Vertical Distribution and Flux of Nutrients in the Sediments of the Mangrove Reclamation Region of Muara Angke Kapuk, Jakarta

Anna Ida Sunaryo Purwiyanto[1*)], Tri Prartono[2], and Alan Frendy Koropitan[2]

1. Department of Marine Science, Faculty of Mathematics and Natural Sciences, Universitas Sriwijaya, Palembang 30662, Indonesia
2. Department of Marine Sciences and Technology, Faculty of Fisheries Marine Sciences, Institut Pertanian Bogor, Bogor 16680, Indonesia

*)*E-mail: anna_ida_sunaryo@mipa.unsri.ac.id*

Abstract

The reclaimed mangrove estuary in Muara Angke Kapuk is a reclaimed area that has not evaded the impacted of pollution and waste in the areas surrounding Cengkareng, Jakarta. This is apparent from the fact that almost all sediments under the mangrove trees are buried under heaps of plastic trash. However, the reclaimed region still has variety of organism, which indicating that the region still has an internal carrying capacity, especially nutrients from sediment. The purpose of this research was to examine the condition of sediment nutrients in this mangrove reclamation region. The research was conducted by taking water samples using a modification of the stratified cup at a sediment depth of 0-15 cm with depth intervals of 2.5 cm, and taking sediment samples using the sediment ring. Pore water samples were measured for dissolved oxygen (DO) and concentrations of ammonia, nitrite, nitrate, and phosphate. Sediment samples were used to obtain porosity values. The data obtained is used to make vertical concentration profiles and analysis of vertical nutrient flux. Vertical nutrient flux analysis was performed with the aid of QUAL2K software version 2.11. The results showed different vertical distributions and flux of nutrients, where *influx* for ammonia and phosphate and an increase in line with increasing sediment depth, while nitrate *efflux* and a decreased concentration. The flux calculation of nitrite as transitory nutrient was not done, but the concentration decreased after a depth of 2.5 cm. This indicates that the high contamination on the surface does not prevent the natural chemical processes so the reclaimed region can still provide nutritional support for its organism.

Abstrak

Distribusi Vertikal dan Fluks Nutrien pada Sedimen Mangrove di Kawasan Reklamasi Muara Angke Kapuk, Jakarta. Kawasan reklamasi mangrove Muara Angke Kapuk merupakan kawasan reklamasi yang tidak lepas dari imbas pencemaran sampah dan limbah di sekitar Cengkareng, Jakarta. Hal tersebut terlihat dari hampir seluruh sedimen yang berada di bawah pohon mangrove tertutup oleh timbunan plastik. Meski demikian, kawasan reklamasi ini masih memiliki beragam biota, sehingga diduga lingkungan ini masih memiliki daya dukung internal, terutama nutrien dari sedimen. Tujuan penelitian adalah mengkaji kondisi nutrien pada sedimen kawasan reklamasi mangrove. Penelitian ini dilakukan dengan mengambil sampel air poros menggunakan modifikasi cawan bertingkat pada kedalaman sedimen 0-15 cm dengan interval kedalaman 2,5 cm, serta sampel sedimen dengan menggunakan ring tanah. Sampel air poros diukur Dissolve Oxygen (DO) dan konsentrasi amoniak, nitrit, nitrat, dan fosfat. Sampel sedimen digunakan untuk memperoleh nilai porositas. Data yang diperoleh digunakan dalam pembuatan profil konsentrasi secara vertikal, analisis fluks nutrien vertikal. Analisis fluks nutrien secara vertikal dilakukan dengan bantuan *software* QUAL2K version 2.11. Hasil penelitian menunjukkan distribusi vertikal dan fluks nutrien yang berbeda-beda, di mana amoniak dan fosfat mengalami *influx* dan peningkatan seiring dengan bertambahnya kedalaman sedimen, sedangkan nitrat mengalami *efflux* dan penurunan konsentrasi. Penghitungan fluks nitrit yang merupakan nutrien peralihan tidak dilakukan, namun konsentrasinya mengalami penurunan setelah kedalaman 2,5 cm. Hal tersebut mengindikasikan bahwa tingginya pencemaran di permukaan tidak menghalangi proses kimia alami sehingga kawasan reklamasi tersebut masih dapat memberi dukungan nutrisi bagi biota.

Keywords: fluxes, Muara Angke Kapuk, nutrient, porewater, sediment

1. Introduction

The mangrove ecosystem in the reclaimed region of Muara Angke Kapuk is an ecosystem which located at the estuary of the Cengkareng channel. Although it is a reclaimed area, the ecosystem is cant be seperated from the wide range of external environmental pressures, especially pollution and waste from factories around

Cengkareng. Polluted waste can be clearly seen from the physical condition Cengkareng and local channels around the channel, where the non-degradable waste accumulates along the river banks. Waste pollution in Cengkareng channel is confirmed by Rochyatun and Rozak [1] where the channel is one of the western part of Jakarta Bay waters with high levels of heavy metals (Pb, Cd, Cu, Zn and Ni). Pollution quite influences estuarine conditions, which is the blackish gray sediment at the mouth of the estuary area that indicates low levels of oxygen.

Those pollution affects ecosystems in the surrounding areas, including the reclaimed mangrove areas. Cengkareng mangrove reclamation area is one sector of the Muara Angke Wildlife Refuge managed by the BKSDA. This reclaimed region can be regarded as a successful reclamation area despite the pollution. This is proven by the diversity of organism, including benthos (especially crab) and birds, thus indicating that the region still has a carrying capacity to produce nutrients that come from the environment, such as sediment. Therefore, the purpose of this study is to examine the condition of the nutrients contained in the reclaimed mangrove sediments.

2. Methods

Sampling Locations. The research was conducted in February-March 2011 in the protected forest region of reclaimed mangrove at Muara Angke Kapuk, Jakarta. This study used 3 point sampling (Figure 1). The samples taken at each sampling point are samples of pore water and sediment.

Pore water Sampling. Water samples obtained were used to determine the concentration of nutrients contained in mangrove sediment. The samples were drawn using a stratified cup which is a modification of the principles *pore water peeper* developed by Buffle and De Vitre [2].

Water samples were taken from a vertical shaft, from a depth of 0 cm, 2.5 cm, 5 cm, 7.5 cm, 10 cm, 12.5 cm, and 15 cm. Water sampling was initially conducted by implanting a stratified cup for 3 days. This was done to ensure that the water was in a homogeneous condition, and to obtain the required number of samples. Samples of pore water accumulated in the cup was extracted by using a 50 ml syringe pipette and directly transferred to a sample bottle carefully to prevent air bubbles.

Sediment Sampling. Sediment sampling was conducted by using the sediment ring and aims to determine the sediment porosity. The sediment ring was buried in sediment until reach the upper ring, and then then the ring is taken from the bottom with a shovel. Once the ring has been removed, closed on both sides placed in a box.

Sediment ring used has a diameter of 20 cm and height of 5 cm. Therefore, sediment porosity is measured at intervals of 5 cm, ranging from the surface (0 cm) to a depth of 15 cm, thus three separate porosity data are obtained.

The data Acquisition. DO data are measured directly in the field, shortly after the pore water is obtained. Measurement of ammonia concentrates (NH_4^+) was

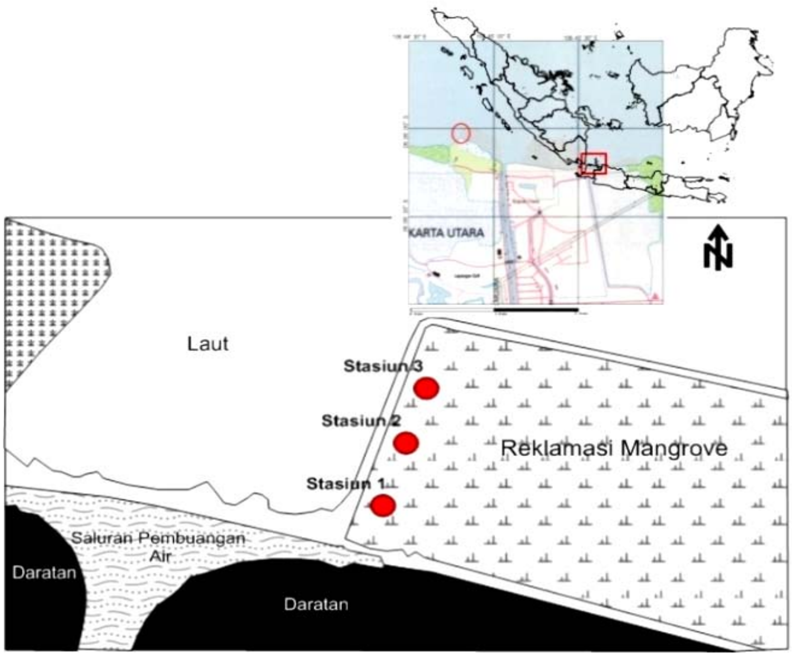

Figure 1. Research Location in the Reclaimed Mangrove Region of Muara Angke Kapuk, Jakarta

calculated using the Nessler Method. Measurements of the nitrite concentrate (NO_2^-) and nitrate (NO_3^-) were made using the Cadmium Reduction Method, and the measurement of phosphate (PO_4^{2-}) was performed by using the Ascorbid Acid Method. Porosity data were obtained by following the procedures from the Soil Research Institute [3].

Data Analysis. The data obtained are presented in graphical form to obtain vertical nutrient profiles, and nutrient fluxes were obtained using the box model QUAL2K program version 2.11. Nutrient fluxes which calculated by QUAL2K program assumed that flux occurring in each box represents the area between the two sediment depths, i.e. depth of the top and bottom (Figure 2) of the sediment surface. In this study, of the seven layers of sediment depth (0-15 cm depth), 6 box models were obtained (Table 1).

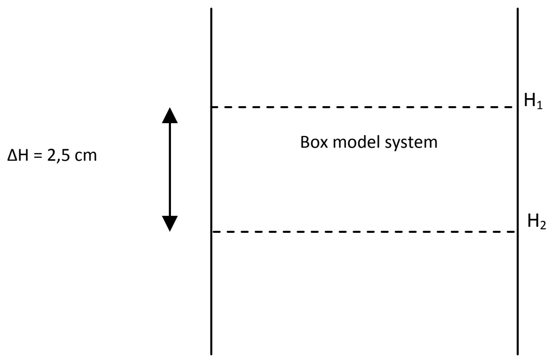

Figure 2. Illustration of the Model System QUAL2K Box Representing Sediment and Pore Water Conditions in the Area between the Two Depths

Table 1. The Principle of the QUAL2K Box Model Program

Box model	Specification
1	represents the area between the depths of 0 to 2,5 cm from the sediment surface
2	represents the area between the depths 2.5 to 5 cm from the sediment surface
3	represents the area between the depths of 5 to 7,5 cm from the sediment surface
4	represents the area between the depths of 7,5 to 10 cm from the sediment surface
5	represents the area between the depths of 10 to 12,5 cm from the sediment surface
6	represents the area between the depths of 12,5 to 15 cm from the sediment surface

Each flux generated a flow of nutrients that occurred in each box, either internally or externally. Nutrients simulated by QUAL2K program include NH_4^+, NO_3^-, and PO_4^{3-}. This is because these three nutrients are the main outcome of the mineralization process, whereas NO_2^- is considered as an intermediary ion so its flux is not taken into account.

3. Results and Discussion

Vertical Profiles of Nutrients. Concentrations of nutrients (NH_4^+, NO_2^-, NO_3^-, PO_4^{3-}) in pore water in the reclaimed mangrove Muara Angke Kapuk have distinct vertical changes. The vertical profile of each nutrient is presented in Figure 3.

In general, nutrients in the reclaimed sediments increased up to15 cm for NH_4^+ and PO_4^{3-}. At the surface to a depth of 2.5 cm at first NH_4^+ initially decrease from 87.53 µmol/l to 85.42 µmol/l, after that NH_4^+ increased to 321.63 µmol/l at 15 cm. PO_4^{3-} concentrate increased from 7.00 µmol/l to 34.94 µmol/l. Concentrations of NO_2^- has increased on the surface to a depth of 2.5 cm from 0.201 µmol/l to 0.782 µmol/l and then decreased to 0.258 µmol/l at a depth of 15 cm. Contrary to NH_4^+, the NO_3^-concentrate increased to a depth of 2.5 cm, i.e. from 97.52 µmol/l to 99.23 µmol/l. After passing through the depth of 2.5 cm, NO_3^- then declined to reach 27.57 µmol/l at a depth of 15 cm.

Vertical changes in the nitrogen concentrate (NH_4^+, NO_2^-, NO_3^-) in Figure 3 indicate the presence of a chemical reaction mechanism in the sediment. The increase of NH_4^+ along with a decrease in NO_3^-indicates an anaerobic process, i.e. denitrification. The dominance of denitrification processes occurring in the sediment is also strengthened by the decreasing oxygen content (Figure 4).

At the sediment surface to a depth of 2.5 cm, the NH_4^+ concentrate decrease along with an increase in NO_3^{-i} is due to the availability of oxygen up to a depth of 2.5 cm. Availability of sufficient oxygen at this depth causes an aerobic process to occur. But after passing through a depth of 2.5 cm oxygen has decreased significantly and this insufficient for the anaerobic process to take place. The Water Planet Company [4] explains that denitrification will begin to occur in conditions where oxygen is less than 0.5 mg/l. In addition to decreased oxygen content, the anaerobic process also occurs because of limited concentrations of nitrates, both the nitrates that are naturally contained in the sediment, and nitrates that are transposed from former processing [5].

Decreases in $NO_3^-$and $NO_2^-$and an increase inNH_4^+ were also found in studies conducted in other regions. Liu *et al*. [6] conducted a study on the coast of Bohai Sea, China

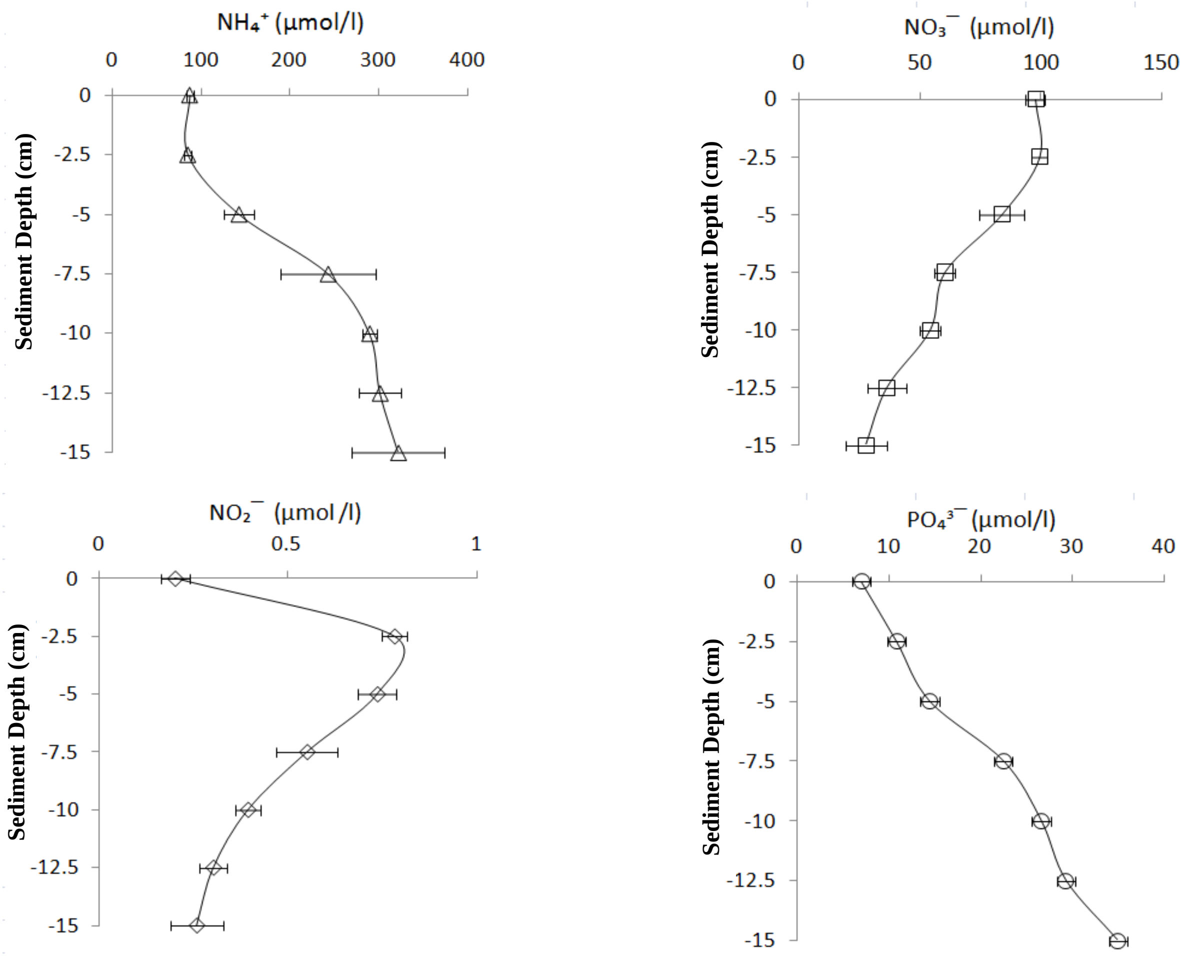

Figure 3. Vertical Profiles of NH_4^+, NO_2^-, NO_3^-, and PO_4^{3-} in Pore Water According to Sediment Depth (cm)

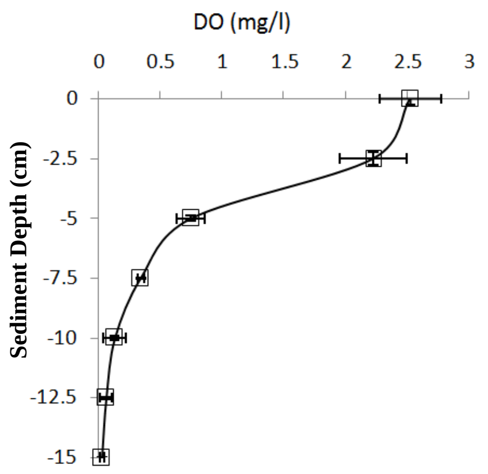

Figure 4. Oxygen Content (mg/l) in Pore Water in Relation to Depth (cm)

and observed the reduced of NO_3^- and NO_2^- sharply as a description of denitrification rate, especially at the sediment-water interface. Similarly, Woulds *et al.* [7] with the location of the study at Pakistan Margin Oxygen Minimum Zone (OMZ) also obtained similar results.

The mechanism of chemical sediments also affects the PO_4^{3-}concentration (Figure 3). Sediment that has low oxygen results the in the reduction of Fe^{3+} which is naturally present in nature becomes Fe^{2+}. Fe ions have the ability to bind phosphate ions in the form of HPO_4^{2-}. Fe^{2+} formed in low oxygen conditions has lower ability to bind HPO_4^{3-} than Fe^{3+}. This causes HPO_4^{3-} to be released from the chemical bond and dissolve in water. Increased ion HPO_4^{3-} in water also causes PO_4^{3-} to increase. An increase in PO_4^{3}-was also obtained and confirmed by Chester [8]; Anschutz *et al.* [9]; Chakrabarty and Das [10]; Geurts *et al.* [11], and Gerhardt *et al.* [12].

Nutrient flux. Nutrients contained in the pore water do not only change in concentration. Each nutrient experiences displacement from one layer to another layer of sediment through the pore water absorption in the sedimentary layers. This is evidenced by looking at the nutrient flux between sediment depth layers presented in Figure 5.

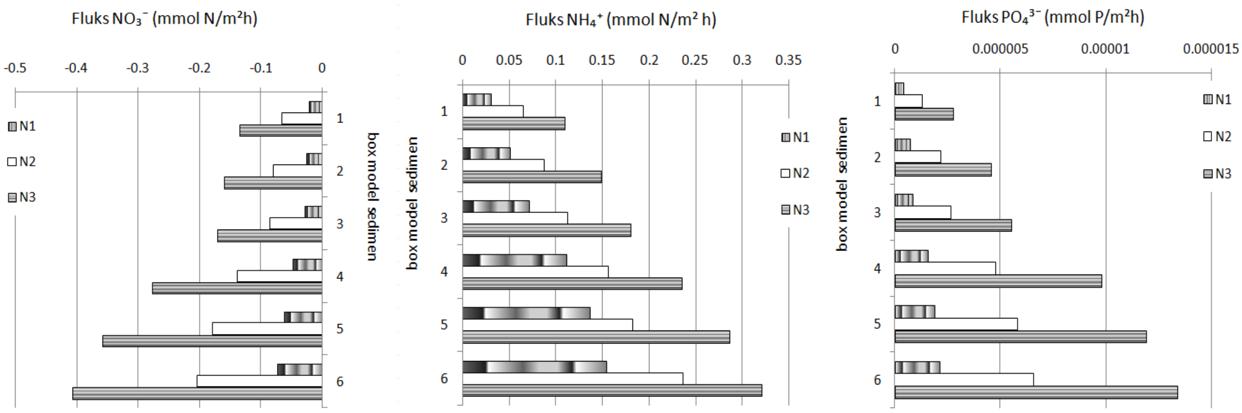

Figure 5 Profile Flux NH_4^+, NO_3^- and PO_4^{3-} (mmol/m^{2}h). Negative and Positive Directions in the Figure Represent the Flux Direction, which a Negative Direction Flux Indicates Out of the Box (Efflux), and a Positive Direction Indicates Flux into the Box Model (Influx). Symbols N1, N2, and N3 Indicate the Sampling Point

In Figure 5 can be seen the different flux of each nutrient. NH_4^+ has influx with a range of 0.030 to 0.321 mmol N/m^{2}h, while NO_3^- has *efflux* with a flux range value of -0.022 to -0.406 mmol N/m^{2}h, and PO_4^{3-} has influx in the range of 0.00000042-0,00001338 mmol P/m^{2}h. The direction of the influx of nutrients shows the flow of nutrients from the water column into the box model, resulting an increasing of nutrients in the box model. Efflux shows the flow of nutrients from the box models into the water column, resulting in decreasing of the concentration of nutrients in the box model.

The range concentration of the flux that occurs in each nutrient in the model box shows the size of flow or the movement of nutrients that occurs between the model box with the sediment surface. This resulted in larger difference in concentration that occur between box models and the sediment surface, the flow of nutrients that occurs will be greater.

Flux in NH_4^+ and PO_4^{3-} is seen in the vertical profile (Figure 3), the influx corresponds to the concentration gradient in the field. Both concentration of nutrients in the sediment-water interface (0 cm depth) is less than the concentration at the depth beneath the sediment, indicating that indeed there is an increase in NH_4^+ concentration and PO_4^{3-} in line with increasing depth. The increasing differences in concentrations that occur between each model box and surface sediments also results in greater flux values. The same principle is true of NO_3^-, although in a different direction.

NO_3^- flux that occurs in these mangrove forests indicate that there is a supply which is essential to support life on the surface. NO_3^- is one form of inorganic nitrogen that is used directly in photosynthesis. According to Domingues *et al*. [13], phytoplankton use as much as 7.2 x 10^{-3} untill 19,6 x 10^{-3}mmol/h, of NO_3^- which is still far from the NO_3^-flux value from sediment to surface sediment.

The presence of PO_4^{3-} in the sediment indicates a high level of PO_4^{3-} on the surface that is still able to meet the needs of photosynthesis. High levels of PO_4^{3-}were also found by Hassler *et al*. [14] who later confirmed that if the nutrients are consumed by phytoplankton, NO_3^- is the first nutrient to be depleted.

Both of these points indicate that flux is important to support survival of the organism in the reclamation region. In addition, the compatibility of the flux results obtained in modeling with the changes in nutrient concentration in the field (Fig. 3) indicate that this modeling can be used to describe the flow of nutrients that occur in mangrove forest sediment.

Nutrient flux that occurs between the inside and the sediment surface is basically not always the same in every region, even in the value and direction of flux. Thouminen *et al*. [15] were used to obtain laboratory chamber efflux of 0.88 to 1.9 mmol/m^{2}h of NH_4^+, NO_3^- efflux amounted to 1.1 to 1.3 mmol/m^{2}h, and the PO_4^{3-} efflux reached 23 to 0.3 mmol /m^{2}h. Bally *et al* [16] obtain the addition of NH_4^+ and PO_4^{3-} in the pore water (influx) in the Seine Estuary muddy sediments, 0,1-0,3 mmol/m^{2}h for NH_4^+ and 0,3-0,8 mmol/m^{2}h for PO_4^{3-}. The difference is believed to be due to the different variables used in the modeling. Thouvenot *et al*. [17] used a bi-layer model and monolayer model, where the different variable between the two is the algae trapped in the sediment. Furthermore, Chikondi *et al*. [18] also used three modeling scenarios, the first scenario is the model basis, the second scenarioa reduced sediment transport by 30%, and the third scenario expanded the agricultural area. These three scenario also produced flux with different directions and values.

4. Conclusions

The reclaimed mangrove sediment of Muara Angke Kapuk has nutrients with different vertical distribution patterns for each type. It was influenced by the chemical processes that continue to occur naturally even though the surface sediment was covered by a lot of plastic garbage. Based on modeling results, in addition to changes in the concentration of the sediment layers, each nutrient has a different flux in both direction and value. Our data indicated that the high pollution occurring on the surface, was not impede the natural process that occurs.

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References

[1] E. Rochyatun, A. Rozak, Makara Sains. 11/1 (2007) 28 (in Indonesia).
[2] J. Buffle, R.R. de Vitre, Chemical and Biological Regulation of Aquatic Systems, CRC Press, Inc., Florida, 2007, p.369.
[3] Balai Penelitian Tanah, Petunjuk Teknis Analisis Kimia Tanah, Tanaman, Air, dan Pupuk, 2nd ed., Balai Penelitian Tanah, Bogor, 2009, p.143 (in Indonesia).
[4] The Water Planet Company, Nitrification and Denitrification, *http://www.thewaterplanetcompany.com/docs/WPC_Nitrification&Denitrification.pdf*, 2010.
[5] K. Karlson, E. Bonsdorff, R. Rosenberg, Ambio. 36 (2007) 161.
[6] S.M. Liu, J. Zhang, W.S. Jiang, J. Oceanogr. 59 (2003) 377.
[7] C. Woulds, M.C. Schwartz, T. Brand, G.L. Cowie, G. Lawb, S.R. Mowbray, Deep-sea Res. II 56 (2009) 333.
[8] R. Chester, Marine Geochemistry, Unwin Hyman Ltd., London, 1990, p.520.
[9] P. Anschutz, G. Chaillou, P. Lecroart, Estuar. Coast. Shelf. Sci. 20 (2007) 1.
[10] D. Chakrabarty, S.K. Das, Bio Systems 90 (2007) 309.
[11] J.J.M. Geurts, A.J.P. Smolders, A.M. Banach, J.P.M. van de Graaf, J.G.M. Roelofs, L.P.M. Lamers, Water Res. 44 (2009) 3487.
[12] S. Gerhardt, K. Boos, B. Schink, J. Limnol. 69 (2010) 54.
[13] R.B. Domingues, T.P. Anselmo, A.B. Barbosa, U. Sommer, H.M. Galvao, Estuar. Coast. Shelf. Sci. 91 (2011) 282.
[14] C.S. Hassler, J.R. Djajadikarta, M.A. Doblin, J.D. Everett, P.A. Thompson, Deep-Sea Res. 58 (2011) 664.
[15] L. Tuominen, Mäkelä, KK. Lehtonen, H. Haahti, S. Hietanenand, J. Kuparinen, Estuar. Coast. Shelf. Sci. 49 (1999) 83.
[16] G. Bally, V. Mesnage, J. Deloffre, O. Clarisse, R. Lafite, J.P. Dupont. Mar. Pollut. Bull. 49 (2004) 163.
[17] M. Thouvenot, G. Billen, J. Garnier, J. Hydrol 341 (2007) 55.
[18] G.M. Chikondi, V. Joshua, S.J.K.S. Phiri, J. Agric. Res 5/6 (2010) 424.