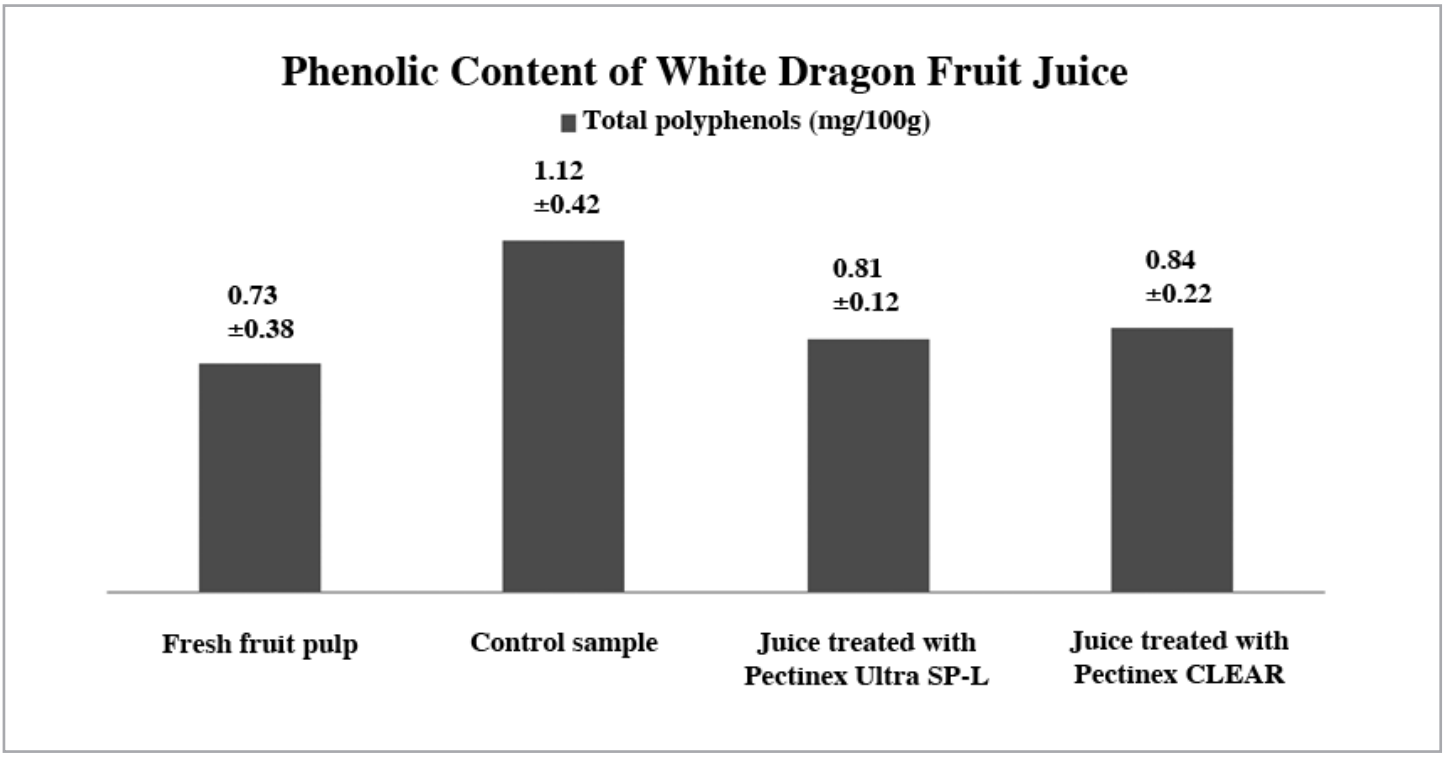


Figure 4: Phenolic content of white dragon fruit juice

white dragon fruit juice was 11.70% - 12.07%, it can be concluded that carbohydrate in dragon fruit juice was higher than that of other tropical fruits such as guava and papaya, and lower than that of mango, pineapple and banana. The calories in fresh and processed dragon fruit juices are less than 100 kcal and can be considered as low. Thus, dragon fruit juice can be classified as a healthy beverage.

3.2 Effect of Enzymatic Treatment on Vitamin C and Total Polyphenols Contents of White Dragon Fruit Juice

Table 3 shows the data obtained for vitamin C and total polyphenols content in white dragon fruit juice. The untreated pulp had slightly higher vitamin C content than enzyme-treated and control samples. The slight reduction was due to the effects of the heat applied during the treatment. Miller and Rice-Evans [23] suggested that the phenolic antioxidants of fruit juices protect the vitamin C content from oxidative degradation. Phenolics are important because of their contribution to the sensory quality of fruits (colour, astringency, bitterness and flavour), which may be affected during the technological processes used for obtaining the juices and other transformation products [8]. Fair amounts of polyphenols were found in white dragon fruit juices which were 0.73 to 1.12 mg/100g juice as gallic acid equivalents (GAE). Higher amounts of phenolics were found in processed pitaya juice as shown by the chart in Figure 4 which suggests that dragon fruit beverages are rich in antioxidants capacity than in the unprocessed mash. The presence of phenolics components play a significant contributory role as antioxidant; which is important in the maintenance of health and protection from coronary heart disease and certain cancers [23].

4.0 CONCLUSION

Recently, dragon fruits have attracted great interest from the fruit growers to the fruit processing industries due to their nutritional and health benefits. Processing of dragon fruit juice using enzyme is important to produce high quality fruit juice that meets the consumer interest. Application of enzyme proved to increase the juice recovery as well as the juice physicochemical characteristics. It also increased the nutritional composition in the juice such as protein, carbohydrate and total polyphenols. The protein content after enzymatic treatment using Pectinex CLEAR increased to 0.33% w/w from 0.17% w/w of the raw juice. Carbohydrate content also increased up to 3% from its initial value after treatment using Pectinex Ultra SP-L enzyme. Total polyphenols contents were slightly increased after treatment using both enzymes.

Degradation mechanism of pectin depends on the types of enzymes used. This explains the differences in chemical compositions, physicochemical parameters, vitamin C and total polyphenols between enzyme-treated juice and untreated juice. From the results, it was found that the effects of Pectinex Ultra SP-L and Pectinex CLEAR were different on white pitaya juice due to the different ways pectinases act on the pectins. This study showed the effect of pectinases application on the chemical composition, vitamin C and total polyphenols of white pitaya juice. The use of pectinase as a processing aid in the production of pitaya juice proved to be an important step in order to enhance the efficiency of the whole system [24].

Table 3: Vitamin C and total polyphenols contents of white dragon fruit juice

Treatment	Vitamin C (mg/100g)	Total Polyphenols (mg/100g)
Fresh fruit pulp (untreated pulp)	2.05±0.03	0.73±0.38
Control sample (pasteurized only)	2.09±0.01	1.12±0.42
Juice treated with Pectinex Ultra SP-L	1.56±0.006	0.81±0.12
Juice treated with Pectinex CLEAR	1.57±0.006	0.84±0.22

Values given are the mean of three replicates ± standard deviation

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PROFILE



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DETERMINATION OF WATER REQUIREMENT IN A PADDY FIELD AT SEBERANG PERAK RICE CULTIVATION AREA

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ABSTRACT

Malaysia experiences water shortages as a result of a combination of drought, urbanisation and pollution. [1]. There are regions of water stress mainly due to low water resources supply, high demands, large agriculture area with consumes a large portion of avaiable water, rapid industrialisation and increasing population and peak irrigation demand during the dry season. The distribution of the rainfall in time and space has resulted in limited availability of water of acceptable quantity for water supplies in some parts of the country [2]. More than 80% of the freshwater resources developed in Asia, are used for irrigation. Of this, more than 90% of the total irrigation water is used for rice production [3]. Water requirement is important in cultivation practices of rice involve water being supplied to the paddy fields before the planting activities begin. This study was carried out to determine the total water requirement needed for 1.82 hectares of paddy field in Seberang Perak rice cultivation area. Water is supply continuously until about 10 days before harvesting. Water is required to bring the fields to saturation, and to establish a layer of water in the fields to facilitate land preparation. There-after water is required to supplement natural losses from the fields and to satisfy the consumptive use by the plant. These two distinct phases of water requirement are termed as pre-saturation and normal growth period. Saturation of water, effective rainfall, evapotranspiration and seepage percolation will be calculated for determination of crop water requirement during the pre-saturation and normal growth periods. Pre-saturation and normal growth period involve 14 days and 105 days respectively. For the establishing of the water layer, an average of 10 cm had been used for the whole growing period. Saturation of water and seepage percolation had been calculated by using the data collected from the study area. Meteorological data from the nearby station had been used for calculation of evapotranspiration and effective rainfall. In this study, the result showed that the total of 775 mm of water needed to be irrigated in 1.82 hectares of paddy plot area. This total water requirement of the paddy field had been calculated for one season of paddy plantation.

Keywords: *Normal Growth Period, Paddy Field, Pre-Saturation Period, Water Requirement*

1.0 INTRODUCTION

Total annual water requirement for agricultural use are exceedingly large especially for rice. Water required by a rice crop in a given period of time need to be considering for normal growth under field conditions. The amount of water required for a given crop depends on state of development of soil, quantity and type of fertiliser given, quality of water used and the climatic conditions. Measurement or estimation of the rate of crop water use is required for determination of irrigation water requirement. The available water for irrigation, however, is becoming increasingly scarce due to decreasing resources and quality, and increased competition from nonagricultural water users [3]. Recently, the demand of water for industrial, municipal, and other use has been increasingly as less water will be available for agriculture.

In developing countries, the growth in water demand for industrial and municipal uses, in absolute terms, is expected to exceed the growth in water demand for agriculture between 1995 and 2020 [4]. As the main source of the irrigation, the decreasing quality of surface water nowadays will retard the normal growth of paddy. Surface water can be exposed to the environmental pollution easily. The dusts and the chemical materials from the

factory for instance will directly affecting the quality of the surface water.

Nowdays, groundwater has become an important source of water to meet the increasing requirement for domestic, industrial and agricultural needs [2]. Therefore, groundwater can be other alternative for irrigation of paddy. As an irrigation source, groundwater had been used in Malaysia in several places. In the Meranti Underground Irrigation Scheme, Kelantan, the water source was taken from groundwater. As the first underground irrigation scheme, it successfully prompted many similar schemes in the state.

In this study, the total water requirement for paddy plantation is determined so that the capability of the aquifer to fulfill the paddy field water requirement will be known.

Study Area

The Seberang Perak rice cultivation area is situated in Peninsular Malaysia in the state of Perak. It is located at Mukim Bandar where the specific location of this study is Blok C of Kampung Jejawi at Seberang Perak. Kampung Jejawi is situated to the left of Perak River and close to Teluk Intan, Kg. Gajah and Pasir Salak. This study area is located at latitude of 4°2' to 4° 9' North and longitude of 100° 55' to 101° 00' East where it is under the project of Integrated Agriculture Development Area (IADA), Ministry of Agriculture. This region is characterised by a warm and humid monsoon climate with average rainfall of 2393 mm (2000 to 2008). The type of soil in this region is clay loam. Planting of rice is the main activity among the residents of Kampung Jejawi. The main source of irrigation in the Seberang Perak is from the surface water which is Perak River. The method for planting the rice is by the direct seeding method. The area of this field is 1.82 hectares. The average time taken for pre-saturation is 14 days and the average of standing water depth is 10 cm for the whole season of planting.

2.0 LITERATURE REVIEW

Water Resources for Irrigation of Paddy Field

Lee *et al*., [3] reported that more than 90% of the world's rice is produced and consumed in Asia. More than 80% of the freshwater resources developed in Asia, are used for irrigation. Of this, more than 90% of the total irrigation water is used for rice production. Global rice demand in 2020 is projected to increase by 35% over the 1995 level. With this projected increase, the constraints on water resources will be further aggravated since most of the rice is produced with irrigation.

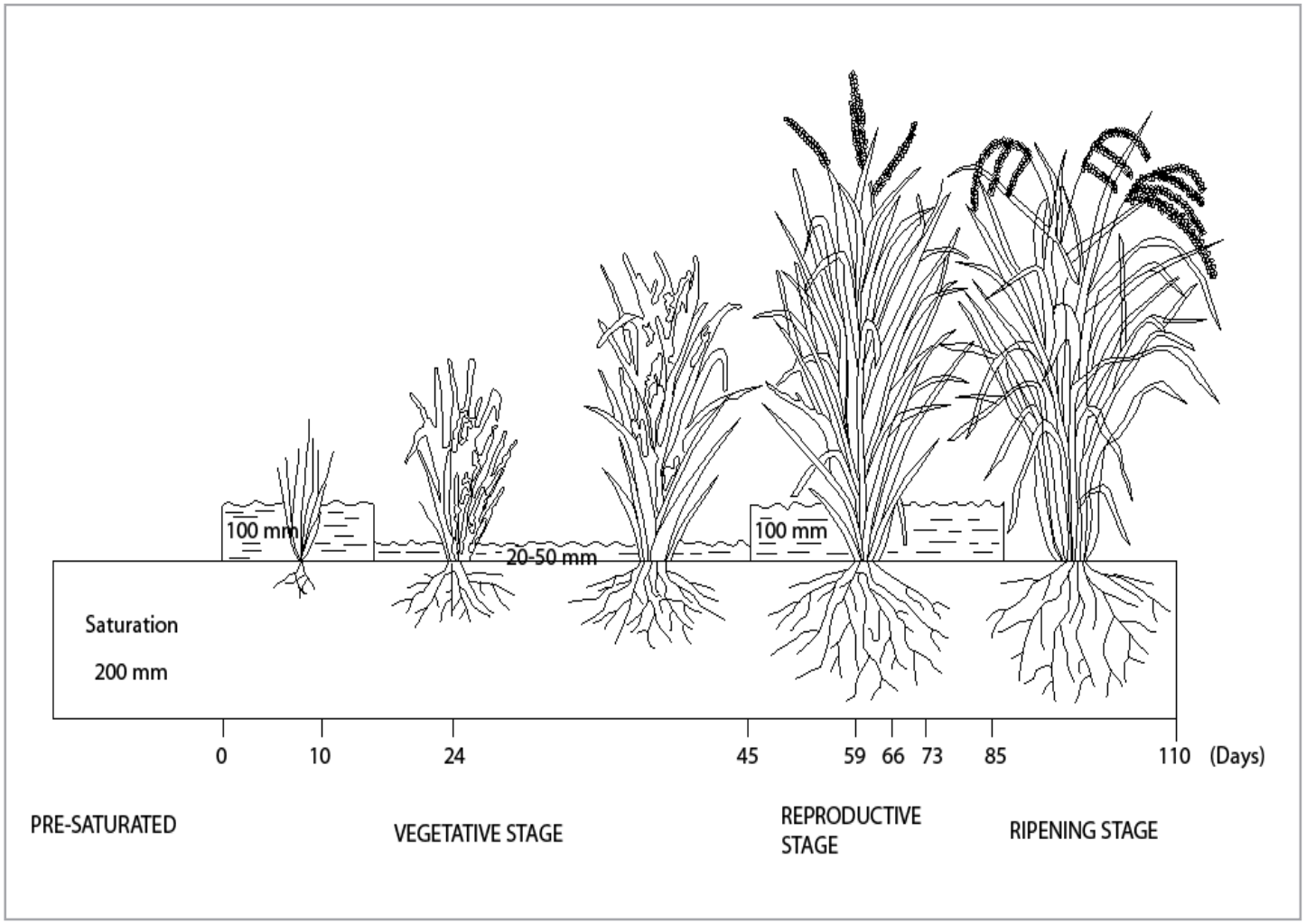


Figure 1: Water Level for Paddy at Different Growth Stages (Source: [8])

Water Requirement (WR) for Rice

The crop water requirement (*WR*) for paddy crops can be defined as the total depth of water needed to meet the water loss of disease free crop, growing in large fields under non-restricted soil conditions and achieving full production through the following processes which are pre-saturation on the field before cultivation, evaporation from field before and after direct seeding, evapotranspiration by paddy during the growth period to maturity, and percolation or infiltration loss [5].

Water Requirement for Pre-saturation Period

Thavaraj [6] indicated that *WR* for pre-saturation alone in Malaysia varied from about 400mm to 500mm, depending on the period required to complete pre-saturation, soil depth to be saturated, water depth to be maintained in the fields and soil porosity. The five factors that influence *WR* in the field during pre-saturation are evaporation from the unsaturated soil; evaporation from the saturated soil surface; infiltration and deep percolation; water required saturating the soil and *WR* for establishing a water layer in the field. To pre-saturate and inundate fields before planting of the crop, more than half of water supplied is being used for pre-saturation and the rice plant does not consume this pre-saturation water at it initial stage of growth. In order to avoid the delaying of planting of the rice during this pre-saturation period, the maximum capacity should be delivered. The *WR* for pre-saturation is theoretically 150 to 200mm, but it can be as high as 650 to 900mm when its duration is long (24 to 48days) [7]. In Malaysia, pre-saturation period will not exceed one month. For standing water depth, an average of 100mm is used for the pre-saturation period as shown in figure 1 below.

Water Requirement at Different Growth Stage of Rice Crop

Rice varieties of the tropics complete their cycle within a general range from 110 to 210 days. The growth of rice plant is divided into three phases which are vegetative, reproductive, and ripening phases. Figure 1 shows the water level at different stages of growth for paddy. In vegetative stage, the activities from transplant to panicle initiation take place. The duration varies from 1½ to 3 months. Vegetative stage includes the tillering. Tillering means that several stems develop on one plant. If the rice is sown directly (broadcast), the two stages combined are called vegetative stage. On mid season or reproductive stage the activities include from panicle initiation to flowering and the duration approximately one month. This stage includes stem elongation, panicle extension and flowering and late tillers may die. Late season or ripening stage contains activities from flowering to full maturity and the duration approximately one month. This stage includes grain growth. Table 1 shows the water requirement for rice cycle which indicate that the water requirement at the stage of vegetative, reduction and spikelet formation is very critical.

The Inflow of Water in the Paddy Field

(i) Effective Rainfall

Effective rainfall is the amount of water available for crop growth from rainfall except surface runoff loss. Effective rainfall during irrigation seasons depends on rainfall amount, rainfall intensity, topography, soil infiltration rate, soil moisture, water management practices and so on. [10]

Table 1: Water Requirement for rice cycle [9]

Day After Planting	Growth Stage	Requirement
30	Vegetative	Very critical
40	Active	Critical
60	Maximum	Critical
70	Initiation	Critical
80	Reduction	Very critical
100	Spikelet Formation	Very critical
115	Ripening	Not Required
130	Harvest	Not Required

Table 2: Water levels during rice cycle for broadcasting system [9]

Stage	Water Level
Rotovation	5cm
1 day before seed broadcasting	Drain all water
7 to 10 days after broadcasting	3 to 5cm
15 to 20 days before harvesting	Drain all water

(ii) Saturation

In the month before sowing or transplanting, water is needed to saturate the root zone. The amount of water needed is depends on the soil type and rooting depth [8]. For soil saturation depth, a Department of Irrigation and Drainage (DID) standard value of 150 mm is applied [3].

(iii) Establishment of Water Layer

A water layer is established after transplanting. By determination of the percolation and seepage losses the amount of water needed for maintaining the water layer has already been taken into account. However the amount of water needed to establish the water layer still has to be considered. Various approaches are being used with respect to the depth of the water layer. Sometimes a water layer of 100mm is established after transplant and maintained throughout the growing season [8]. In other cases the water layer is reduced to 20 to 50 mm during the latter part of the vegetative stage and brought back to 100 mm during the mid-season stage as shown in figure 1. Table 2 shows the water level during rice cycle for broadcasting system.

Water Losses in the Paddy Field

Water is lost through evaporation (*E*) from free surface, transpiration (*T*) from the crop, seepage and percolation of the soil, bund leakages and runoff from the field.

(i) Evapotranspiration (*ET*)

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes [11]. Since it difficult to separate *E* and *T* during crop growth, they are often expressed in one term; evapotranspiration (*ET*). At sowing nearly 100% of *ET* comes from evaporation, while at full crop cover more than 90% of *ET* comes from transpiration [11].

(ii) Seepage and Percolation, S and P

Percolation represent the rate of the vertical movement of water beyond the root zone to the water table, while lateral seepage represents the rate of the movement of subsurface water between fields [12]. Because of seepage and percolation occur simultaneously and are difficult to separate in the field, therefore they are usually considered together. Wickham [13] found that percolation and seepage as the most elusive components in conducting water balance studies due to the difficulty of making accurate measurements. In most cases he found that a clear differentiation is not possible between the two components and they are, therefore, considered together.

By depending upon texture and structure of the soil, depth of water table, depth of field submergence and intensity of puddling, a considerable amount of water in flooded rice is lost as percolation [14]. Kung *et al*., [15] reported that *WR* of rice in Thailand ranged from 520 to 2549mm out of which 273 to 1275mm was percolation. *WR* values of 750-2500mm were reported by Dastane *et al.*, [16] for India from which about 60% was lost as percolation. In general, percolation rates may range from 1mm per day in well-puddled heavy soils to 20mm per day or more in light textured soils [15].

3.0 METHODOLOGY

Crop Water Requirement

The water required during pre-saturation period can be calculated as in Equation (1) as follows:

$$WR_{ps} = SAT + WD_i + E + SP - EFR \quad (1)$$

Where,

WR_{ps} is water requirement during pre-saturation (mm), *SAT* is saturation water (mm), WD_i is initial depth of flooding (mm), *E* is evaporation rate (mm), *SP* is percolation loss (mm) and *EFR* is effective rainfall (mm).

Water required during the normal irrigation supply period, can be calculated by using the formula like shown in Equation (2) below like suggested by Lee *et al.*, [3]:

$$NIR = ET_j + SP_j + RP_j - WD_j - ERF_j \quad (2)$$

Where,

NIR is net irrigation requirement (mm), ERF_j is effective rainfall (mm), *RP* is required ponding depth (mm), *ET* is crop evapotranspiration (mm), *SP* is seepage and percolation (mm), *WD* is water depth in the field (mm) and *j* is period of water management.

The *RP* and *WD* value is being taken to be equal for this calculation. Therefore, the formula for calculating water requirement for normal growth is like shown in Equation (3) below:

$$NIR = ET_j + SP_j - ERF_j \quad (3)$$

Where,

NIR is net irrigation requirement (mm), ERF_j is effective rainfall (mm), *ET* is crop evapotranspiration (mm), *SP* is seepage and percolation (mm) and *j* is period of water management.

The Inflow of Water into the Paddy Field

(i) Saturation of Water

Saturation of paddy soil which depends on the porosity of the soil and depth of the top soil can be calculated as in Equation (4) below:

$$SAT = n \times D \quad (4)$$

Where,

SAT is saturation (mm), *n* is porosity of the plow layer soil (%) and *D* is depth of the plow layer (mm). There are 7 points of the soil porosity at the plow layer that had been taken for analysing. The depth of the top soil had been determined as 8 cm by analysing the soil resistance result that had been taken by using the soil penetrologger

(ii) Initial Depth of Flooding

For Seberang Perak Irrigation Schemes, an average of 10 cm is being taken as the initial depth of flooding.

(iii) Effective Rainfall

In Seberang Perak irrigation scheme, where water is continuously supplied, excess water is drained whenever it exceeds maximum allowable level of water in the field. Surface runoff in this study area is considered to be zero because of the area of paddy field is flat.

Lee *et al.*, [3] suggested that for weekly calculation, effective rainfall can be calculated as in Equation (5) below:

$$ERF = 0.6 \times RF \text{ if } RF < 50 \text{ mm/week}$$

or

$$ERF = 0.3(RF - 50) + 30 \text{ if } RF > 50 \text{ mm/week} \quad (5)$$

Where,

EFR is effective rainfall (mm/week) and *RF* is rainfall (mm/week). The weekly rainfall is being calculated by using the summation of the rainfall in the whole week. Daily rainfall data for calculation of effective rainfall had been taken from the Hospital Teluk Intan Station.

Water Losses in the Paddy Field

(i) Evaporation Rate (*E*)

In the early stages of crop growth, most water is used through evaporation. Therefore evaporation rate is important to be taken into the water requirement of the pre-saturation period. The value of *E* had been taken from the climatologically data of Hospital Teluk Intan Station.

(ii) Crop Evapotranspiration (*ET*)

The estimation of consumptive use for irrigated crops is determined by the crop coefficient-reference *ET* procedure. Reference *ET* (ET_o) is computed for a hypothetical reference crop according to the FAO paper no. 56 methodology [9] and is then multiplied by an empirical crop coefficient (K_c) to produce an estimate of crop *ET*, as in Equation (6):

$$ET_c = K_c \times ET_o \quad (6)$$

Where,

ET_c is crop evapotranspiration (mm/day), K_c is crop coefficient and ET_o is reference evapotranspiration (mm/day).

Accordingly, the ET_o is calculated using the FAO Penman-Monteith method recommended in FAO paper no. 56, which use all parameters that govern energy exchange and corresponding latent heat flux (evapotranspiration) from uniform expanses of vegetation. Most of the parameters are measured or can be calculated from weather conditions. It requires daily, weekly and monthly meteorological data including air temperature, humidity, sunshine duration and wind speed. The FAO Penman-Monteith equation used for 24 hour calculation of ET_o and using daily or monthly mean data can be simplified as in Equation (7):

$$ET_o = \frac{0.408\,\Delta\,(R_n - G) + \gamma\,(900/T) + 273]\,u_2(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34u_2)} \quad (7)$$

Where,

ET_o is reference evapotranspiration (mm/day), Δ is slope of saturated vapour pressure per temperature curve (kPa/ ºC), γ is psychrometric constant (kPa/ ºC), u_2 is wind speed at 2m height (m/s), R_n is total net radiation at the crop surface (MJ/m^{2}day), *G* is soil heat flux density (MJ/m^{2}day), *T* is mean daily air temperature at 2m height (ºC), e_s is saturation vapour pressure (kPa) and e_a is actual vapour pressure (kPa).

The meteorological data for computing reference evapotranspiration include maximum and minimum temperature (ºC), maximum and minimum relative humidity (%), wind speed at 2m height (m/s), height above mean sea level altitude (m), solar radiation (MJ/m^2), and latitude. The daily values of all

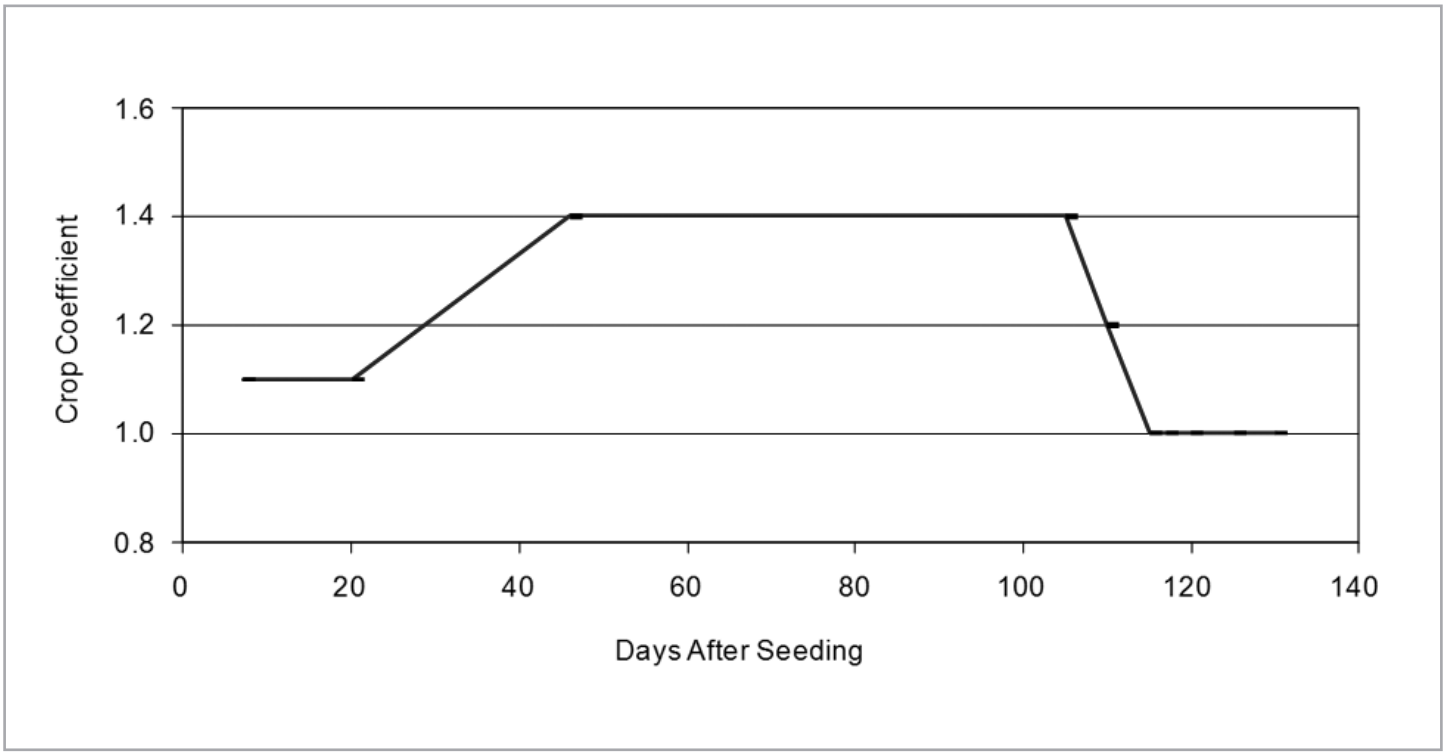


Figure 2: Suggested crop coeffient, K_c values for Rice (MR84) [18]

Table 3: Crop Coefficient, K_c value for rice [18]

Days(after seeding)	7	20	46	105	110	115	117	120	125	130
K_c	1.1	1.1	1.4	1.35	1.2	1	1	1	1	1

components to calculate reference evapotranspiration, were taken from Hospital Teluk Intan (latitude: 4° 02'N; longitude: 101° 01'E) station.

Crop coefficients can be influenced by cultivation, local climatic conditions and seasonal differences in crop growth patterns [17]. The crop coefficient in this study was referred from the result of Chan and Cheong [18]. Chan and Cheong determined crop coefficient values for rice field in Tanjung Karang which are shown in Figure 3 and Table 3. This might be useful for rice in Seberang Perak Irrigation Schemes.

(iii) Seepage and Percolation (S and P)

Seepage and percolation are two movements that often practically inseparable [19]. The deep percolation (*DP*) is the amount of water goes deeper into the soil (below the root zone) vertically. *DP* is influenced by changes in the conditions of rice fields including soil texture and structure, top and subsoil thickness, standing water depth, water and soil temperature and salinity, depth to the groundwater table, and other topographical conditions [19].

Darcy's law was used for estimation of daily percolation rate out of the root zone layer [20] and is given as Equation (8) below:

$$DP = \frac{-K_s \, \Delta h}{\Delta Z} \tag{8}$$

Where,

DP is percolation out of the root zone (mm per day); K_s is the saturated hydraulic conductivity (mm per day; after accounting for puddling effects) and $\Delta h/\Delta z$ the head gradient [21].

For determination of hydraulic conductivity, the formula as shown in Equation (9) below:

$$K_s = \frac{\sum Z}{\frac{Z_1}{K_1} + \frac{Z_2}{K_2}} \tag{9}$$

Where,

K_s is saturated hydraulic conductivity (cm/s), K_1 is hydraulic conductivity at medium 1 (cm/s), K_2 is hydraulic conductivity at medium 2 (cm/s), $\sum Z$ is total thickness of layer (cm), Z_1 is thickness of the layer 1 (cm) and Z_2 is thickness of the layer 2 (cm).

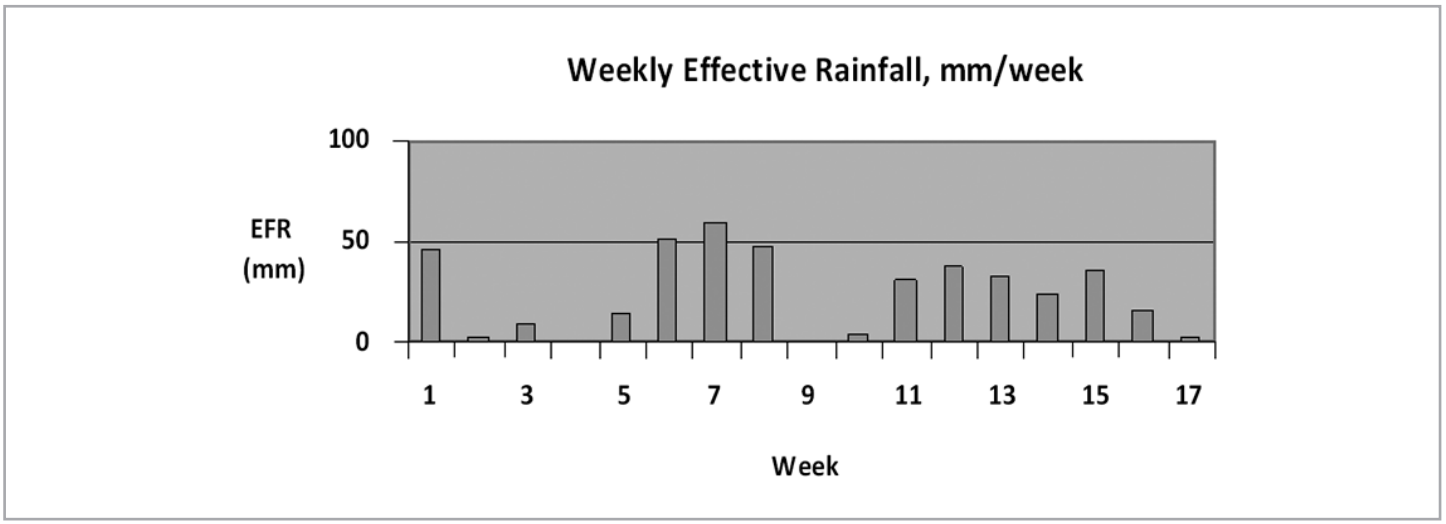


Figure 4: Weekly effective rainfall which depends on different conditions

Site Description

Five soil water pressure sensors were installed at the field of paddy to monitor the pressure of the soil. Proper installation had been done at five different depths which are 5, 20, 40, 65 and 75 cm. Before the installation, the device was soaked in the water for several days to make sure that all the pores in the device are filled with water. Then, the device was coated with the soil to make sure that there will be a contact between the soils and watermark sensor after installation. Data are recorded using the data logger which been connected. Time interval for each measurement is 60 minutes. A longer period of data reading will be able to take by using this data logger.

Climatogical Data Collection

The daily climatologically data that is being used for calculation of water requirement are supplied by the Malaysian Meteorological Department. The lists of daily data are from year of 2000 until year of 2008. Daily data of rainfall, maximum and minimum temperature, 24 hour mean relative humidity, maximum surface wind speed and direction, evaporation, solar radiation and cloud cover had been used.

4.0 RESULTS AND DISCUSSIONS

Determination of Crop Water Requirement

Saturation of water, effective rainfall, evapotranspiration and seepage percolation are the parameters included in the formula of crop *WR* determination. Two components important in the determination of saturation of water are soil porosity and depth of the plow layer. The soil porosity at plow layer is 51.69%. The value of saturation of water is 41 mm. Figure 4 below shows the calculated weekly effective rainfall which depends on different conditions.

The daily calculation of crop evapotranspiration is based on the formula of crop coefficient multiplying by reference evapotranspiration. Table 3 shows the changes value of crop coefficient which depends on the day of growth. The starting value which is 1.1 had been used after seven days of seeding. The results from soil water pressure sensors show that the values of soil moisture are 0 kPa for depth of 5, 20 and 45 cm. This shows that the soil of the field is saturated. As the water requirement in the paddy field needs to be determined so that capability of the aquifer be known, the value of 3mm/day for percolation will be used in this calculation. This recommended value is based on the findings from many fields tests on *SP* conducted by the Ministry of Agriculture, Malaysia and published by the *Asian Development Bank* (ADB) [22] and it is assumed to be constant throughout the growth period.

Total Water Requirement for One Season

The calculation of *WR* is based on the weekly condition where the summation of evaporation (*E*), evapotranspiration (*ET*), and seepage and percolation (*SP*) are needed for the whole week. The weekly value of effective rainfall that had been calculated previously will be used directly in the formula. The saturation value which is 42 mm and 100mm of initial depth of flooding value will be used for calculation of *WR* during pre-saturation for the whole week. While the daily value of evaporation and seepage percolation will be summed respectively for the whole seven days. The duration of pre-saturation period is 2 weeks. Total *WR* of the study area is the summation of the *WR* during pre-saturation and during normal growth of period. Total *WR* is 775 mm/season and the volume of water needed for one season is 13,010 m^3. Table 4 below shows the water requirement during pre-saturation and normal growth period calculated from the formula suggested as in Equation 1.

Flow Rate of Paddy Field

The calculation of flow rate is based on the formula of total *WR* which is 775 mm/season multiplying by the area of paddy field which is 1.82 hectares. The total growth is 119 days where the duration of pre-saturation and normal growth is 14 days and 105 days respectively. The value of flow rate is 1.36 l/sec.

Table 4: Water requirement during pre-saturation and normal growth period

WEEK	PRE-SATURATION	NORMAL GROWTH
1	*140*	*-*
2	*189*	*-*
3	*-*	*41*
4	*-*	*52*
5	*-*	*36*
6	*-*	*3*
7	*-*	*-14*
8	*-*	*2.4*
9	*-*	*50*
10	*-*	*60*
11	*-*	*33*
12	*-*	*21*
13	*-*	*20*
14	*-*	*33*
15	*-*	*11*
16	*-*	*42*
17	*-*	*56*
TOTAL (mm)	*329*	*446*
WR (mm/season)	*775*	

5.0 CONCLUSIONS

The main objective of this study is to determine the *WR* in a paddy field for one season of paddy plantation. This *WR* needs to be determined so that the capability of the aquifer to fulfill the paddy field *WR* will be known. The summation of calculated weekly effective rainfall is 409 mm/season. Besides that, the losses like deep percolation and *ET* also the main parameters in calculating the *WR*. The amount of deep percolation and *ET* in this study area is 357 mm/season and 491 mm/season respectively. From the results, there is a difference between *WR* during pre-saturation and during normal growth where during the pre-saturation period, saturation of water and water level of paddy field need to be considered. *WR* during pre-saturation is 329 mm and during normal growth is 446mm. Overall, *WR* in a paddy field is 775 mm/season where the volume of water required for one season is 1.4 x 104 m^3. This means that the potential of groundwater to be extracted should meet the amount of water needed for the paddy plantation activities. ■

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SEBERANG PERAI RICE SCHEME IRRIGATION WATER QUALITY ASSESSMENT

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ABSTRACT

Rivers are the main sources of water for agricultural purposes in Malaysia. The Seberang Perai Rice Irrigation Scheme in the state of Penang is one of the eight main rice growing areas in Malaysia. The scheme consists of five (5) sub-schemes and irrigation water for each sub-scheme are supplied from either the Muda river, Jarak river, Kulim river or the Kerian river with pumping or gravity intakes. Agricultural fertilisation entails significant economic and environmental costs. Nitrogen (N) is the most commonly applied nutrient in crop production. However, excess N inputs, pesticides, and herbicides for rice crop not only adds costs to crop production but can be environmentally damaging to the plant and the environment. This study was carried out to improve irrigation water quality in order to ensure that environmental concerns are built into the operation and monitoring activities of the rice irrigation scheme. Water quality data were used to determine the water quality status whether in clean waters (80-100), slightly polluted waters (60-<80) or very polluted waters (<60) category and to classify the rivers in Class I, II, III, IV or V based on existing Water Quality Index (WQI). From 18 years-data for the period from 1990 – 2007, Water Quality Index (WQI) was computed based on 6 parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3N), pH, Dissolved Oxygen (DO) and Suspended Solids (SS) as a means for water quality assessment. Increasing DO concentration and concurrent low concentrations of BOD and COD is the trend in the scheme. WQI calculated in this study ranged from 69.9% to 82.2%. Two rivers (Kerian and Jarak River) were considered slightly polluted in comparison with the general rating scale of the water quality index. Agricultural activities may be contributing to this trend, but water quality nonetheless is also affected seriously by through industrial and domestic use. The data also showed that the Muda and Kulim River is relatively clean. However, there is not much difference in the water quality index of the four rivers, between upstream and downstream sections. Based on the results of this study and it must be qualified here that the results are only referring to the period of the data sourced, the water quality of the rivers can be classified into Class III and IV by on overall river classification based on the DOE-WQI. The results of this study can be a basis for future studies on irrigation water quality in the other projects.

Keywords: *Rice Irrigation, Seberang Perai Scheme, Water Quality Assessment, Water Quality Index*

1.0 INTRODUCTION

Water scarcity, pollution, and other water-related environmental and ecological problems have been increasing rapidly in many areas of the world. In some countries and regions, water is already being transferred out of irrigation and into urban industrial uses, putting additional stress on the performance of the irrigation sector [4]. Although the achievements of irrigation in ensuring food security and improving rural welfare have been impressive, past experience also indicates problems and failures of irrigated agriculture. In addition to large water use and low efficiency, environmental concerns are usually considered the most significant problem of the irrigation sector. Environmental problems include excessive water depletion, water quality reduction, waterlogging, and increase salinity. The marked reduction in annual discharge of some of the world's major rivers, evident in long-term hydrological records has been attributed, in part, to the large water depletion as a result of irrigated agriculture. In some basins, excessive diversion of river water for irrigation

(and other uses) has brought environmental and ecological disasters to downstream areas. Groundwater pumping at unsustainable rates has contributed to the lowering of groundwater tables and to saltwater intrusion in some coastal areas. Many water quality problems have also been created or aggravated by changes in stream flows associated with agriculture's consumptive uses. Moreover, inappropriate irrigation practices, accompanied by inadequate drainage, have often damaged soils through over-saturation and salt build-up. The United Nations Food and Agriculture Organisation estimated that between 60 to 80 million hectares are affected to varying degrees by water logging and salinity [1]. Finally, these irrigation induced environmental problems threaten not only agricultural production systems but also human health and the environment.

Improved water management can help minimise offsite water quality impacts of irrigated production. Irrigated agriculture affects water quality in several ways, including higher chemical-use rates associated with irrigated crop production, increased field salinity resulting from applied water, accelerated pollutant transport with drainage flows, groundwater degradation due to increase deep percolation to saline formations, and greater in-stream pollutant concentrations due to flow depletion. Although agriculture is usually associated with its positive impacts on human life, irrigation practices may be associated with negative impacts on environmental conditions, which may eventually curtail the sustainability of irrigation projects. Environmental management of available rice water is essential for increased crop production. Environmental management that improves irrigation efficiency has the potential to greatly increase rice production as well as social livelihood. Irrigation projects have an imperative importance in third world countries to realise development policies like poverty reduction and food self sufficiency but such projects are usually given much societal considerations nevertheless they should be environmental friendly so as to assure their sustainability maintaining the existing productivity.

In the past, the environmental problems in Malaysia were largely due to discharges from the agro-based sector mainly rubber and palm oil industries, and domestic sewage. The control of pollution from processing of raw natural rubber and crude palm oil has proven to be very successful and resulting in the organic wasteload reduction of more than 90% of the total load generated. As the country progresses in industrialisation, a new set of environmental problem emerges.

Table 1: River water quality parameters for morning system

Water Quality Classes*						
Parameter	**I**	**IIA**	**IIB**	**III**	**IV**	**V**
Ammoniacal Nitrogen (NH_3N) (mg/l)	0.1	0.3	0.3	0.9	2.7	2.7
BOD (mg/l)	1	3	3	6	12	12
COD (mg/l)	10	25	25	50	100	100
DO (mg/l)	7	5-7	5-7	3-5	3	1
SS (mg/l)	25	50	50	150	300	300
pH	6.5-8.5	6.5-9.0	6.5-9.0	5.0-9.0	5.0-9.0	–
Phosphorus (mg/l)	N.L	< 0.2	< 0.2	< 0.1	–	0.1 <
Nitrate (mg/l)	–	–	–	–	–	

N. L. = Natural levels

Source: Department of Environment, Malaysia

**Class I : (Water Supply I) No treatment necessary, (Fishery I) Acceptable for very sensitive aquatic species*

**Class IIA : (Water Supply II) Conventional treatment required, (Fishery II) Acceptable for sensitive aquatic species*

**Class IIB : Acceptable for recreational use with body contact*

**Class III : (Water Supply III) Extensive treatment required, (Fishery III) Acceptable for common and tolerant species. Acceptable for livestock drinking*

**Class IV : Acceptable for irrigation*

**Class V : None of the above*

Table 2:. Formulae for calculation of Water Quality Index (WQI)

Index	WQI Calculation	Ranges
NH_3N (SIAN)	$= 100.5 - 105\ x$ $= 94\ e^{0.573x} - 5\ \lvert x - 2 \rvert$ $= 0$	For $x \leq 0.3$ For $0.3 < x < 4$ For $x \geq 4$
BOD (SIBOD)	$= 100.4 - 4.23\ x$ $= 108\ e^{0.053x} - 0.1\ x$	For $x \leq 5$ For $x > 5$
COD (SICOD)	$= - 1.33\ x + 99.1$ $= 103\ e^{0.0157x} - 0.04\ x$	For $x \leq 20$ For $x > 20$
DO* (SI DO)	$= 0$ $= 100$ $= - 0.395 + 0.03\ x^2 - 0.0002\ x^3$	For $x \leq 8$ For $x \geq 92$ For $8 < x < 92$
SS (SISS)	$= 97.5\ e^{0.00676x} + 0.05\ x$ $= 71\ e^{0.0016x} - 0.015\ x$ $= 0$	For $x \leq 100$ For $100 < x < 1000$ For $x \geq 1000$
pH (SIPH)	$= 17.2 - 17.2\ x + 5.02\ x^2$ $= - 242 + 95.5\ x - 6.67\ x^2$ $= - 181 + 82.4\ x - 6.05\ x^2$ $= 536 - 77\ x + 2.76\ x^2$	For $x < 5.5$ For $5.5 \leq x < 7$ For $7 \leq x < 8.75$ For $x \geq 8.75$
WQI	$= 0.15$ x SIAN + 0.19 x SIBOD + 0.16 x SICOD + 0.22 x SIDO + 0.16 x SISS + 0.12 x SIPH	

** = DO is in % saturation*

x = concentration in mg/l for all parameters except pH

The major sources of water pollution in the country remain as sewage disposal, discharges from small and medium-sized industries that are still not equipped with proper effluent treatment facilities and land clearing and earthwork activities. Based on 2005 records, 52 river basins (44%) were polluted with suspended solids (SS) resulting from poorly planned and uncontrolled land clearing activities; 18 river basins (15%) with high biochemical oxygen demand (BOD) resulting from industrial discharges; and 33 river basins (28%) polluted with ammoniacal nitrogen (NH_3N) from animal husbandry activities and domestic sewage disposal [5]. The objective of the study is to analyse irrigation water quality for better management and monitoring activities of a rice irrigation scheme, in this case the Seberang Perai Scheme.

2.0 STUDY AREA

Although irrigation in Malaysia is almost entirely devoted to rice cultivation, rice production still fall short of the demand of an increasing population. The eight designated granaries (granary areas are by law not allowed to be used for purposes other than rice growing) totaling 217,000 ha are located for rice cultivation in Malaysia producing 65% of the country's needs. However, with the addition of about 45,000ha of land put under rice cultivation in Sabah and Sarawak in 2009, it is expected to raise the level to some 85%. With the changing trends among the younger population going with less rice as a staple, the country may see a surplus for export in the near future. The Seberang Perai Rice Irrigation Scheme is located at about 100^0 8' ~ 100^0 32'E longitude and 5^0 8' ~ 5^0 32'N latitude. The scheme area covers an area of 10,999 ha of rice land. The scheme consists of five sub-schemes and has four main water sources. The irrigation water for the Sungai Muda and the Pinang Tunggal sub-schemes is taken from the Muda river through the Bumbong Lima pump station and the Pinang Tunggal pump station, respectively. A part of water pumped up at Pinang Tunggal pump station flows into the Kreh river, a tributary of the Jarak river and is then used as irrigation water for the Pokok Tampang Block in the Sungai Jarak sub-scheme. A headwork and the Padang Cempedak pump station on the Jarak river also supply water to the Pokok Tampang Block as well as the Padang Menora Block also in the Sungai Jarak sub-scheme. The Sungai Kulim sub-scheme is provided irrigation water from the Sungai Kulim headworks on the Kulim River. In the Sungai Acheh sub-scheme, water for irrigation is mainly supplied from a headwork on Kerian river.

Table 3: General rating scale for the water quality index (Percentage) in Malaysia

USAGE/INDEX (%)	10	20	30	40	50	60	70	80	90	100 %
GENERAL	VERY POLLUTED					SLIGHTLY POLLUTED		CLEAN		
PUBLIC WATER SUPPLY	NOT ACCEPTABLE			DOUBTFUL	NECESSARY TREATMENT BECOMING MORE EXTENSIVE			MINOR PURIFIC REQUIRED	PURIFICATION NOT NECESSARY	
RECREATION	NOT ACCEPTABLE	OBVIOUS POLLUTION APPEARING	NOT FOR BOATING	DOUBTFUL FOR WATER CONTACT	BECOMING POLLUTED STILL ACCEPTABLE NEED BACTERIA COUNT		ACCEPTABLE FOR ALL WATER SPORTS			
FISH, SHELLFISH AND WILDLIFE	NOT ACCEPTABLE		COARSE FISH ONLY	HANDY FISH ONLY	DOUBTFUL FOR SENSITIVE FISH	MARGINAL FOR TROUT	ACCEPTABLE FOR ALL FISH			
NAVIGATION	NOT ACCEPTABLE		OBVIOUS POLLUTION APPEARING	ACCEPTABLE						
TREATED WATER TRANSPORTATION	NOT ACCEPTABLE	ACCEPTABLE								
	10	20	30	40	50	60	70	80	90	100 %

3.0 WATER QUALITY ANALYSIS

An environmental water management program requires information including the existing water quality, the influence of human activities on water quality and criteria for the present and planned uses. This information can be generated only from a record of long term water quality data and past experience of the use of water of known quality for the various purposes.

Parameters

A permanent water quality monitoring system that is designed particularly to check the quality of drainage water from the paddy fields as well as to monitor effectiveness of management actions such as controlling the use of agro-chemicals by farmers would be of utmost importance but however, currently is not available. Table 1 indicates a list of the parameters, which is a minimum requirement set required for a monitoring system. Other parameters can be included when it is necessary. The standard value of each parameter within the various water quality classes, which are defined by the Department of Environment, Malaysia (DOE) are also shown, and water quality should be maintained above the Class III classification at all times.

Water quality parameters were collected from DOE Pulau Pinang, during the field survey. The data from the DOE stations were analysed to give an overall picture of the water quality condition of irrigation water. In the interpretation of water quality data it is important to understand and acknowledged the spatial trends of parameters such as dissolved oxygen, biochemical oxygen demand and chemical oxygen demand. These spatial trends are especially important for water quality modeling as it will roughly indicate the assimilative capacity of the river. Changes in general water quality can also be evaluated with the water quality index (WQI) being adopted by the DOE. Using WQI values for the evaluation of drainage water allows for comparison with other water quality data.

Water Quality Index

The Department of Environment (DOE) has been conducting monitoring of rivers since 1978, primarily to establish the status of water quality, detect changes and identify pollution sources. Water quality data were used to determine the water quality status in clean, slightly polluted or polluted categories and to classify the rivers into Classes I, II, III, IV or V based on the all important WQI. The formula for the calculation of WQI is presented in Table 2, and is computed based on the six main parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3N), pH, Dissolved Oxygen (DO) and Suspended Solids (SS). The general rating for the water quality index in Malaysia is presented in Table 3. At the moment there is apparently no systematic water quality monitoring system to particularly check a level of agro-chemicals in the water for irrigation. However, even if there is, sample sizes are expected to be rather small and data collection is not coherent and thus the data cannot be directly compared.

4.0 DATA

Technical and socio-economic field surveys were carried out in the study area. Drawing upon information identified in the literature and gathered from responses to the unstructured questionnaire, the main environmental impacts were identified, and assessed in terms of their current and likely future importance for agriculture and the environment. Much of this information was of qualitative in nature (for example, based upon expert opinion), the assessment has been a predominantly qualitative one. Data collection on rainfall, water quality parameters (BOD, COD, SS, NH_3N, DO, pH), were done during the field survey. The data covers the 18-year period of 1990 through to 2007 and was provided by DOE. Crop information relevant to the study such as fertiliser, pesticide, herbicide and yield was made available from the Department of Agriculture. Other crop information such as growth period, length of crop, agronomic practices were gathered from domain experts while a few were extracted from available publications. The knowledge on water management in the Seberang Perai Rice Irrigation Scheme was gathered from domain experts; the project engineer, assistant executives, irrigation engineers and field operation staff from the Department of Irrigation and Drainage through unstructured interviews or discussions, field visits, reports and documents available on the management aspects in the scheme.

5.0 AGRICULTURAL INPUTS

Application of Fertilisers

Urea at 100 kg/ha and compound fertiliser (17.5 : 15.5 : 10) of 200 kg/ha based on an agronomic recommendation of 80 kg of Nitrogen, 30 kg of P_2O_5 and 20 kg of K_2O are subsidised for each crop season. Most of farmers in the scheme depend on the subsidised fertiliser of about 80 kg/ha only while some farmers opted on their own to apply additional fertilisers at their own expense. Compound fertilisers are commonly used as additional fertilisers. The fertiliser application method according to the Malaysian Agricultural Research and Development Institute (MARDI) recommendation is adopted in the scheme. Average fertiliser application amounts in the scheme are as follows: Urea – 94.1 kg/ha, Compound – 156.5 kg/ha, Others – 48.9 kg/ha, Nitrogen Contents – 78.0. Applications of fertilisers by farmers who practice direct seeding are made between 14 to 75 days after seeding. Manual broadcast of fertilisers is the common practice where farmers use motor blowers. According to the "*Reconnaissance Soil Survey of Pinang and Province Wellesley*", the majority of soils in the scheme are classified as Class I or II of soil suitability class for agriculture. In general, it can be said that the scheme has the potential to support good plant growth with good yields. However, some cases of copper deficiency had been reported during the field survey.

Pesticide and Herbicide Use

Pests account for about 30% of agriculture crop losses in the field a further 10-12% in storage [3]. The pests include insects, plant diseases, weeds, mites, rats and others. Various techniques could be employed to control these pests; for example by destroying them directly (mechanical control), utilizing temperature or humidity to reduce the survival of pests (physical control), modifying the agriculture ecosystem in ways that makes it no longer suitable for pests to live in (cultural control), controlling the entry and movement of the pests (legislation control), utilizing the natural enemies of the pests (biological control), manipulating the immunity of the crop against the pest (host-plant control). The most common method used here to control pests is through chemical control using pesticide. A pesticide is known as the chemical tool used to manage all kinds of pests by controlling, preventing, repelling, destroying or mitigating any pest. The farmer's preference of using pesticides to control pests is due to pesticides being easy to obtain and use. They provide the result expected by the farmers and is probably the only tool available when there is an outbreak of the pest.

The shift to direct seeded rice in the country has aggravated the pest problem, especially weeds and insects. Apart from the impact on pest species, direct seeding has also affected the pest surveillance and forecasting techniques as the techniques were previously based on a transplanting modus operandi. Operations to control outbreaks have become more difficult to implement effectively, especially if the crop has reached the maximum tillering stage and beyond. Among the insects reportedly becoming more prominent as a result of implementing direct seeding are the brown plant hoppers and the leaf rollers.

The problem of weed competition with rice is of great economic importance in Malaysia because it causes a 10–35% reduction in grain yield. About RM14.5 million is spent annually on herbicides for rice alone, and this amounts to approximately 7% of the total expenditure on herbicides [2]. Weed management is critical to ensure good yields with the direct seeding method. Hence with the introduction and establishment of direct seeding emphasis was and is being given to weed control. It has been observed that 2 - 4 weed species are dominant in the scheme. The noxious weed, *E. crus-galli* is dominant in plots. Grassy weeds, especially *E. crus-galli* and *L. chinensis*, still remained dominant in direct-seeded rice fields. Graminicides, especially molinate, at the rate of 3.0 kg ai ha^{-1} is applied at 7 days before seeding or 14 days after seeding. Sulfonylurea herbicides such as bensulfuron, metsulfuron, pyrazosulfuron and cinosulfuron are often used for broad-leaved weed control, while chlorimuron is used in areas heavily infested by sedges in the scheme. Some farmers who adopted the practice with chemical control, usually used the phenoxy compound 2,4-D sufficiently to control the broad-leaved weeds. Farmers in the scheme are advised to prepare land well, practice good water management together with appropriate herbicide technology. The scheme stressed that water management is very important to keep weed population down in paddy field.

6.0 RESULTS AND DISCUSSIONS

6.1 Water Quality Parameters

Water pH

pH is important in natural waters and in water treatment. Aquatic organisms are sensitive to pH changes and require a pH value from 6 to 9. The pH measures in logarithmic scale 1-14, where 7 is neutral, 1 is extremely acidic and 14 are extremely

alkaline. The pH values in the study area range from 5.10 to 8.15 with the average value of 6.63. The highest pH value was found in the Muda River while the lowest value in downstream of the Kerian River. The average pH values were 6.76, 6.39, 6.37 and 5.72 for the Muda, Kulim, Jarak and Kerian rivers, respectively. The pH values are slightly below neutral value. This indicates that only minimal amount of acidic industrial effluents had been discharged into the rivers. But all the pH values are within the permissible limit (Class IV) for irrigated agriculture.

Dissolved Oxygen (DO)

The DO test is one of the most important analyses in determining the quality of the natural waters. The effect of oxidation of wastes on streams, the suitability of water for fish and other organisms and the progress of self-purification can be evaluated from the dissolved oxygen content. The oxygen content of water depends on physical, chemical biological and microbiological processes.

The analysis for DO is a key test in water pollution and waste treatment process control. Oxygen is vital for the life cycle of living organisms in waterways. It is also essential to sustain species reproduction and development population. Standards for DO vary but the following recommendation serve as a guide for fresh water fish. Habitats for warm water fish population should contain DO concentrations of not less than 4.0 mg/L. Habitats for cold-water fish population should not be less than 5.0 mg/L. Rivers of the Seberang Perai Irrigation Scheme showed a wide range of DO levels ranging from 1.5 to 7.2 mg/L. The average value was found to be 4.35 mg/L which falls into Class III.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand test for natural water yields the oxygen equivalent of the organic matter that can be oxidised by a strong chemical oxidising agent in an acidic medium. For samples from a specific source, COD can be positively correlated to BOD, organic carbon or organic matter. The COD observed in natural streams and rivers may range from 2mg/L to 100 mg/L. Of the 4 DOE River sampling stations, one was found to have values greater than 50 mg/L, the standard for class III. The range of values for these four is 10-196 mg/L. But the average COD values are 8.4 mg/L, 31.36 mg/L, 13.33 mg/L and 21.88 mg/L for the Muda, Kulim, Jarak and Kerian rivers, respectively. BOD levels greater than 5 mg/L indicates the high positive correlation between BOD and COD values.

Biochemical Oxygen Demand (BOD)

The most widely used parameter in water quality analysis is the measure of the amount of oxygen used by the indigenous microbial population in water in response to the degradable organic material. The 5-day BOD (BOD5) is widely used. Typical reported concentrations of BOD5 for streams and rivers throughout the world range from 2 mg/L to 65 mg/L. BOD measures the amount of dissolved oxygen used by bacteria to oxidise organic matter in the water sample during a certain period of time. It indicates the amount of organic inputs from various sources into the rivers. Discharge from oil palm mills and rubber factories contribute to the BOD loadings in rivers of the scheme. Typical palm oil effluent and rubber effluent contain BOD ranging from 20,000-35,000 and 814-1,747 mg/L respectively. In this respect, the Kulim River falls into Class III of the DOE water quality standard, while the other 3 rivers fall into Classes I and II. The range of values for these four rivers is 1.05-6.60 mg/L.

Suspended Solid (SS)

The suspended solid test quantifies all the solids in the water, suspended and dissolved, organic and inorganic. This parameter is measured by evaporating a sample to dryness and weighing the residue. The total quantity of residue is expressed as milligrams per litre (mg/l) on a dry mass of solid basis. A drying temperature slightly above boiling (104°C) is sufficient to drive off the liquid and the water absorbed to the surface of the particles, while a temperature of about 180°C is necessary to evaporate the occluded water. SS is an important parameter to determine the level of concentration of domestic wastewater and it also affects the turbidity of water.

Solids refer to matter suspended or dissolved in water or wastewater. Solids may adversely affect water or effluent quality in a number of ways. Water high in suspended solids may be esthetically unsatisfactory for purposes such as bathing. Solids analysis is important in the control of biological and physical wastewater treatment processes and assessing compliance with wastewater effluent limits set by the regulatory agency. The highest SS value was found to be 387 mg/L in the Kulim River while the lowest value was recorded in the Kerian River.

Ammoniac Nitrogen (NH_3N)

The presence of ammonium ions in water is connected with the process of the biochemical decomposition of protein substances contained in household and industrial sewage. The presence of ammonia-nitrogen in surface water usually indicates domestic pollution. Data shows the value of NH_3N at all sampling station ranged from 0.1 mg/L to 7 mg/L. The highest NH3N value recorded at the Kulim River was 7 mg/L and the lowest NH3N value recorded at the Muda River was 0.1 mg/L. The highest value of NH3N was most probably due to the discharges from scattered industrial activities and a probable malfunctioning sanitation system.

6.2 Water Quality Indices

The water quality index is a mathematical instrument used to transform large quantities of water quality data into a single number which represents the water quality level while eliminating the subjective assessments of water quality and biases of individual water quality experts. The WQI is a method that combined numerous water quality parameters into one concise and objective value representing the state of water quality trends in a river. The WQI can be defined as a number on scale from 0 to 100 that is used to show the water quality.

The WQI of the four rivers of the scheme is presented in Figure 1. WQI calculated ranged from 69.9% (Jarak River)

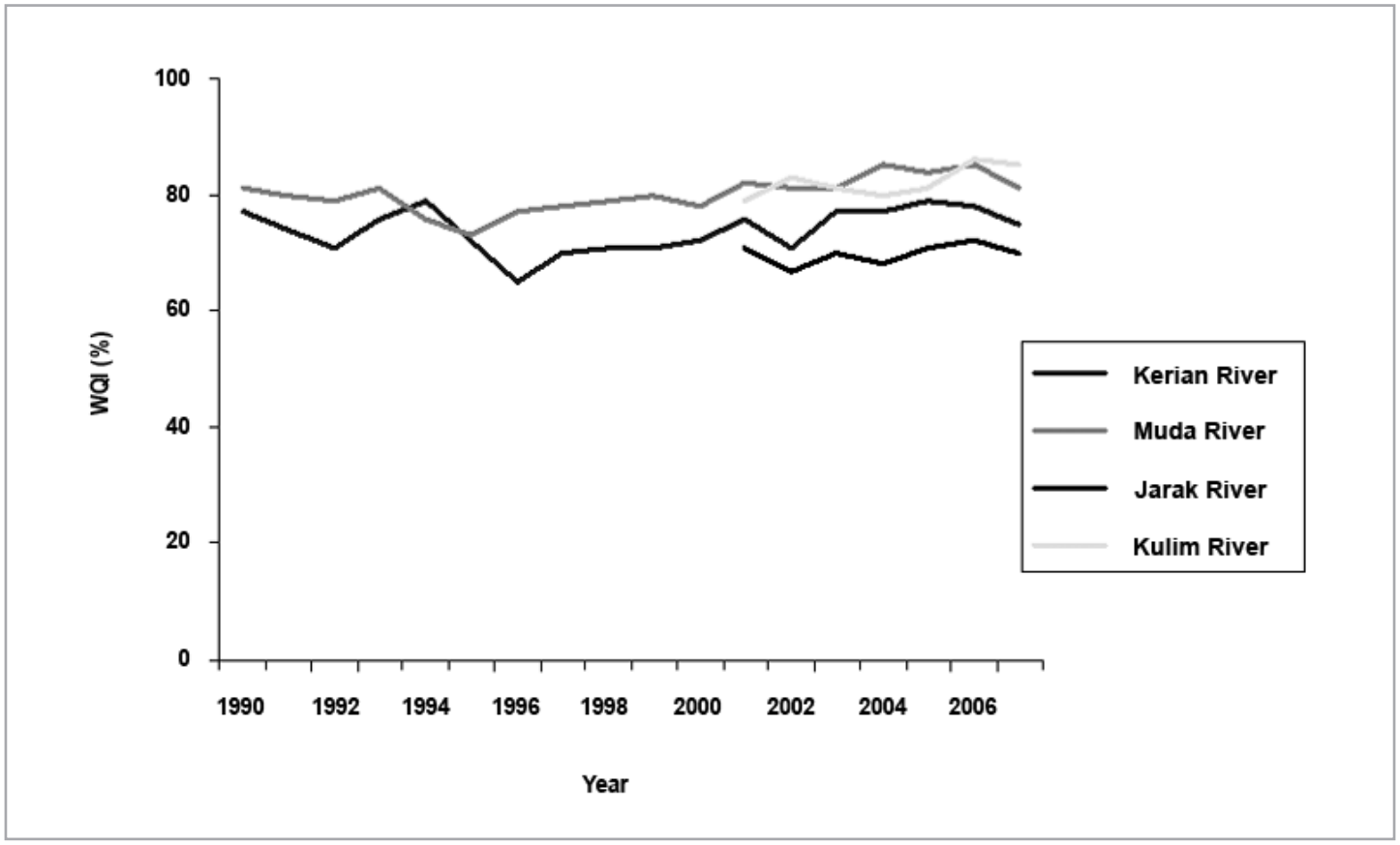


Figure 1: River Water Quality Indices in the Seberang Perai Rice Irrigation Scheme for data from 1990-2007

to 82.2% (Kulim River). This range is acceptable for wildlife including aquatic life, but waters with values less than 80% are considered as slightly polluted for general use. Two rivers (Kerian and Jarak rivers) were considered slightly polluted in comparison with the general rating scale of the water quality index. Agricultural activities may be contributing to this trend, but water quality nonetheless is also affected seriously by industrial use and domestic use. The data shows that the Muda and Kulim rivers are relatively clean. However, there is not much difference in water quality between upstream and downstream sections in each of the four rivers. The Sungai Muda sub-scheme is the largest irrigation area in this scheme, and its major source of water supply is the Muda River. Most of the drainage water from this rice field is discharged into the sea through various waterways. It is noted that the quality of water in this river had been gradually deteriorating during 1990 to 2000.

7.0 CONCLUSIONS

Seventy-five percent of the available surface water resources (river water) in Malaysia are used for rice irrigation. However, many of the rivers in Malaysia suffer from pollution. In this study, four rivers (with 18 years of data for the period from 1990 to 2006) were considered for irrigation water quality assessment. The following are the salient conclusions from this study and it must be qualified that the results are valid for the data period considered and they may have worsened or improved since then:

(i) The pH values in the study area ranges from 5.10 to 8.15 with an average of 6.63. The highest pH value was found in the Muda River while the lowest, downstream of Kerian River. The average pH values were 6.76, 6.39, 6.37 and 5.72 for the Muda, Kulim, Jarak and Kerian river respectively. The pH values are slightly below neutral value indicating only minimal amount of acidic industrial effluents had been discharged into the rivers. But all the pH values are within the permissible limit (Class IV) for irrigated agriculture.

(ii) A wide range of DO levels exist in the rivers in the irrigation scheme and the range is from 1.5 to 7.2 mg/L. The average value of 4.35 mg/L indicates the water is of Class III quality.

(iii) Of the four DOE sampling stations, one has readings greater than 50 mg/L, the standard for class III. The average COD values are respectively, 8.4 mg/L, 31.36 mg/L, 13.33 mg/L and 21.88 mg/L for the Muda, Kulim, Jarak and Kerian rivers.

(iv) The Kulim River falls into Class III of the DOE water quality standard, while the remaining 3 rivers fall into Classes I and II as far as the parameter 5-day BOD (BOD5) is of concern. The range of values for these four rivers is 1.05-6.60 mg/L.

(v) The highest SS value was found to be 387 mg/L in the Kulim River and the lowest value was recorded in the Kerian River. All SS values are still included within the acceptable range for agricultural purposes.

(vi) NH_3N readings at all sampling station ranged from 0.1 mg/L to 7 mg/L. The highest NH3N value was recorded at Kulim river with 7 mg/L and the lowest was recorded at Muda river, with 0.1 mg/L.

(vii) Water Quality Index (WQI) computed based on six parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3N), pH, Dissolved Oxygen (DO) and Suspended Solids (SS), evaluated for the four rivers ranged from 69.9% (Jarak River) to 82.2% (Kulim River).

Water quality data indicated that two rivers (Kerian and Jarak rivers) in the scheme are slightly polluted due partially treated domestic waste and industrial pollution sources. It should be reiterated that the increasing level of pollutants in the rivers will remain an issue affecting human well being if proper attention is not given right at the very source of the problem. Efforts made must be adequate to ensure that river environment and water quality do not deteriorate further. Other human interferences include using chemicals (fertilisers, herbicides and pesticides) that cause surface and groundwater contamination and further water quality. Reducing fertiliser applications not only contributes towards lower production costs for rice cultivation but also less nitrogen (N) leaching into the soil and contamination of surface and ground water. Nevertheless, altered N fertilisation may also affect pests and their natural enemies. Remedial measures to be taken include the use of appropriate chemicals (the ones with low toxicity, biodegradable and mobility in soil) with appropriate application techniques and scheduling, and by maintaining unsprayed buffer areas near streams and applying chemical only during dry weather.

8.0 ACKNOWLEDGEMENT

The authors would like to extend their appreciation to the staff at the Seberang Perai Irrigation Scheme in Pulau Pinang and also to the Department of Environment, Pulau Pinang for all the assistance rendered during the period of study at the end 2008. The conclusions are portrayed as they were derived and at the authors are solely responsible for the findings. ■

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PINK GUAVA JUICE PASTEURISATION: FOULING DEPOSIT AND CLEANING STUDIES

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ABSTRACT

Pasteurization is a common sterilization process in food industry to prolong the shelf life of the food product. However, fouling deposit problem is one of the major problems of the pasteurisation. This work provides fundamental studies on fouling deposition of pink guava juice (PGJ) and cleaning of it. A basic tubular heat exchanger set-up was used to perform pasteurization and cleaning. Pasteurisation was operated under industrial pasteurisation temperature of PGJ, which was at 93°C. Alkaline-based cleaning solution was utilised for ex-situ cleaning at different concentrations (0.2, 0.3, 0.4%v/v Na_2O), 65°C and 1 l/min. Microstructure study of the deposits before and after cleaning was carried out using ESEM. Proximate analyses were performed to determine the composition of PGJ. A study on the hardness and stickiness of the fouling deposit was done using a texture analyser. The presence of seedstone in pink guava juice was analysed using a particle analyser. Cleaning performance was monitored via the changes of remaining deposit and clarity of the cleaning outlet. The findings shown that seedstone from pink guava juice ranging from 168 to 200μm and carbohydrate was found to be a major composition (47.7% of fouling deposit consists of carbohydrate). Comparison between the hardness and stickiness of the deposits at two different flow rates showed that fouling deposits were harder and denser at higher flow rate. Findings from this work provide basis knowledge for further study on fouling and cleaning of PGJ.

Keywords: *Cleaning, Fouling Deposit, Heat Exchanger, Pink Guava Juice*

1.0 INTRODUCTION

Pasteurisation is a common sterilisation process in food industry to prolong the shelf life of the food product. However, not many people aware about the fouling deposit problem, which is one of the drawback of the pasteurisation. Pasteurisation, a process taken place at high temperature (>50°C) enables harmful bacteria to be killed and thus increase the shelf life and safety of the product. The temperature required to meet this is depending on the type of raw food materials that involved in the process. It is an essential step required in most food industries [1]. Heat exchanger is the common unit operation use for pasteurisation.

Most process of beverages and dairy products in food industries are operated for 24 hours a day and for almost every day. The heat exchanging mechanisms are taken place between the product and the heating medium. The primary objective of heating process is to kill the harmful bacteria. Even though the bacteria are being killed during this process, chemical reaction and the properties of the product changes as well. Very often, these changes produce scaling or precipitation on the inner surface of processing equipment which is known as fouling deposit.

Fouling deposit, a term use to describe the deposition of unwanted material formed on solid surfaces of processing equipment. Its formation can reduce the efficiency of the heat exchanger and consequently affects the pasteurisation process [2]. Fouling layer formed on the wall acts as a barrier to heat transfer. Besides that, it can reduce the pipe flow area, thereby resulting in pressure drop and inefficiency of heat transfer [2]. As a consequence, this will affect the industry's productivity and economy.

In this study, pink guava juice (PGJ) was used as the model fluid of the research. Pink guava is tropical fruit and Malaysia is

among the top in the world that producing pink guava puree for PGJ [11] and as ingredient for other food products. Furthermore, currently there is no publication on PGJ fouling deposit, according to an extensive literature survey by Tan (2009) [10] and Ho (2009) [4]. A basic tubular heat exchanger (THE) set-up for obtaining pink guava juice fouling deposit and for performing cleaning was constructed enabling the study to be conducted in continuous flow condition. The obtained deposit can be a physical model for fouling deposits from industrial scale heat exchanger. Fouling characteristics study was performed on the fouling deposits. The influences of different operating conditions on fouling formation were investigated while characterisation of the fouling layer such as texture, composition and microstructure were performed. Cleaning performance was also investigated under the influences of temperature, cleaning chemical concentration and flow rate. Alkaline-based detergent was used as alkaline is the best cleaning agent for carbohydrate-based and protein-based deposits [2]. The results from this study will provide basic knowledge on PGJ fouling deposit, where its formation rate and formulation for cleaning can be further understood.

2.0 MATERIALS AND METHODS

Pink Guava Juice

Pink guava puree was supplied by Golden Hope Food & Beverages Sdn. Bhd., Sitiawan, Malaysia. It was diluted with distilled water at the ratio of 1:3:7 (sugar: pink guava: water), to produce pink guava juice. The percentage of Brix used was in the range of 7.0-11.0 and the Brix set for this experimental study was 11° Brix and the Brix percentage of the pink guava juice was determined using the refractometer.

Cleaning Chemical Solution

A single stage cleaner, Principal (ECOLAB) was used to remove fouling deposit. It is an alkaline-based detergent that is formulated for the cleaning of food, dairy and beverage processing equipment. The properties of Principal are shown in Table 1. The main cleaning agent in Principal is sodium oxide (Na_2O). Principal was diluted with distilled water to obtain three chemical concentrations (0.2%v/v, 0.3%v/v, 0.4%v/v Na_2O).

Basic Tubular Heat Exchanger (THE) Set-Up

A rig constructed of 304 stainless steel pipe with the outer diameter of 22mm and it was joined by Type A/ non manipulative, British standard compression fittings. These fittings were utilised in developing the rig that resembles a concentric tube exchanger.

The design of this heat exchanger (Figure 1) was based on the concept that the heat from the heating medium will transfer heat to the stainless steel pipe and eventually to the pink guava juice in the pipe in order to pasteurise the pink guava juice to the desired temperature. The pink guava juice was prepared and stored in a tank (20L) before being pumped into the tube that is immersed in glycerol. The heat exchanger contains 3 passes with length of 0.17m for each pass to provide a sufficient holding time for heating. One K-type thermocouple was placed near the outlet of the heat exchanger and another was placed in the heating medium to monitor the temperature of the pink guava juice and heating medium, respectively. Pink guava juice is then recycled to the tank.

Table 1: The properties of principal

Property	Description
Color	Light yellow
Specific gravity at 68(20)	1.237
Pounds per gallon	10.20(4.67kg)
pH	
1.0% solution	12.3
0.1% solution	11.1
Alkalinity	
Active as Na_2O	12.2%
Total Na_2O	14.0%
Chlorine	3.0%

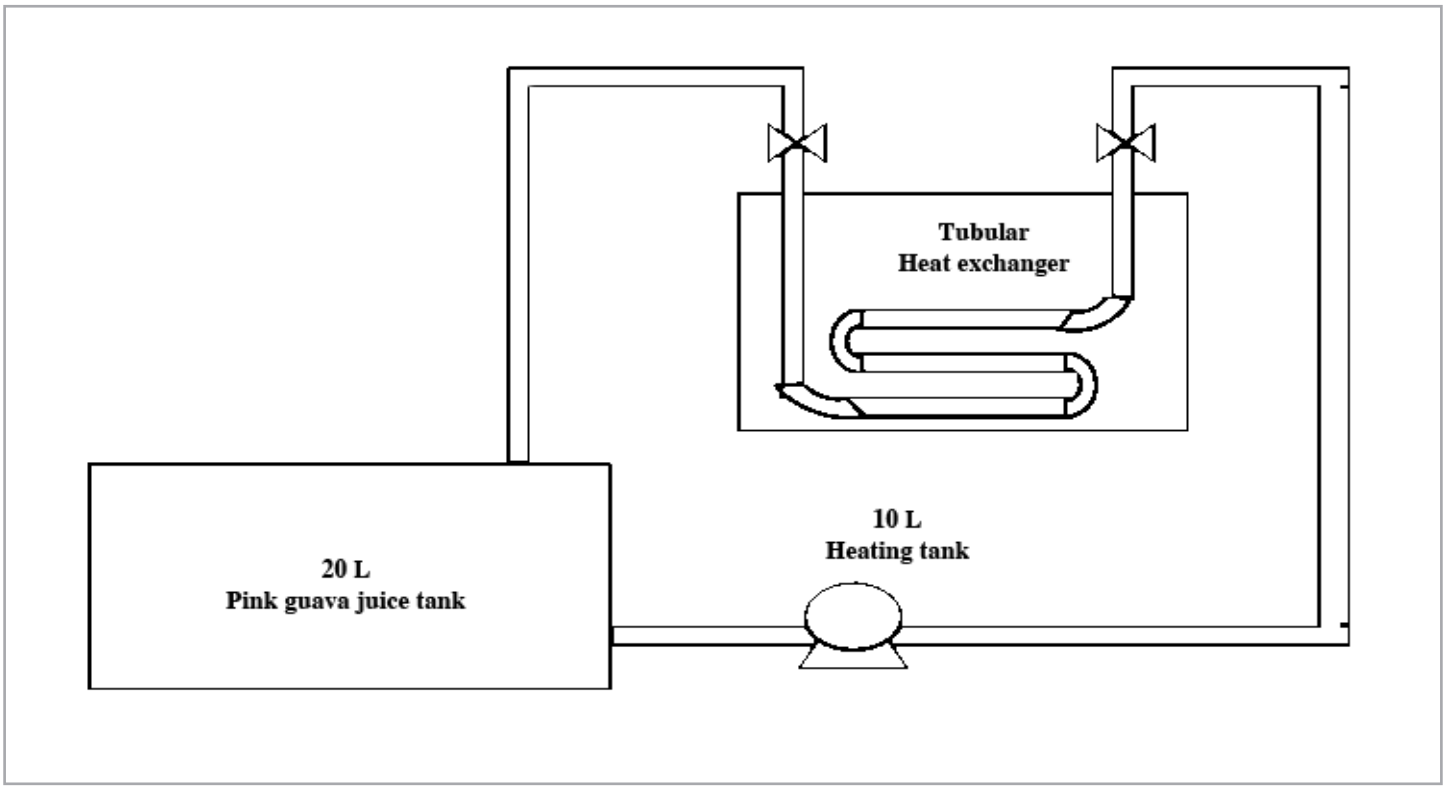


Figure 1: Basic tubular heat exchanger (THE) set-up

During cleaning of the THE, the tank was filled with cleaning chemical solution and the temperature of the heating tank was set to the desired cleaning temperature.

Temperature and Time for Pasteurisation

Pink guava juice is pasteurised at temperature range of 93°C-97°C and with holding time for 30s, according to the normal industrial practice. This information was obtained from Golden Hope Food & Beverages Sdn. Bhd and it provides a benchmark for the lab scale study. While the flow rate and pasteurisation period were based on the experimental capacity, which were 0.5 and 1 liter/min for the flow rate and the pasteurisation period was set for 1 hour.

Cleaning Methods and Parameters

Here, two methods were used to perform cleaning: (*a*) ex-situ method with a shakable water bath [5] and (*b*) in-situ method with a basic tubular heat exchanger [10]. The first method was employed to perform preliminary cleaning studies in which then an optimum cleaning chemical concentration can be found. Then, the optimum cleaning chemical concentration was applied to the second method. Cleaning was started with the first method because the second method requires more cleaning solution, thus this procedure can reduce the experimental number for the second method and the cleaning chemical usage.

For the first method the cleaning parameters were Principal concentrations (0.2%v/v, 0.3%v/v, 0.4%v/v Na_2O) and 50 rpm of shaker speed (to simulate the flow at 1 l/min [5]). While for the second method, the cleaning parameters were 0.4%v/v Na_2O (optimum concentration) and 1 l/min of cleaning solution flow rate. The temperature applied for both methods was 65°C. Principal supplier has recommended the cleaning temperature is between 60°C and 66°C for obtaining an optimum cleaning performance.

Proximate Analysis

This analysis was carried out to determine the compositions of moisture, fat, ash, fiber, protein and carbohydrate contents. Moisture content was determined by using the oven method. Fat content was determined by using the Soxhlet method, while protein content was examined using the Kjeldahl method. Determination of ash was measured by drying the sample in a muffle furnace up to 550°C. The fiber content analysis was carried out according to the procedures described by AOAC, 1995 [3].

Texture Analysis

For texture analysis, the hardness and stickiness of pink guava juice fouling deposit were examined by using the texture analyser (TA-XT Plus, Stable Micro Systems, UK). The parameters and specification of texture analyser for performing hardness and stickiness analyses were stated in Table 2.

Particle Analysis

The presence of seed-stone in pink guava juice was analysed for the size distribution. Pink guava puree was sieved with cheesecloth to separate the seedstone from the puree.

The sieved residue was then laid flat and distributed evenly on a thin layer of aluminium foil before drying in the oven at 40°C for 24 hours. The dried residue was scrapped with spatula and kept in petri dish. The sample was stored in the desiccators prior to particle analysis. In analysing the particle size of the seedstone, particle analyser (Scirocco 2000, Malvern, UK) was used.

Cleaning Monitoring Techniques

Cleaning progress was quantified: (*a*) by weighing the fouling deposit before and after the cleaning and (*b*) by measuring the clarity of the liquid outlet. Electronic weighing machine (Cartorius BS224S) was used for the first technique. The clarity of the liquid outlet was measured in relation to the light absorbance level. This technique was based on Beer-Lambert law that the light absorption of solution is directly proportional to its concentration. Thus, the greater the concentration of the remaining dissolved fouling deposit in the cleaning solution outlet, the greater the amount of light is absorbed. UV-Vis Spectrophotometer (UV mini 1240) was utilised to measure the light absorbance level.

Microstructure Analysis

Critical point drying was chosen as the choice of fixation technique for pink guava juice fouling deposit. Standard critical point drying (CPD) protocol was used for preparing the samples. After fixation with 4% glutaraldehyde in 0.1 M cacodylate and 2% buffered osmium tetroxide, the samples were dehydrated through a graded series of acetone (30%, 50%, 75% and 95% - once for 10min at each step), and then were immersed in 100% acetone for three times at 15 min each. The samples were then transferred to Bal-Tec CPD 030 critical point dryer (BAL-TEC AG, Switzerland) using liquefied carbon dioxide as transitional fluid before coated with gold by a sputter coater (Bal-Tec SCD 005, BAL-TEC AG, Switzerland). Then the dried sample was transferred to ESEM (XL30 Environmental Scanning Electron Microscopy, Philips, Holland) chamber, to obtain the ESEM micrograph for microstructure analysis.

3.0 RESULTS AND DISCUSSIONS

Fouling deposits from basic THE set-up differ physically from those obtained from shakable water bath system [4]. Figure 2 shows the fouled heat exchanger tubes, which were obtained at different flow rate conditions. For fouling deposit study in the basic THE, the controlled parameter was the flow rate. The flow rates used were 0.5 liter/min and 1 liter/min, which were the same flow rates used in the shakable water bath system (the flow rate is equivalent to the shaker speed) [5].

From Figure 2, the amount of fouling deposit formed was higher at the flow rate of 1 liter/min compared to the fouling deposit formed at 0.5 liter/min. The area of deposition was mainly at the

Table 2: Parameters and specification of texture analyser for hardness and stickiness analysis of pink guava juice fouling deposit

Parameter	Value	Description
Probe	P20	The size of the probe used: cylindrical; 20mm
Test Mode	Compression	Initial probe direction and force polarity
Pre-test speed (mm/s)	1	Probe speed while searching for trigger point
Test-speed (mm/s)	2	Speed of approach to target distance after triggering
Post-test speed (mm/s)	2	Speed at which the probe returns to start point
Target mode	Strain	Target parameter
Strain (%)	30	Specify target strain base on trigger height
Trigger type	Auto	The initiation of data is defined
Trigger force (g)	5	Amount of force for TA to initiate data capture
Trigger distance (mm)	2	Pre-travel distance before initiating data capture

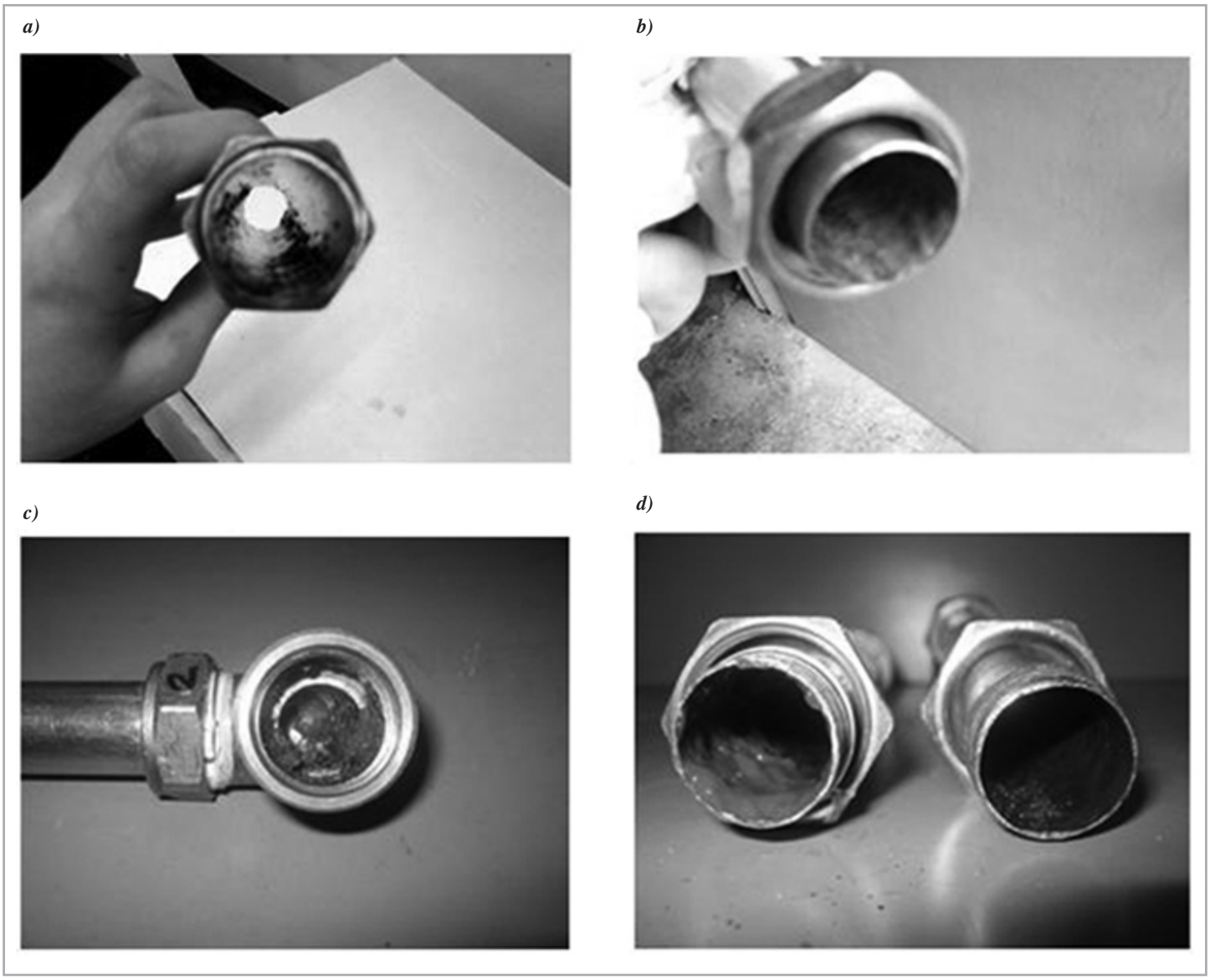


Figure 2: PGJ fouling deposit after heating process at flow rate of: (a)-(b) 0.5 liter/min and (c)-(d) 1.0 liter/min

Table 3: Compositions of PGJ and its fouling deposit

Component (%)	Pink Guava Juice	Fouling Deposit
Moisture Content	89.09	50.3
Ash	0.54	0.83
Protein	0.93	1.22
Fiber	0.73	1.3
Fat	0.2	0.09
Carbohydrate	8.51	46.27

Table 4: Hardness of PGJ fouling deposit

Test	Hardness, Force (g)	
	Fouling Deposit, 0.5 liter/min	Fouling Deposit, 1 liter/min
1	23.9021	70.8240
2	30.3161	71.3198
3	28.8171	68.3017
4	27.6751	69.8121
5	29.5616	70.2205
6	26.7268	69.1772
Mean	27.8331	69.9426
Standard Deviation	2.3162	1.0997

Table 5: Stickiness of PGJ fouling deposit

Test	Stickiness, Force (g)	
	Fouling Deposit, 0.5 liter/min	Fouling Deposit, 1 liter/min
1	15.2568	32.3685
2	20.8214	33.5813
3	20.108	33.9749
4	20.4647	34.4659
5	18.0391	34.9702
6	19.0736	35.5021
Mean	18.9606	34.1438
Standard Deviation	2.0795	1.1071

lower tube, which was the result of sedimentation and non-fill tube. The amount of deposition through the tube was not uniform. The top deposit texture was soft and soggy, resembled semi-solid. While the lower deposit texture was hard and quite dry. Generally different textures of the deposit are influenced by the temperature and the duration of heating, which then promotes ageing [6]. The fouling deposit from this experimental set-up is more appropriate to represent the fouling deposit from industry than the deposit from shakable water bath system. This is due to the experimental condition that includes the effect of continuous flow state.

Table 3 shows the results of the proximate analysis of PGJ and PGJ fouling deposit. From the table, the solid content of PGJ is approximately 10.92%. The solid content consists primarily of carbohydrate, which is approximately 77.94% of solid content. While the major composition of PGJ fouling deposit is carbohydrate (46.27%). Thus PGJ fouling deposit is carbohydrate-based deposit. Grassoff (1997) [7] classified fouling deposit based upon its main composition and he has concluded that carbohydrate-based deposit is easy to remove but if cameralisation occurred, the removal process will be harder. Other researches on carbohydrate-based fouling deposit were using tomato paste [8, 9] as their material of study.

Tables 4 and 5 show the hardness and stickiness of PGJ fouling deposits that were obtained from the basic THE set-up. The hardness of the fouling deposit from heating process at 1 liter/min is 251% higher than the fouling deposit from the heating process at 0.5 liter/min. Thus, the velocity of the flow has a major effect on the hardness of the fouling deposit. A faster flow rate resulted in a harder fouling layer. According to [2], a biofilm/ fouling layer can be more compact and dense under high velocities. At low velocity, the structure can be more open and fluffy, resulting in fouling deposit structure that was not dense and hard. The open structure enables more air to be trapped within the structures. Similar trend was also observed for stickiness, in which fouling deposit formed at 1 liter/min was stickier than the deposit formed at flow rate of 0.5 liter/ min (Table 5).

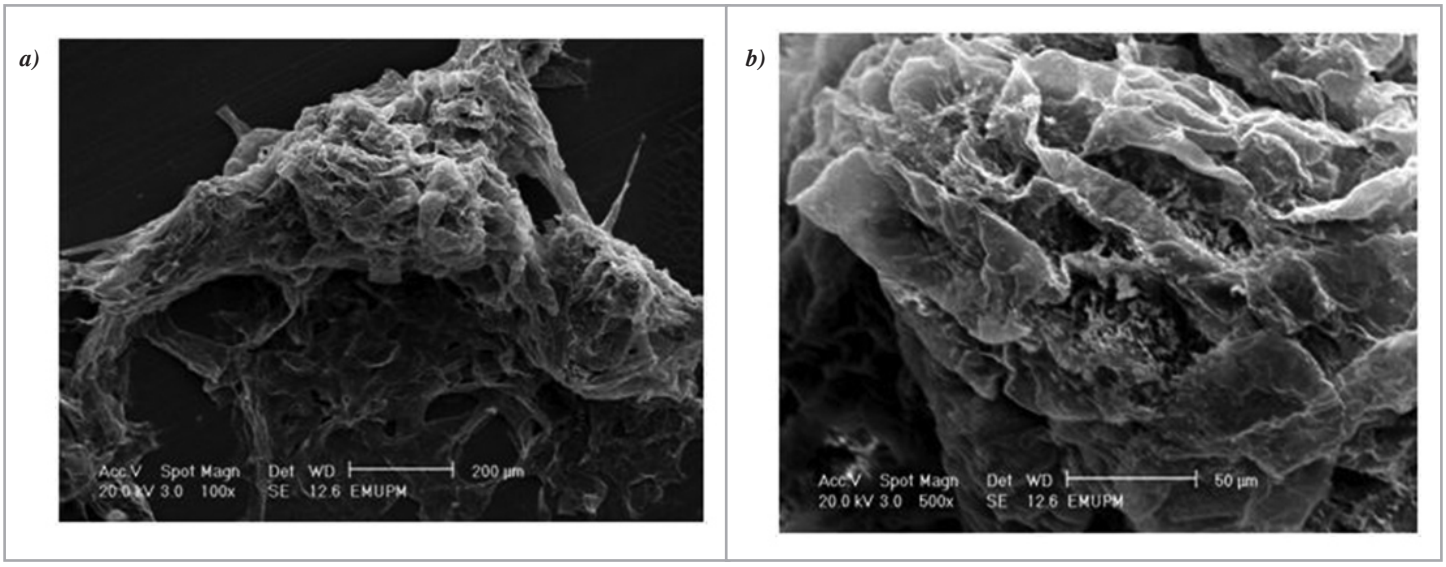


Figure 3: ESEM micrograph of pink guava juice at: a) 100x and b) 500x magnification

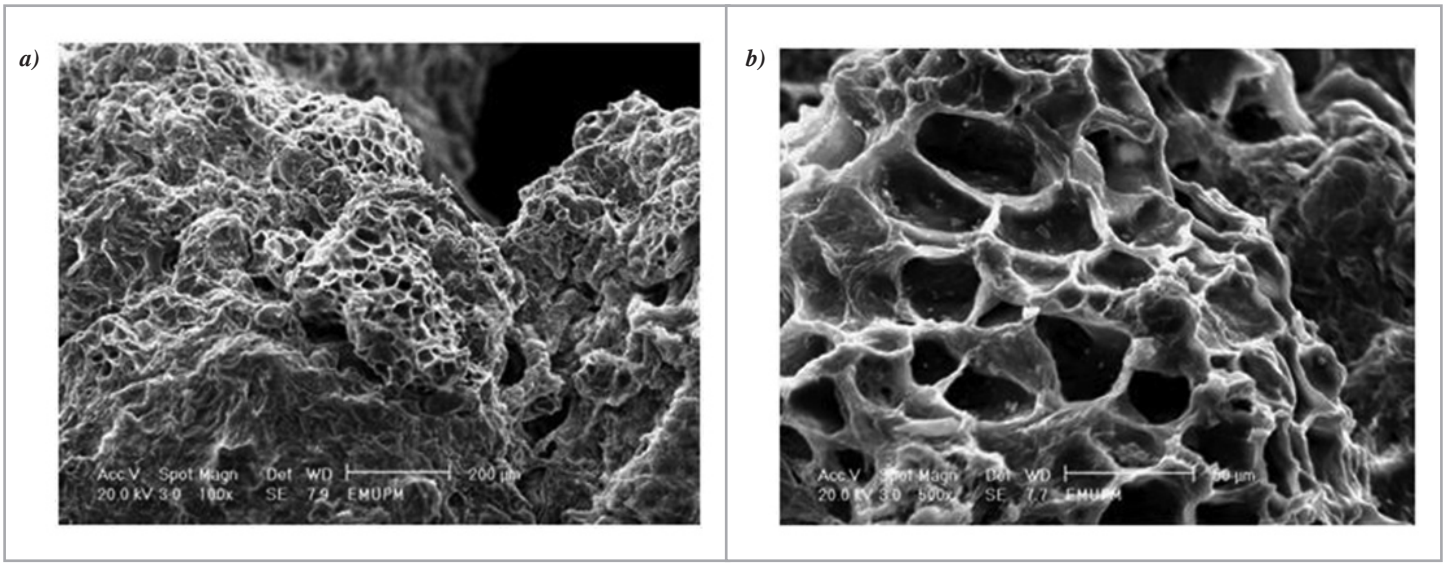


Figure 4: ESEM micrograph of PGJ fouling deposit at: a) 100x and b) 500x magnification

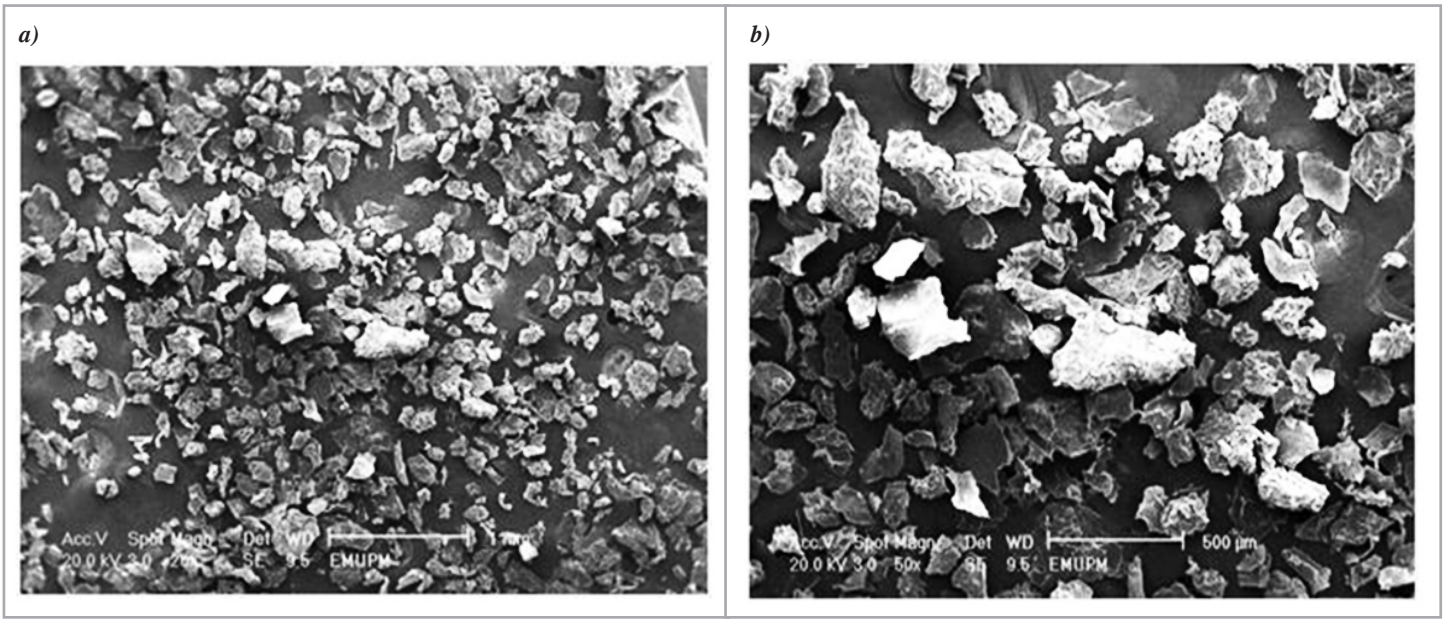


Figure 5: ESEM micrograph of the particles, 'seed-stone' at: a) 25x and b) 50x magnification

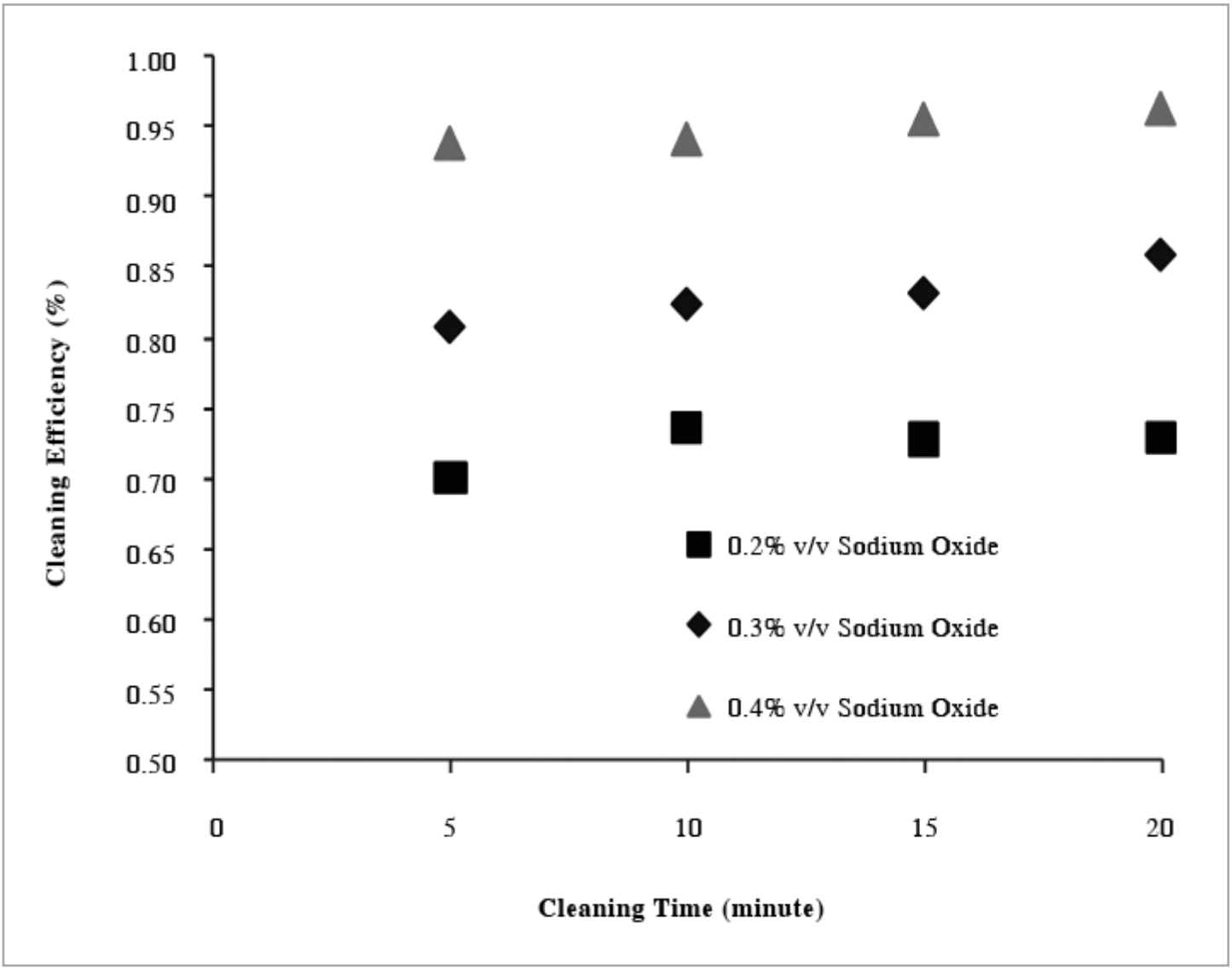
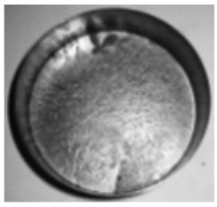
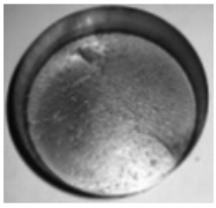
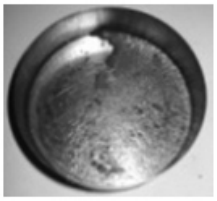
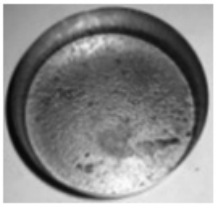
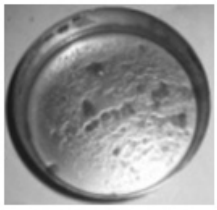
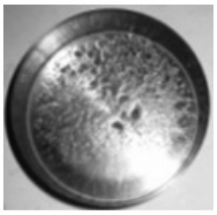
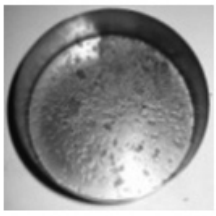
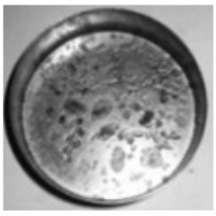
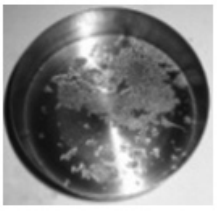
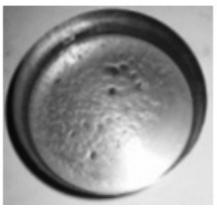
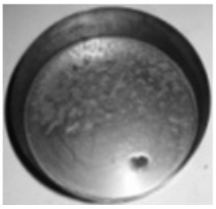
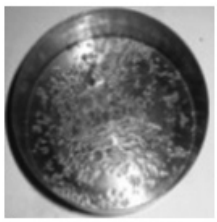
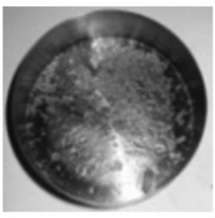
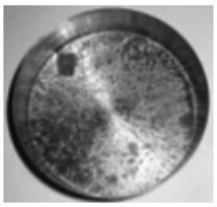
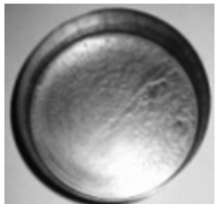
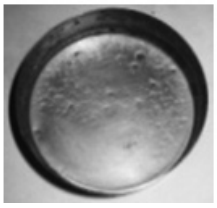
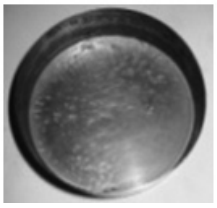


Figure 6: Cleaning efficiency for shakable water bath cleaning method (ex-situ method) at 65°C, 50 rpm and different cleaning solution concentrations

Table 6: Condition of fouled plates from ex-situ method before and after cleaning at 65°C, 50 rpm and at different cleaning solution concentrations

Cleaning time (minute)	5	10	15	20
Before cleaning				
After cleaning with 0.2%v/v Na_2O				
Before cleaning				
After cleaning with 0.3%v/v Na_2O				
Before cleaning				
After cleaning with 0.4%v/v Na_2O				

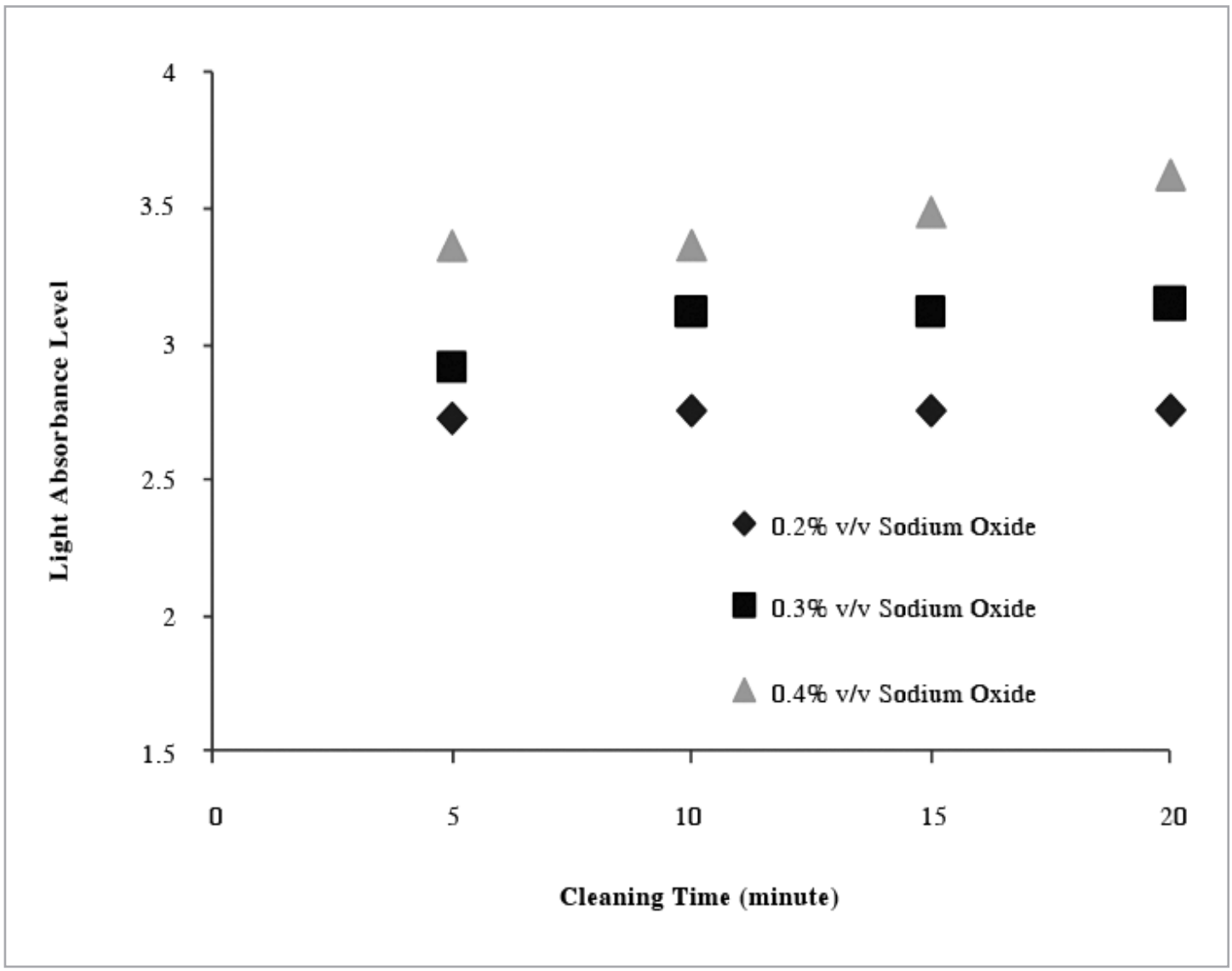


Figure 7: Light absorbance level for the outlet of shakable water bath cleaning method (ex-situ method) at 65°C, 50 rpm and different cleaning solution concentrations

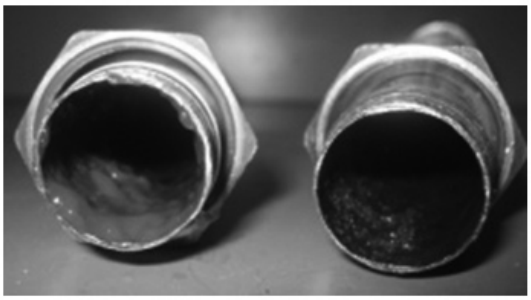
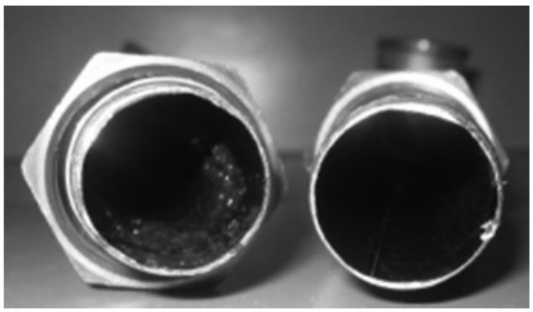
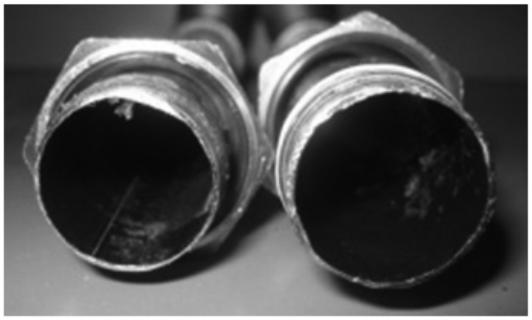
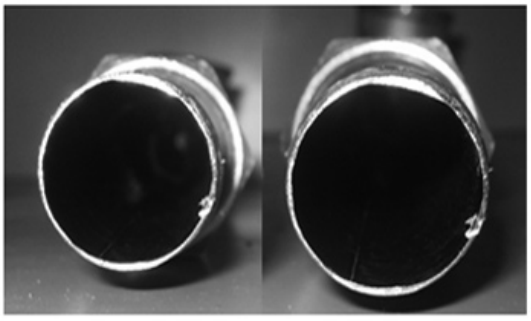
The microstructure of PGJ and PGJ fouling deposit are dissimilar. Figure 3 shows the ESEM micrograph for PGJ. The micrograph shows that PGJ contains very fine sacs of carbohydrates and networks of fibers. Seed-stones were not observed in the micrograph (Most probably they were covered by the sacs and network of fibers). There was a distinct characteristic between the juice and the fouling deposit. In the fouling deposit as shown in Figure 4, the sacs were no longer observed. A dough like structure was observed. Besides, the fouling deposit looked dense, hard and porous to some extent. The observation may lead to the conclusion that heat treatment of pink guava juice has led to the denaturation of some of the organic matters, which is mostly carbohydrates as shown by the proximate analysis results in Table 3. The sacs of carbohydrate burst due to retrodegradation and form aggregates which settle with the seed-stones that were entrapped in the network. The microstructure of fouling deposit from this experimental set-up was developed gradually due to the continuous flow and thermal effect, which differ from those deposits obtained from the shakable water bath system [5]. Thus the microstructure is comparable to other fouling deposit obtained from similar flow system, such as milk fouling deposit [8].

The uniqueness of PGJ fouling deposit is due to the presence of seed-stone, which is insoluble in water. The sedimentation of the seed-stone will influence the hardness of the fouling deposit. This characteristic is not present in well-defined milk fouling deposit. Figure 5 shows the micrograph for the seed-stone. The size of the seed-stone is ranging from 168 to 200μm.

When discrete and fine particles like seed-stones are present in a fluid, they cannot take part in any deformation that the fluid may undergo. The result is an increasing resistance to shear, which is greater than a pure fluid [2]. Therefore the suspended solid resulted in an increased resistance to shear and hence suspended on the wall of the heat exchanger in which fouling deposit was eventually formed.

Carbohydrate-based fouling deposit can be cleaned by water alone but the cleaning performance is not efficient [8, 9]. Cleaning of PGJ fouling deposit with water alone requires high temperature and shear stress effect to increase the removal activities, but only

Table 7: Condition at different pipe sections after cleaning at 65°C, 0.4%v/v Na2O and 1 l/min

Cleaning time (minute)	Pipe Sections	
	Pipe joints	Cylinder tubes
0		
10		
15		
20		

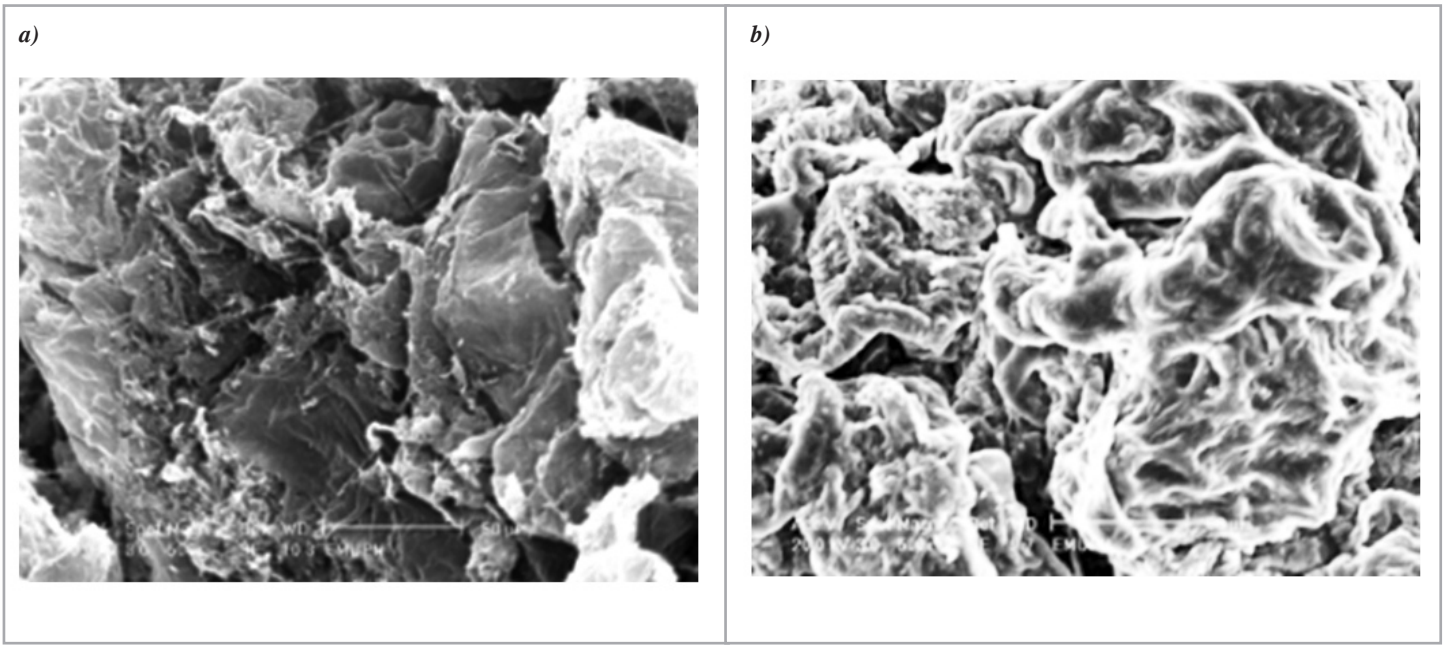


Figure 8: ESEM micrograph of PGJ fouling deposit: a) after exposed to 0.2% v/v Na2O and b) after exposed to 0.4% v/v Na2O for 20 minutes at 65°C (500x magnification)

50% removal was observed after cleaning for one hour [10]. In this study, cleaning was performed with formulated cleaning solution, Principal. From the preliminary cleaning study with shakable water bath cleaning method, cleaning performance was greatly improved when the cleaning solution was applied. Table 6 shows the changes on the fouled plate before and after cleaning at 0.2, 0.3 and 0.4% v/v Na_2O. The pictures illustrate that less than 20 minutes is required to remove almost all of the deposit. This indicates that the chemical solution reacted better than water as cleaning agent. The chemical reaction weakens the intermolecular forces. The deposits remained on the plate is reduced when the chemical concentration increases from 0.2%v/v to 0.4%v/v Na_2O. This suggests that higher concentration provides both a greater driving force for chemical diffusion and a higher reaction rate.

Cleaning efficiency was determined by weighing the fouling deposit before and after being exposed to the cleaning agent. The cleaning efficiency increases 10% for every increment in chemical concentration. Figure 7 illustrates that when more deposits are detached, the greater the concentration of remaining solution and the greater the amount of light is absorbed. Figure 6 and 7 show that the ex-situ cleaning with 0.4%v/v Na_2O has the best cleaning efficiency and highest light absorbance level. Thus cleaning study with in-situ method was only performed at this concentration.

Table 7 clearly illustrates the remaining fouling deposit at different sections of pipe tubes and joints after cleaning for 10, 15 and 20 minutes. Less deposit was found with the increase of cleaning time. Longer duration of cleaning with 0.4%v/v Na_2O results in better cleaning effect.

Figure 8 indicates that chemical concentration affecting the deposit microstructure. Figure 8 shows that the deposit dissolved away and formed amorphous clumps after being contacted with cleaning chemical. The morphology changes of the deposits vary with detergent concentration. Increase in chemical concentration produces more void with bigger size. Figure 8(b) illustrates that there is a dramatic change in the deposit structure after exposed to 0.4%v/v Na_2O. This observation demonstrates that increase in chemical concentration might reduce the strength of the deposit structure, thus assisting the cleaning process.

4.0 CONCLUSIONS

This study used PGJ as a model fluid to obtain PGJ fouling deposit, which has not been studied previously. PGJ fouling deposit is classified as carbohydrate-based deposit. PGJ fouling deposit is unique compared to milk fouling deposit, due to it is containing particles, which are known as seed-stone. These fine particles (168 to 200μm) were embedded in the fouling deposit and were observed only on the fouling deposit, as heating process denatured some of the components that covering the seed-stone. The presence of the seed-stone might influence the hardness of the fouling deposit. A basic THE set-up was developed to ensure the deposit is similar to industrial-based deposit. The texture of the fouling deposit at different flow rates revealed that fouling deposit formed during a faster flow rate process has a harder and stickier texture compared to fouling deposit formed during a slower flow rate due to the fouling layer may be more compact and dense under high velocities. While in the presence of low velocity, the structure may be more open and fluffy. The cleaning process was only performed at flow rate 1 l/min (50 rpm) for shakable water bath method (ex-situ method) and 1 l/min for the basic THE set-up, as both methods used the preliminary designed rigs that can be improved in the future. Cleaning results

show that chemical-induced cleaning is better than cleaning with water alone, in term of cleaning time and cleaning efficiency. Chemical-induced cleaning can also reduce the water and energy consumption in cleaning. From both ex-situ and in-situ methods, cleaning was significantly improved when the cleaning chemical concentration was increased. This can be explained by the action of the cleaning agent in weakening the microstructure of the fouling deposit, hence assisting the cleaning. In conclusion, this work has discovered some important characteristics of PGJ fouling deposit and the basic THE set-up has successfully produced the PGJ fouling deposit. Thus findings from this work can benefit PGJ industry in Malaysia. Findings from this work will provide the basis for future study on properties of PGJ fouling deposit and its cleaning aspects.

5.0 ACKNOWLEDGMENT

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PROFILES



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Note that upon acceptance of an article for publication, the author is requested o submit a camera-ready format of the manuscript with single-spacing, double-column and font of 10 (Times). Illustrations and keywords of the paper should be included in the text. An electronic copy of the manuscript should also be submitted. The author is also requested to submit a passport-sized photograph and a short biography. This information will be sent to the author by the Editor.

B) STYLE FOR DRAFT OF MANUSCRIPT FOR REVIEW PROCESS

The draft of manuscript for a review process shall in .pdf format.

The manuscript should be typewritten using double-spacing, font of 12 (Times); on one side of sheet only and in a single column format. The format for IEM Journal follows that of the IEEE Transactions (USA).

As we practice blind review, please do not put your name and address in the manuscript.

Provide an informative 100 to 250 words abstract at the head of the manuscript.

All sections should be numbered in Roman such as 1, 11, *etc*. with the title in capitals.

Sub-sections should be numbered in alphabet such as A, B, C, *etc*.

Sub-sub-sections (if any) should be numbered as A., A.2, *etc.*

Numbered all equations in round brackets ( ) flush to the right. The equation should be in the center.

References in the text should be cited each by a reference number in square brackets, *e.g.* [12] or [4-6], *etc.*

In the reference section, the references should be written as follows:

Style for papers: Reference Number, Author, first initials followed by last name, title (*italics*), location and publisher, year, chapter or page numbers, month, and year.

Style for books: Reference Number, Author, first initial followed by last name, title (*italics*), location and publisher, year, chapter or page numbers (*if desired*).

Sample format for references is as follows:

(*for paper*)
[3] M. Khalid, S. Omatu, and R. Yusof, "Temperature Regulations with Neural Networks and Alternative Control Schemes" *IEEE Trans on Neural Networks*, Vol. 6, No. 3, pp. 572-582, May, 1995.

(*for book*)
[4] S. Omatu, M. Khalid, and R. Yusof, *Neural-Control and Its Applications*, London: Springer-Verlag, 1995.

If your paper is in Bahasa Melayu, please provide an abstract in English.

C) STYLE FOR CAMERA READY MANUSCRIPT (PRE-PUBLICATION)

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Include all illustrations in between the text (if possible). An electronic copy should be submitted.

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D) STYLE FOR ILLUSTRATIONS

Try to include the illustrations in between the text.

Originals for illustrations should be sharp, noise-free and of good contrast.

Each illustration must be numbered such as "Figure 1, Figures 2-3, *etc*." and have a meaningful caption at the bottom. For tables, the caption must be at the top.

On graphs, show only the coordinate axes, or at most the major grid lines, to avoid a dense hard-thread result.

All lettering should be large enough to permit legible reduction of the figure to column width, perhaps as much as 4:1. Typing on figures is not acceptable.

Photographs should be glossy prints, of good contrast and gradation and any reasonable size.

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