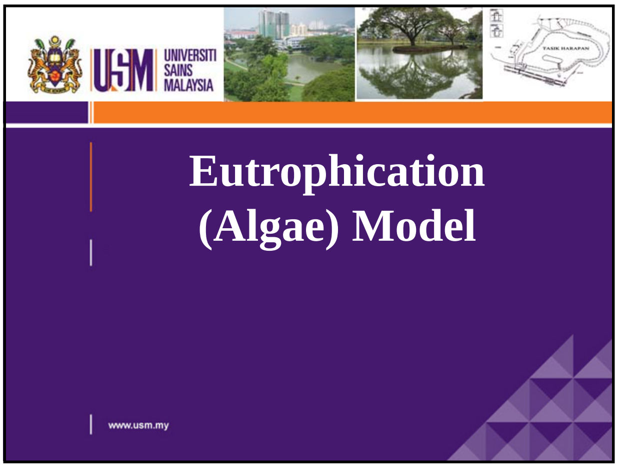
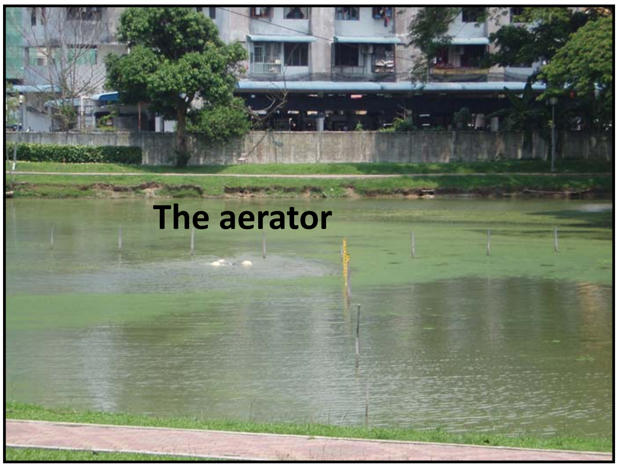
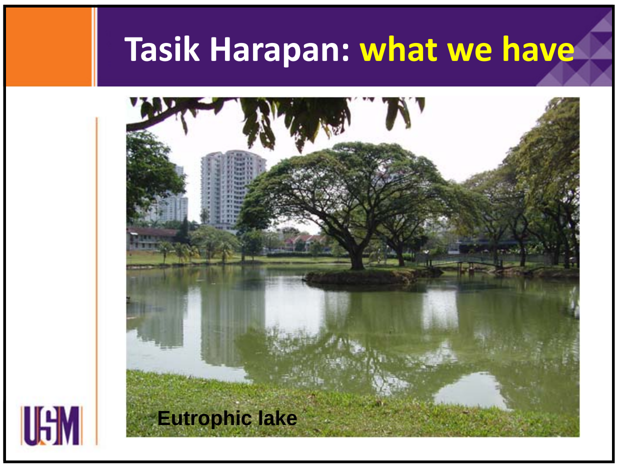
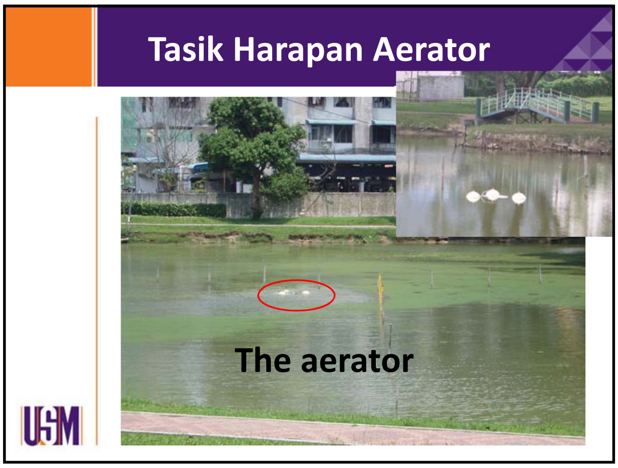

UNIVERSITI SAINS MALAYSIA
Eutrophication
(Algae) Model
www.usm.my


The aerator


Tasik Harapan: what we have
Eutrophic lake


Tasik Harapan: what we get
Algae Bloom


Tasik Harapan: what we want
Healthy Lake


Tasik Harapan Aerator
The aerator

Water Quality Parameters

Table 1 Mean water quality parameters for Tasik Harapan

Parameter	Mean ± s.d
DO (mg/L)	5.20 ± 1.900
BOD (mg/L)	8.00 ± 2.000
Chlorophyll a (mg/L)	0.33 ± 0.064

Table 2 Mean water quality parameters used in this paper

Parameter	Mean values
DO (mg/L)	5.20, 6.00
DO (saturation) (mg/L)	7.50
BOD (mg/L)	8.00
Chlorophyll a (mg/L)	0.33

Analytical Model

$$\frac{d\ell}{dt} = -\alpha\ell + \gamma$$

$$\frac{dc}{dt} = -\alpha\ell + \beta\left(c_s - c\right) + \delta\sin\left(\sigma t - 7\pi/12\right)$$

ℓ = BOD level, mg/L

c = DO level, mg/L

c_s = DO saturation level, mg/L

t = time, day

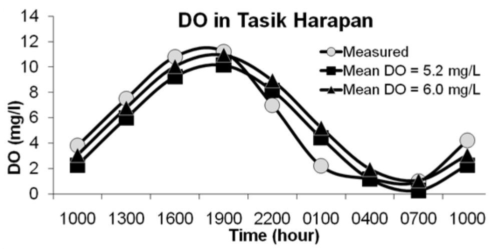
β = reaeration rate, day^{-1}

γ = BOD loading, mg/L/day;

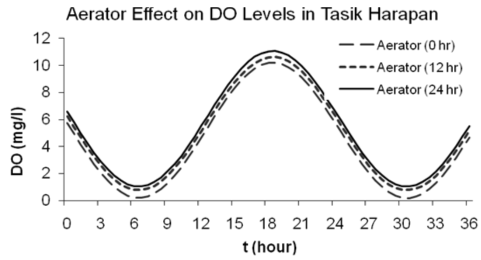
α = BOD decay rate, day^{-1}

σ = frequency for a 1-day cycle, 2π/day

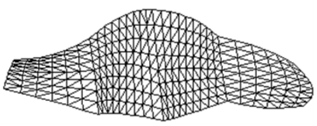
Measured and simulated DO



Aerator effect on DO levels in Tasik Harapan



Finite Element

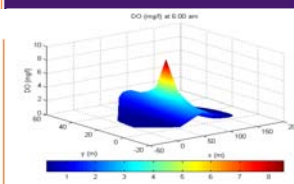


$$\overset{\circ}{\ell} + u\ell_x + v\ell_y - D_x\ell_{xx} - D_y\ell_{yy} + \alpha\ell = \gamma$$

$$\overset{\circ}{c} + uc_x + vc_y - D_x c_{xx} - D_y c_{yy}$$

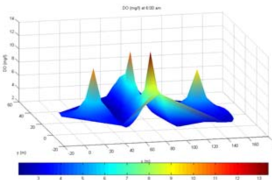
$$+\alpha\ell - \beta\left(c_s - c\right) - \delta\sin\left(\sigma t - 7\pi/12\right) = \Phi$$

Mechanical Aerator

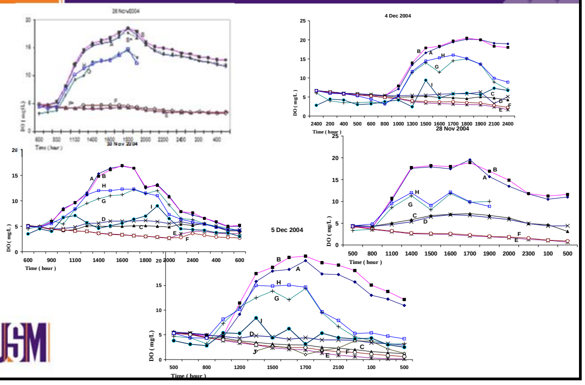


⟵ One aerator

Four aerators ⟶



TH Measured Do



Refined photosynthesis model

Table 3 Respiration rates R_e (mg/L/d) estimated using linear regression

Day	Experiment 1		Experiment 2	
	R_e	R^2	R_e	R^2
1 (26/11/04)	1.6	0.716	1.4	0.879
2 (28/11/04)	3.6	0.986	3.4	0.987
3 (30/11/04)	3.9	0.991	3.8	0.979
4 (04/12/04)	4.7	0.996	4.1	0.987
5 (05/12/04)	5.6	0.959	4.8	0.969

Table 4 Reaeration rates β d^{-1}

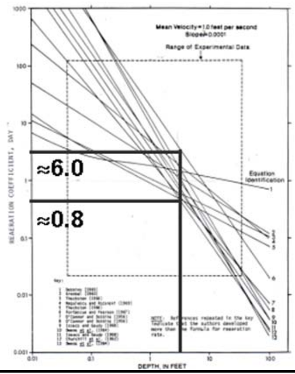
Experiment	Date				
	26 Nov	28 Nov	30 Nov	4 Dec	5 Dec
1	4.3	6.2	4.4	3.3	3.7
2	5.2	7.0	4.4	3.3	4.3

Refined photosynthesis model

Table 5 Photosynthesis rate δ mg/L/d in lake and bottles estimated using curve regression

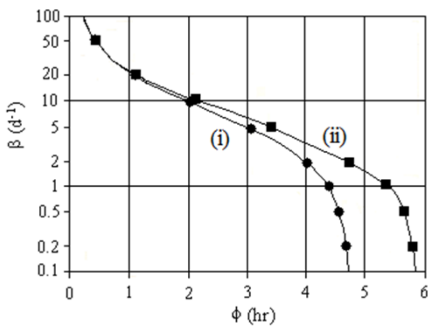
Day	Tank 1		Tank 2		Tasik Harapan	
	δ_1	C	δ_2	C	δ_{TH}	C
1	43.7	0.85	43.4	0.83	33.5	0.97
2	47.1	0.87	44.0	0.89	25.5	0.92
3	37.7	0.94	37.7	0.95	27.0	0.95
4	48.1	0.92	50.1	0.94	43.3	0.95
5	50.7	0.93	51.6	0.93	34.4	0.94

USEPA Reaeration β Estimation



Delta Method β Estimation

Estimation of β using (i) Delta Method (ii) time of DO peak, ϕ = tan^{-1} (σ/β)



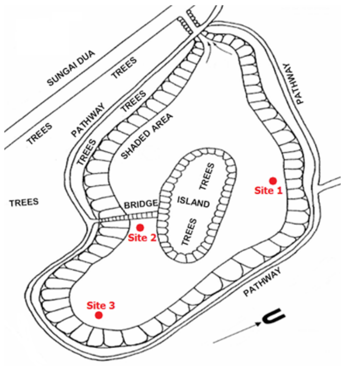
Role of Mudball & EM Solution

Role of Mudball & EM Solution

Role of Mudball & EM Solution

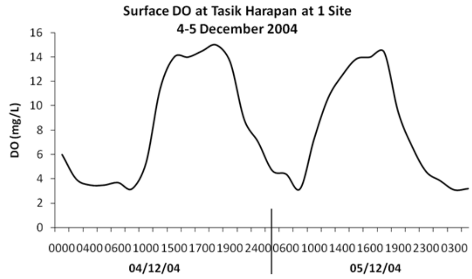
- An attempt has been made beginning August 2010 to use mudball and effective microorganism (EM);
- In an effort to improve water quality in Tasik Harapan, with undocumented success (Asha et al., 2010);
- We therefore attempted to verify the effectiveness of the EM solution method by comparing DO level in Tasik Harapan for the period November-December 2004 and the period December 2010-January 2011.

Three sampling sites at Tasik Harapan



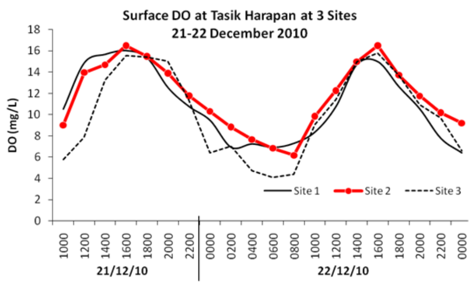
Tasik Harapan Measured DO 4-5 Dec 2004

Over the diurnal cycle, surface DO varies from a low of around **3.5 mg/L** in the early part of the morning (6:00 am) to a maximum of **15 mg/L** in the late afternoon (5:00 pm) on **4-5 December 2004**.



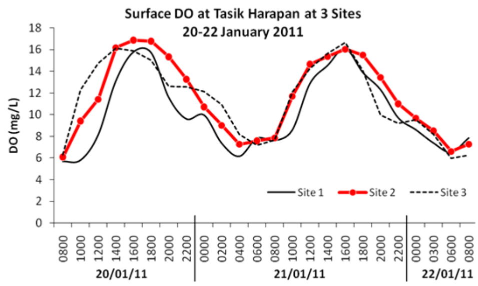
Tasik Harapan Measured DO 21-22 Dec 2010

For the period four months after continuous EM release (**Dec 2010 to Jan 2011**), the surface DO varies between a low of about **4 mg/L** in the early morning to a high of **17 mg/L** in the late afternoon



Tasik Harapan Measured DO 20-22 January 2011

For the period four months after continuous EM release (**Dec 2010 to Jan 2011**), the surface DO varies between a low of about **4 mg/L** in the early morning to a high of **17 mg/L** in the late afternoon



Role of Mudball & EM Solution

- DO 2004 : 3.5 – 15 mg/L;
- DO 2011 after application of mudball & EM : 4 – 7 mg/L;
- Diurnal patterns of DO before and after the continuous release of EM demonstrate close similarity;
- Post EM-release DO indicates increase DO levels due to increased photosynthesis;
- ⇒ Eutrophic state in TH has not been reduced by four months of release of EM.

USM

Role of Mudball & EM Solution

- Based upon this preliminary data;
- It may be surmised that the continuous release of EM in TH;
- May have even caused a slight increase in photosynthesis;
- If we allow ourselves the liberty to use photosynthesis = eutrophication;
- Then we may arrive at the tentative findings;

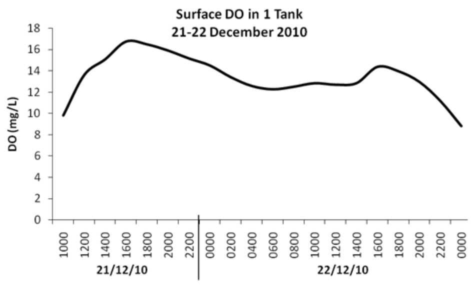
USM

Role of Mudball & EM Solution

- That EM solution application in Tasik Harapan might have even contributed slightly to increase eutrophication, contrary to its planned objective;
- Anecdotal evidence, as witnessed from the deep green color of Tasik Harapan, may add further credential to this hypothesis;
- In any case, the jury is still out in the open, awaiting further in-depth analysis.

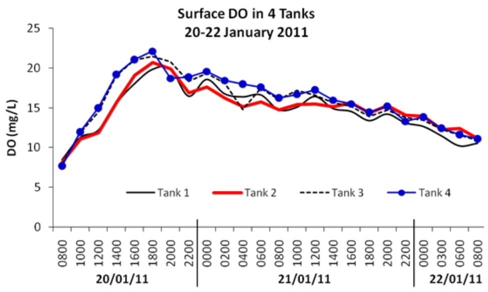
USM

Role of atmospheric reaeration



USM

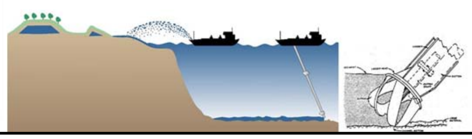
Role of atmospheric reaeration



USM

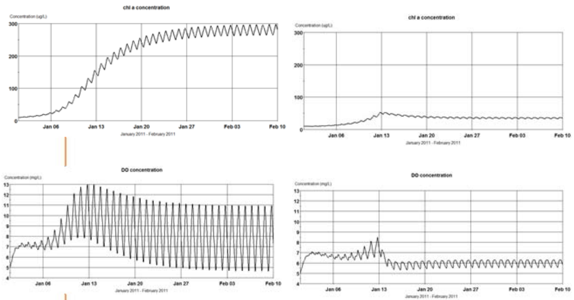
Removal of sediment nutrients

- Mechanical aeration is not a solution to eutrophication;
- Similarly, EM solution and mudball;
- Removal of nutrients accumulated in the sediment layers;
- Is a viable option to rehabilitateTasik Harapan;



USM

Removal of sediment nutrients



Before Removal | **After Removal**

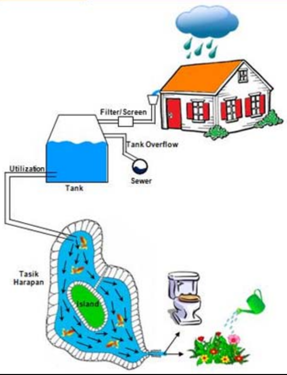
Conclusion

- Tasik Harapan is highly eutrophicated;
- Wild fluctuation of DO over the diurnal cycle;
- Reaching 18 mg/L in late afternoon;
- Mechanical aerator not effective;
- Does not remove the source of nutrients;
- Adding DO is meaningless in TH;

Conclusion

- Mudball and EM solution did not appear to reduce the degree of eutrophication in Tasik Harapan;
- Addition of mudballs may even ↑ turbidity;
- And add additional nutrients;
- Further complicate eutrophication process;
- Removal of sediment from the lake bottom;
- Viable option that deserves more careful study;

Conclusion



- Sediment removal is sustainable in long run;
- If a source of water can be found;
- In the form of rainwater harvesting;
- To provide flow to Tasik Harapan;
- Should be closely look at in the near future.