Original Research Article

A Comparative Study of Discrete Dynamical System and Moving Average Model in Assessing and Predicting Availability of Clean Water.

***Abstract*:**

Many developing countries, Malaysia included, are constantly faced with problems in managing water resources as there is lack of integration and holistic approach with little participation from the general public and other stakeholders apart from the government. In this study, two quantitative model which are the discrete dynamical system and moving average is applied to obtain the forecast value of clean water in Malaysia's river basin by using open source data with minimal cost of analysis. The findings suggested that moving average method is superior as it provides better accuracy in forecasting with small error rate. The method is easy to understand, used standard MS Excel in computing, and need only minimal requirement of the machine's operating system. Continuous assessment to the quality level of clean water in Malaysia's river basin should be strictly regulated to ensure the right course of action to manoeuvre effective countermeasure for this issue. Among the counter measures may be in a form of focused education towards specified target groups, regulatory exercises, as well as awareness campaigns that are more effectively arranged.

Keywords: *water pollution, discrete dynamical system, Malaysia, environment risk*

1.0 INTRODUCTION

Over two thirds of the Earth's surface is covered by water. Water is the most essential component in the world as it forms the basic need for the origin of life (Dwivedi, 2017). Between 1900 and 1995 alone, the demand of water has increased six times more than double the rate of population growth (Postel, 1997), thus poses threat for the existence of life in general. Such dependencies to this limited resource is becoming critical, as water quality became poorer and polluted as time progresses (Utama & Suharta, 2018).

The term 'water quality' is used to state suitability of water to maintain its uses or processes. Any particular use will have certain necessity for physical, chemical or biological properties of water. Examples include standard limit on concentration of toxic substances for drinking water, or the regulation on the level of temperature and pH to support living invertebrate in the water. Andreea and Dunca (2018) emphasizes that it is crucial to maintain quality of water in the rivers as this resource is used extensively, including domestic and residential water supply, irrigation, hydroelectric power plant, transportation and infrastructure, tourism, recreation, and other human or economic activity. For certain rivers, water quality is the result of a few parameters that are interconnected with local and temporal variations influenced by water flow rates throughout the year. Kauffman (2018) stated that water quality has been impaired by nutrient pollution but has recovered in the last several decades and Harichandan et al. (2017) support that the surface water quality in the region is governed by both natural processes such as rainfall rates, weather processes and man-made activities such as urban, industrial and agricultural activities as well as exploitation of human resources.

Among reasons of water pollution includes natural processes of eutrophication (Zieminska-stolarska & Skrzypski (2012), dyeing and screen printing business (Utama & Suharta, 2018), expansion of the mining industry, increasing use of chemicals in agriculture and rapid changes in land activities (Afroz et al, 2014), and farming activities (Anh et al., 2010), to highlight only a few. These have been supported by Marusic (2013) in her article where she stated that the economic activity of society could bring negative changes in aquatic systems, for example, the changing in the water chemical composition and disrupting aquatic systems. Besides that, most of human activities were carried out using water from rivers, which is lately steadily declining. Marusic (2013) also urged that water must meet quality standards in order to be safely used. Taheri Tizro et al. (2014) also stated that the water quality could be affected by salinity overdraw of groundwater, urban and domestic wastewater entrance into surface streams as well as agricultural drainage. In addition, Lodha (2018) stated that water pollution caused by toxic organic pollutants from domestic and industrial output. Whatever the reasons, rapid economic development, pattern change and pattern usage to the industry, agricultural practices and placement concentrations along the river, make river basins prone to pollution (Ahmad Isikaya et al., 2015).

The effect of water pollution is very dangerous to human life. 80% of mortality is due to water pollution (Dwivedi, 2017). Traces of heavy metals that are presence in grains, vegetables, fruit and milk are evidenced of this critical issue. Heavy metals which are causative of large number of un-understood diseases should be treated carefully. Due to water pollution pure water is becoming less scarce day by day. Afroz et al. (2014) indicate that the major problem associated with water pollution is the added pressure for human heart and kidneys to work efficiently when polluted water is consumed regularly. Other health problems associated with polluted water are poor blood circulation, skin lesions, vomiting, cholera, gastroenteritis and damage to the nervous system. Primin (2018) stated that human health must become one of the first priority aspects of water quality protection activity. A very important role in this chain belongs to potable water, drinking water supply and public water supply.

Afroz et al. (2014) highlighted the negative impact on Malaysia’s effort to promote sustainability in the near future, if such pressure to the water system is not handled collectively. Many developing countries, Malaysia included, are constantly faced with problems in managing water resources as there is lack of integration and holistic approach which usually have little participation from the general public and other stakeholders apart from the government (Afroz et al, 2014). However, failure to solve this issue will result in the increase in economic spending as the cost of treating polluted waters are too high and in some instances, polluted waters are not treatable for consumption (Afroz et al, 2014).

In this study, we will showcase how some simpler quantitative models with minimal cost of analysis can help in paving way to contribute to the continuous assessment of the water quality in Malaysia. We will compare two models, the discrete dynamical system method, and moving average method to forecast water quality in Malaysia. This forecast can help us to continuously estimate whether Malaysian water quality is getting better or worse, with countermeasure can be conducted in response to the findings.

2.0 METHODOLOGY

Data Collection

The data set of total number of river basin monitors and clean water in Malaysia from year 1998 to 2015 is obtained from the Department of Statistics Malaysia in Table 1. We will adopt discrete dynamical system and moving average analysis to project the behavior of clean water in Malaysia.

Clean Water in Malaysia			
Year	Total rivers basin monitors	Clean water	Ratio of clean water
1998	120	33	0.275
1999	120	35	0.292
2000	120	34	0.283
2001	120	60	0.500
2002	120	63	0.525
2003	120	59	0.492
2004	120	58	0.483
2005	146	80	0.548
2006	146	80	0.548
2007	143	91	0.636
2008	143	76	0.531
2009	143	70	0.490
2010	143	65	0.455
2011	140	76	0.543
2012	140	74	0.529
2013	140	74	0.529
2014	140	62	0.443

2015	140	71	0.507

Table 1: Data of clean water in Malaysia for 1998 until 2015

The total rivers basin in Malaysia changes for every year. The clean water also change for every year. Therefore, to get the ratio of clean water is calculated based on number of clean water and total rivers basin. The formula ratio of clean water can be developed as follows:

$$Ratio\ of\ Clean\ Water = \frac{Clean\ Water}{Total\ Rivers\ Basin\ Monitors}$$

Discrete Dynamical System

Dynamic system can cater evolution of quantities over time either through seamlessly over time or in discrete time steps. Here, a dynamic system is introduced where the state of the system evolves in a discrete time-frame. The value of data P_n and its corresponding evolution $\frac{\Delta p_n}{p_n(P_{MAX}-p_n)}$ is developed. The predicted value of *n* can be found through the analysis of formulation in MS Excel, thus the long term equilibrium value can be determined.

In order to ensure the fitness of the model, the forecast error, ε can be found for each value of data, from the year 1998 to 2015, with accompanied illustrations. Once the model has been developed, the needed equilibrium value can be ascertained, thus enable analyst to forecast the said model.

Moving Average (k=3)

In this method, the average of the most recent *k* data values in the time series is utilized to forecast the next period. The formulation for a moving average forecast of order *k* is as follows:

$$F_{i+1} = \frac{\sum \quad (most\ recent\ k\ data\ values)}{k} = \frac{Y_t+Y_{t+1}+\cdots+Y_{t-k+1}}{k},$$

where

$F_{i+1} = forecast\ of\ the\ times\ series\ period\ t+1$, and

$Y_t = actual\ value\ of\ the\ time\ series\ in\ period\ t$

3.0 RESULT AND DISCUSSION

Discrete Dynamical Model

In this study, the objective is achieved by developing a model of clean water using discrete dynamical system. When p_{max}= 0.6364, the model is developed as shown in Table 2.

Year	Clean water	$\frac{\Delta p_n}{p_n(0.6364-p_n)}$
1998	0.2750	0.02190
1999	0.2917	-0.00985
2000	0.2833	0.26996
2001	0.5000	0.00682
2002	0.5250	-0.00707
2003	0.4917	-0.00245
2004	0.4833	0.02046
2005	0.5479	0
2006	0.5479	0.01427

Year	Clean water	$\frac{\Delta p_n}{p_n(0.6364-p_n)}$
2007	0.6364	0
2008	0.5315	-0.00828
2009	0.4895	-0.01049
2010	0.4545	0.03532
2011	0.5429	-0.00246
2012	0.5286	0
2013	0.5286	-0.01748
2014	0.4429	0.02809
2015	0.5071	-0.12922

Table 2: Projection of dynamical system model

Then, the average of $\frac{\Delta p_n}{p_n(0.6364-p_n)}$ can now be determined (0.013968). The recursive relation can be developed as follows:

$$\frac{\Delta p_n}{p_n(0.6364-p_n)} = 0.013968$$

$$p_{n+1} - p_n = 0.013968\, p_n(0.6364 - p_n)$$

$$0.013845p_{n+1} = 1.008889(1 - 0.013845p_n)0.013845p_n$$

Let $a_n = 0.013845p_n$, the model becomes

$$a_n = 0.013845p_n$$

$$a_{n+1} = 1.008889(1 - a_n)\, a_n \qquad (1)$$

where r = 1.008889. Since $|f'(M)| < 1$, the equilibrium value for this system is stable.

Once Equation (1) is formed, the forecast value of clean water in Malaysia for 2016 until 2018 can be conducted. The normalized value, a_n and the predicted values, p_n for each n is shown in Table 3.

Year	a_n	p_n
1998	0.003807	0.2750
1999	0.003827	0.276388
2000	0.003846	0.277778
2001	0.003865	0.279169
2002	0.003884	0.280562
2003	0.003904	0.281957
2004	0.003923	0.283353
2005	0.003942	0.28475

Year	a_n	p_n
2009	0.00402	0.290352
2010	0.004039	0.291755
2011	0.004059	0.293159
2012	0.004078	0.294565
2013	0.004098	0.295971
2014	0.004117	0.297379
2015	0.004137	0.298787
2016	0.004156	0.300196

2006	0.003962	0.286148	**2017**	0.004176	0.301605
2007	0.003981	0.287548	**2018**	0.004195	0.303016
2008	0.004001	0.288949			

Table 3: The normalized value, a_n and the predicted values, p_n for year 1998 until 2018

Based on the findings, the predicted ratio of clean water for river in Malaysia for 2016, 2017 and 2018 are 0.300196, 0.301605 and 0.303016 respectively which indicate that the availability of clean water sources in Malaysia is growing throughout the year.

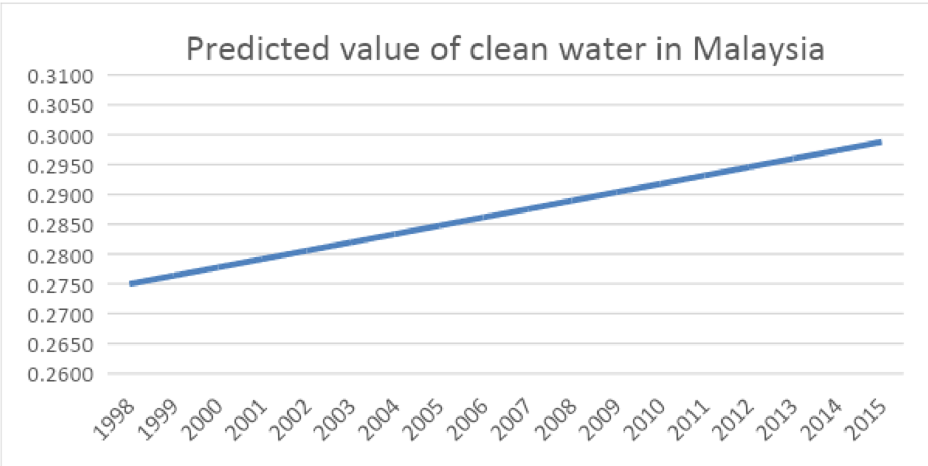

Figure 2: Graph of predicted value of clean water in Malaysia

Figure 2 shows the model with r =1.008889 indicated that the water quality in Malaysia keep increasing (improving) throughout the year.

Test of Fit

Test for the fit of the model is formed to determine whether the model adequately describing the data by comparing the actual values and the predicted values.

n	Actual value	Predicted value	Forecast error	*n*	Actual value	Predicted value	Forecast error
1998	0.27500	0.27500	0.000000	2007	0.63636	0.28755	0.548138
1999	0.29167	0.27639	0.052384	2008	0.53147	0.28895	0.456319
2000	0.28333	0.27778	0.019607	2009	0.48951	0.29035	0.406853
2001	0.50000	0.27917	0.441661	2010	0.45455	0.29175	0.358139
2002	0.52500	0.28056	0.465596	2011	0.54286	0.29316	0.459970
2003	0.49167	0.28196	0.426529	2012	0.52857	0.29456	0.442715
2004	0.48333	0.28335	0.413753	2013	0.52857	0.29597	0.440054
2005	0.54795	0.28475	0.480332	2014	0.44286	0.29738	0.328500
2006	0.54795	0.28615	0.477779	2015	0.50714	0.29879	0.410843

Table 4: Calculation for fit of model

The average error of this model is 0.368287377 which is still low. Hence, this model is fit to be used in forecasting water quality in Malaysia.

Moving Average (k=3)

Another approach used to forecast the clean water in Malaysia is moving average method. We determined the most recent values of the time series that considered relevant is three. The result for the prediction value is shown in Table 5.

Year	Actual	Prediction	Error	Absolute Error	Year	Actual	Prediction	Error	Absolute Error
2001	0.5000	0.2833	0.2167	0.2167	2009	0.4895	0.5719	-0.0824	0.0824
2002	0.5250	0.3583	0.1667	0.1667	2010	0.4545	0.5524	-0.0979	0.0979
2003	0.4917	0.4361	0.0556	0.0556	2011	0.5429	0.4918	0.0510	0.0510
2004	0.4833	0.5056	-0.0222	0.0222	2012	0.5286	0.4956	0.0329	0.0329
2005	0.5479	0.5000	0.0479	0.0479	2013	0.5286	0.5087	0.0199	0.0199
2006	0.5479	0.5076	0.0403	0.0403	2014	0.4429	0.5333	-0.0905	0.0905
2007	0.6364	0.5264	0.1100	0.1100	2015	0.5071	0.5000	0.0071	0.0071
2008	0.5315	0.5774	-0.0459	0.0459					

Table 5: Moving average (*k*=3) for clean water in Malaysia from 2001 until 2015

Based on the results, the average error is 0.0725 which is significantly low, indicating that the forecasted values are closely representing the actual data. Therefore, the findings illustrated that accessibility of clean water in Malaysia increasing moderately.

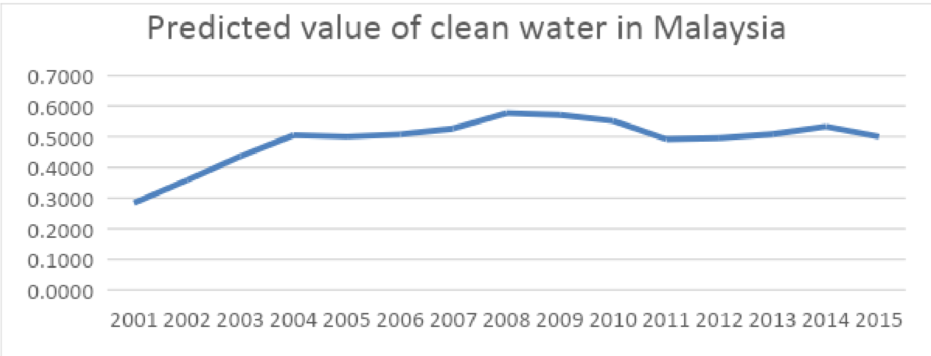

Figure 3: Forecasted value of clean water in Malaysia by using moving average method

Comparison Between Discrete Dynamical System and Moving Average Method

Figure 4 illustrates the result for dynamical system. The prediction value shows a similar pattern with the actual in 1998 until 2000. On 2001 and upwards, the prediction value does not represent the actual value that is quite high than prediction.

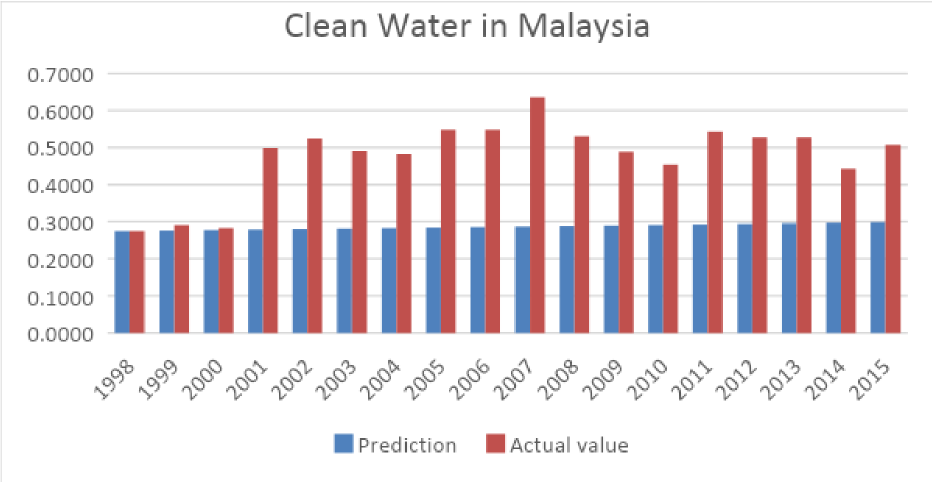

Figure 4: Graph of prediction and actual value for clean water in Malaysia using Discrete Dynamical System

While Figure 5 illustrates the result for moving average method. The prediction values are closely resembled the actual values. The only exception are for the year 2001 and 2002, where the prediction is slightly lower than the actual value.

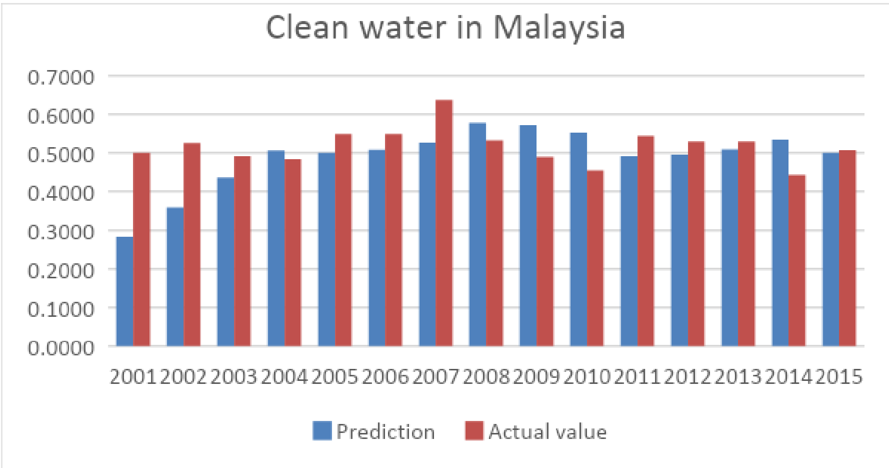

Figure 5: Graph of prediction and actual value for clean water in Malaysia using Time Series Analysis

Therefore, we can suggest the use of moving average method in the evaluation of the future clean water analysis in Malaysia's river basin. This method is easy to implement, understand, and produce reliable results as the error rate is very small, with minimal computation time and requirement.

4.0 CONCLUSION

In this study, a comparison of two forecasting methods were presented to solve the problem of predicting the ratio of clean water in Malaysia's river basin. Such problem is critical to be addressed, as the failure to do so will result in reduced ability of clean water sustainability in the country, resulting to threat of preventable critical disease and non-productive citizens. These two methods of analysis were selected as these methods can be conducted with minimal costs, using only standard operating computer system with standard MS Excel already equipped in most machine. This analysis also make used of available data, thus showed versatility in their implementation.

The findings suggested that the use of moving average method is more superior compared to the discrete dynamical system for the evaluation of clean water in Malaysia due to its small error rate. Thus, the moving average method can be applied to identify the availability of clean water sources in Malaysia for the benefit of the future generation. This was due to significant role of water for the living things to survive. It is hope that such continuous assessment to the quality level of clean water in Malaysia's river basin will be strictly regulated to ensure the right course of action to manoeuvre effective countermeasure for this issue.

Among the counter measures may be in a form of focus education towards specified target groups, regulatory exercises, as well as awareness campaigns that are more effectively arranged. As highlighted by Galadima et al. (2011), pollution in the river water is caused by the lack of education, low budgetary funding, inefficient government policies, corruption, drought and other anthropogenic factors. Lastly, this research is hoped to give important contribution to the related local authority including Ministry of Energy, Science, Technology, Environment and Climate Change so that actions can be taken to preserve Malaysia water sources from pollution.

REFERENCES

Afroz, R., Masud, M. M., Akhtar, R., & Duasa, J. (2014). Water pollution challenges and future direction for water resource management policies in Malaysia. *Environment and Urbanization ASIA 5*(1), 63-81.

Anh, P. T., Kroeze, C., Bush, S. R., & Mol, A. P. J. (2010). Water pollution by Pangasius production in the Mekong Delta, Vietnam: causes and options for control. *Aquaculture Research,* 1-21.

Chaudhry F. N., & Malik M. F. (2017). Factors affecting water pollution: A review. *Journal of Ecosystem & Ecography, 7*(1).

Dwivedi, A. K. (2017). Researches in water pollution: A review. *International Research Journal of Natural and Applied Sciences, 4*(1).

Galadima, A., Garba, Z. N., Leke, L., & Almustapha, M. N. (2011). Domestic water pollution among local communities in Nigeria ----Causes and consequences. *European Journal of Scientific Research, 52*(4), 592-603.

Harichandan, A., Patra, H. S., & Sethy, K. M. (2017). Evaluation of Water Quality of Local Streams at Gandhamardan Iron Mines, Suakati, Keonjhar District of Odisha, India. *Journal of Pollution Effects & Control, 05*(03).

Marusic, G. (April 2013). A study on the mathematical modelling of water quality in "river-type" aquatic systems. *WSEAS Transactions on Fluid Mechanics,* 8(2).

Schwarzenbach, R. P., Egli, T., Hofstetter, T. B., Gunten, U. V., & Wehrli, B. (2010). Global water pollution and human health. *The Annual Review of Environment and Resources*.

Taheri Tizro, A., Ghashghaie, M., Georgiou, P., Voudouris, K. (2014). Time series analysis of water quality parameters. *Journal of Applied Research in Water and Wastewater*, 1(1), 2014, 43-52.

Utama, M. A., & Suharta, N. (2018). The challenges of water pollution: Enforcement of water pollution control. *Hasanuddin Law Review, 4*(1).

Wang, Q., & Yang, Z. (2016). Industrial water pollution, water environment treatment, and health risks in China. *Environmental Pollution, 218*, 358-365.

Ziemińska-stolarska, A., & Skrzypski, J. (2012). Review of mathematical models of water quality. *19*(2), 197-211.

Kauffman, G. (2018). The Cost of Clean Water in the Delaware River Basin (USA). Water,10(2), 95. doi:10.3390/w10020095

Lodha, M. (2018). Water pollution. *International Journal,5(3).*

doi:10.19080/OMCIJ.2018.05.555665

Primin, O. (2018). Clean Water of Russia: Problems and Solutions. IOP Conference Series: *Materials Science and Engineering,365, 022064.* doi:10.1088/1757-899x/365/2/022064

Ahmad Isikaya, H., Juahir, H. (2015). Analysis of Surface Water Pollution in The Kinta River Using Multivariate Technique. *Malaysian Journal of Analytical Sciences*, 19(5), 1019 - 1031