Journal of System Dynamics
Journal of System Dynamics
Volume 1 ● Number 1 ● June 2020 ● pp. 34-41

MODEL DYNAMIC OF WATER QUALITY INDEX BOD-BASED IN INDONESIA

Vidya Mar'atusholikha[1], Irman Firmansyah[2], Hamzah[1]

[1] *Natural Resources and Environtment Management, IPB University*
[2] *System Dynamics Center*

Corresponding author:
Natural resources and environtmental management, IPB University
Campus IPB Barananangsiang, Bogor, Indonesia
phone: (0251) 8332779
e-mail: vidyam260@gmail.com

ABSTRACT
Pollution is a human problem in the present and a problem in the future of human life. Household waste and industrial waste without adequate treatment then flow into waterways, rivers and coastal waters have a significant impact on flora and fauna in the water. Domestic waste, especially increasing Biological oxygen demand (BOD) can reduce dissolved oxygen, which causes anoxic conditions. The system dynamics approach was used by simulating time series data related to BOD pollution in waters from all provinces in Indonesia. Scenarios that can be done to reduce BOD are optimistic scenarios. In the optimistic scenario, it can improve the index by 0.28 while in the moderate scenario reduce the index by 0.15. In an optimistic scenario, 2045 is included in the good category.

KEYWORDS
Anoxic, Biological oxygen demand ,waste, system dynamic, scenario moderat, scenario optimistic.

Introduction

Pollution is a matter of humanity and a problem of the future of human life. Pollution is also a reflection of the inaccurate pattern of relationships between the social system and natural resources and the environment, which should be expected to be able to maintain the sustainability of life support systems. This inaccurate relationship pattern arises as a result of human inability to articulate the meaning of progress and growth for life, which is accelerated by development strategies that are not in line with the principle of sustainability

Household waste and industrial waste without adequate treatment then flow into waterways, rivers and coastal waters have a significant impact on flora and fauna in the water. Household waste can cause pollution, especially increased BOD which can reduce dissolved oxygen, which causes anoxic conditions. Under these conditions, fish and other oxygen-dependent species cannot survive and aerobic organisms are gradually displaced by anaerobic life forms, especially bacteria and limited numbers of invertebrate species. This organic pollution has an important impact on benthic organisms and river and coastal fisheries and other species whose lives depend on the estuary and river organisms [1].

Pollution of river water by pollutants is generally caused by the entry of waste into water. Various development activities that can cause water pollution include human activities, agricultural activities, the industrial sector, and other activities including natural emergence. The limited waste treatment business in these various activities can cause the concentration of waste produced to exceed the assimilation power (the ability to neutralize) water. Most (approximately 85%) of the pollution load entering the sea comes from the mainland and upstream watersheds [2]. This increasingly intensive activity has caused waters to have changed and is likely to have caused damage to the aquatic environment accompanied by a decrease in water quality. This water pollution has an impact on the life of biota, ecosystem resources, and comfort as well as other use-values of the ecosystem. This study has the aim of building a capacity model and carrying capacity index for BOD in Indonesia. Several cases of pollution in Indonesia, including BOD and COD pollution in the Kapuas River in Pontianak, have exceeded the intended class of 70% [3], the waters of the Depapre district are now in the category of mild to moderate pollution [4], rivers in Boentuka sub-watershed, NTT Province has been polluted by various types of waste so that it has experienced a decrease in water quality with a BOD value of 3.60 mg / L and COD of 46.50 mg / L which is at the threshold of the water quality standard of grade 1 [5].

Methodology

In this research, a system dynamics approach was used to simulate time series data from all provinces in Indonesia. System dynamics analysis starts from setting goals in the system [6].

Then the system needs to be determined to achieve the objectives, the formulation of the problem obtained from the results of the study, brainstorming, and expert discussion. Problems in the system are used as a constraint in the effectiveness of the system. The next stage is to identify the system by making input and output diagrams. To make it easier to see a picture of the relationship between variables both input and output, then it is described by a causal relationship (Causal Loop Diagram). The causal loop function is also used to limit the system to be studied [7]. Technical analysis is done by building a structure (Stock Flow Diagram) using Powersim Studio 10 to be able to do simulations, where the grouping of data and input data is done in a structural model [8]. Thus it can be seen the behavior of the system formed. Validation needs to be done so that the model can be scientifically justified.

Model validation is done by comparing the magnitude and nature of the error [7], namely: 1) Absolute Mean Error (AME) is a deviation (difference) between the mean value (mean) of the simulation results against the actual value, 2) Absolute Variation Error (AVE) is the deviation from the simulation variance (actual variance). The acceptable deviation limit is <10% with reference to (1) and (2).

$$AME = [(Si – Ai)/Ai] \quad (1)$$

$$AVE = [(Ss – Sa)/Sa] \quad (2)$$

Result and discussion

The analysis of needs dan problem formulation

System requirements are obtained from identifying the needs of each relevant stakeholder regarding water pollution. System requirements analysis illustrates the level of importance of each stakeholder. Based on the results of the needs analysis, several problems that emerged include industrial control and monitoring, waste minimization, use of organic fertilizers, and reforestation.

Identification of system

There are six groups of variables that affect system performance, namely: (1) Outputs target, namely the purpose of the system being studied to see the success of the model being built. Outputs target in this model is to minimize the BOD pollution load and the better the BOD capacity index; (2) Controlled inputs, i.e. factors driven in the model to obtain the desired output; (3) Uncontrolled inputs, i.e. inputs in the model that greatly affect the performance of the model because it is difficult to control, so it needs to be considered in policy formulation as a model assumption; (4) Environmental input, as a limitation in the model, especially regulations related to water pollution; (5) Unwanted output, which is as output that is not in line with expectations; (6) Management evaluation in controlling BOD. The relationship of variables that affect system performance is presented in Fig 1.

The relationship between variables is reflected in the causal loop, where population growth affects the increase in domestic waste discharges, on the other hand, BOD is also sourced from agricultural activities and industrial activities, BOD can also be generated naturally although the natural factors are relatively small. Overall, this BOD will accumulate in water bodies, thus the burden of pollution can be determined by the presence of debits in rivers in the area and can also be known as the value of the assimilation capacity of water. If an index is made of the comparison, it can be seen how far the burden of pollution is on its assimilation capacity and this illustrates the index criteria for BOD conditions in rivers in Indonesia. A description of the interrelationships in the causal loop is presented in Fig 2.

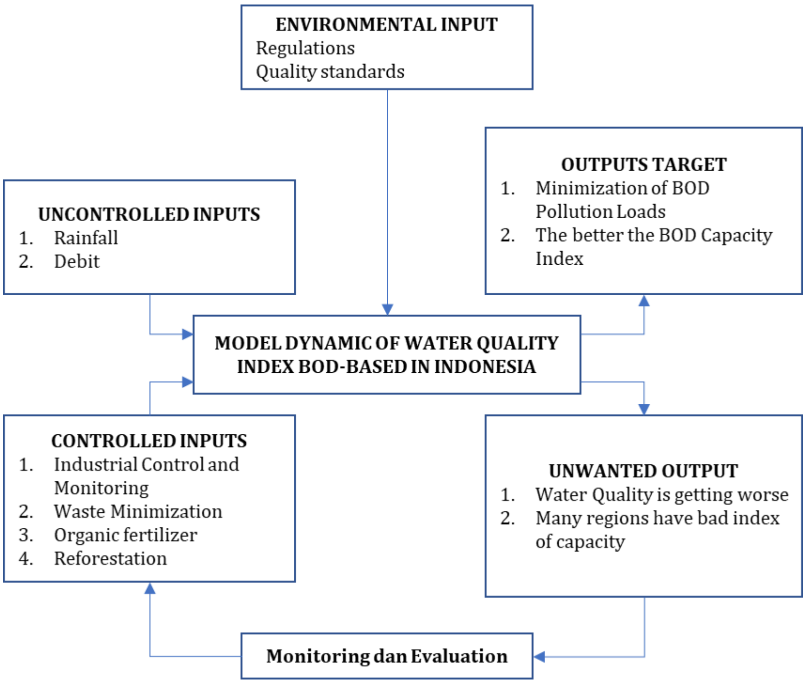

Fig. 1. *Black box diagram for* model of BOD pollution index

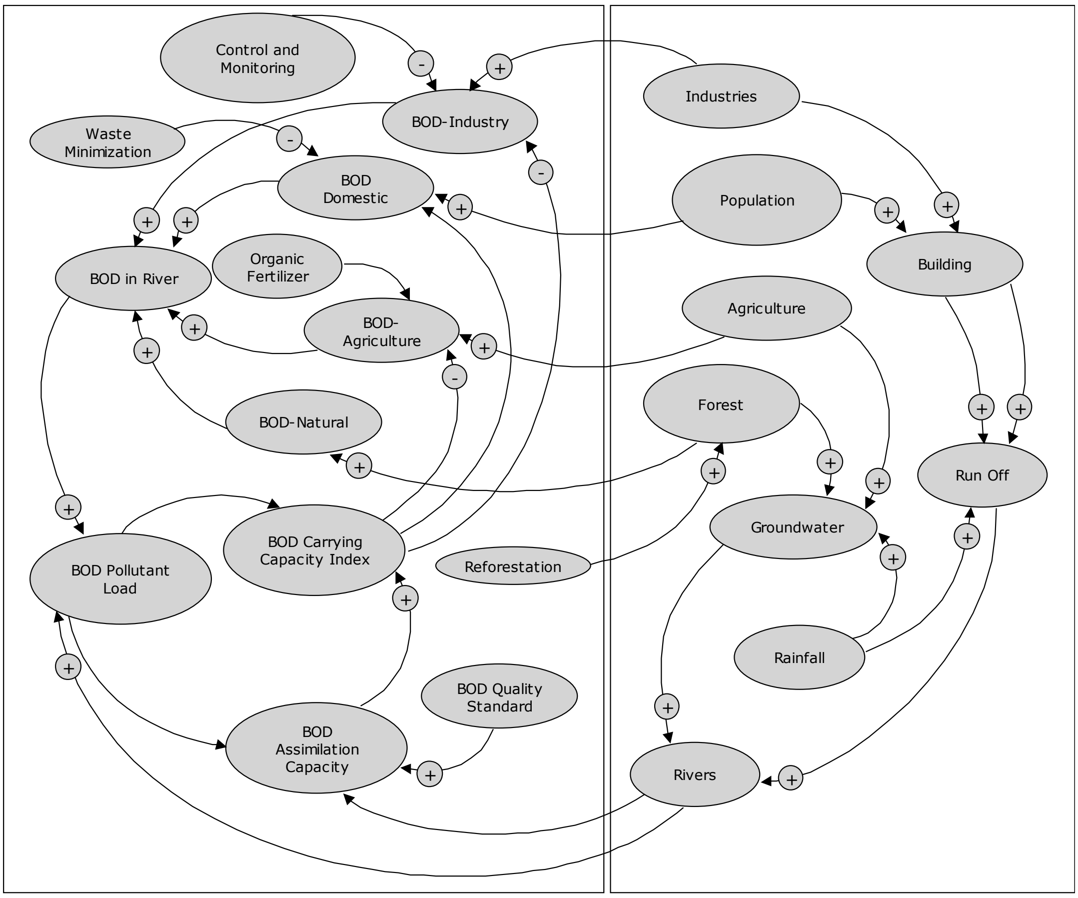

Fig. 2. *Causal loop diagram* model index BOD

The sources of BOD pollutants that enter the river, are found mostly from the domestic or non-domestic sectors such as the agricultural sector, the industrial sector, and the natural sector [1]. National BOD conditions, in 2014 reached 4.63 mg / L with various sources of BOD pollutants coming from the domestic sector, the agricultural sector, the industrial sector, and the natural sector. After weighting from each sector causes BOD, it is estimated that the domestic sector has a role of 2.31%, the agricultural sector has a role of 0.69%, the industrial sector has a role of 1.38% and the natural sector of 0.23%. Simulation results show that the BOD movement from 2014 amounted to 4.63 mg / L, in 2017 amounted to 5.21 mg / L and in 2045 it was projected to be 6.58 mg / L.

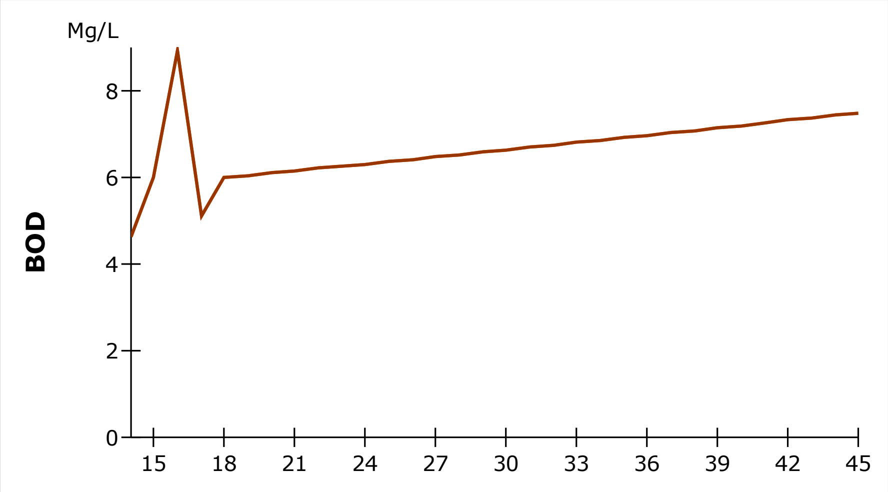

Fig. 3. BOD Pollutant Projection

The sources of BOD pollution originally from the domestic sector, industrial sector, agriculture and nature sector, after projecting the BOD value generated from the domestic sector, in 2014 amounted to 2.30 mg / L in 2017 increased to 2.57 mg / L and in 2045 it is projected to be 3.82mg / L. BOD sourced from the agricultural sector, in 2014 amounted to 0.69 mg / L in 2017 increased to 0.75 mg / L and after projected in 2045 to 0.28 mg / L. Source of BOD from the industrial sector, in 2014 BOD pollution amounted to 1.40 mg / L in 2017 increased to 1.54 mg / L and after projected until 2045 to 3.10 mg / L. The natural sector gave a BOD pollution rate in 2014 of 0.23 mg / L then increased to 2.26 mg / L in 2017 and after it was projected to be 0.27mg / L.

Validation dan model

The performance of system validation can be seen from the comparison value between the real data in the region and the simulation results. The results of the model validation on the BOD variable have an AME value of 0.1646 while for the AVE value of 0.18488; for the variable number of population has a value of 0.0428 while for the value of AVE for AVE of 5.09065; for variable agricultural land use has an AME value of 0.8605 while for the AVE value of 1.44304; for industrial variables having an AME value of 0.0000 while for AVE the value of 0; for the forest variable has an AME value of 0.1637 while for the AVE value of 2.89978. The simulation results show the right level of validation, because both the validation values of AME and AVE are below 10%.

Scenarios and BOD Capacity Index

Moderate scenario

The activities that cause BOD pollution in daily life include waste minimization by 63.80%, use of organic fertilizer by 13.50%, industrial control, and monitoring by 69.53% and reforestation covering an area of 250,000 hectares. Previous studies have shown that after a moderate scenario in the condition of Jakarta bay, BOD pollution does not exceed its assimilation capacity [9]. After a moderate scenario, if the waste minimization activity is 70%, the use of organic fertilizer 30%, industrial control and monitoring by 80% and reforestation of 100,000 hectares will produce a BOD simulation result in 2014 of 4.63 mg / L. In 2017 it produces BOD 5.12 mg / L and is projected in 2045 to be 6.58 mg / L. In 2045 the BOD condition is still beyond the quality of water quality, so an optimistic scenario is needed to improve the BOD condition. The results of the BOD moderate scenario projection are presented in Fig 4.

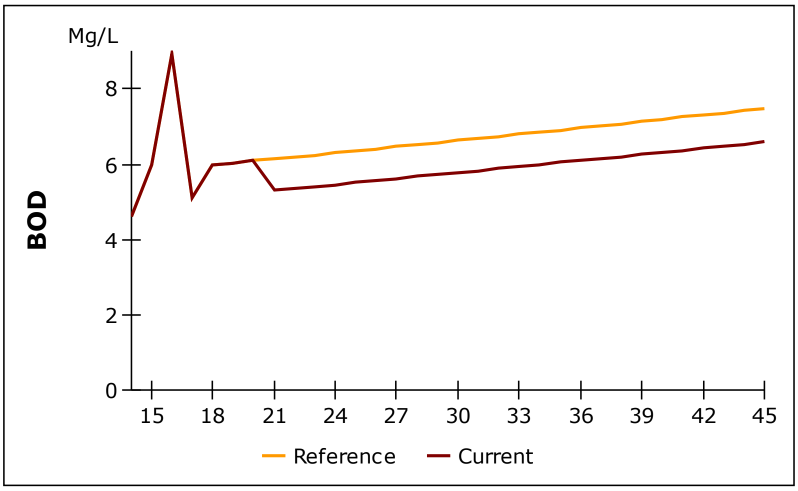

Fig. 4. Moderate scenario BOD

According to the results of a moderate scenario analysis, it results in a difference between the value of the assimilation capacity and the value of the pollutant load as presented in Fig 5. The assimilation capacity is the ability of a water body to receive pollutant waste without causing a decrease in the quality of the water determined according to its designation [10].

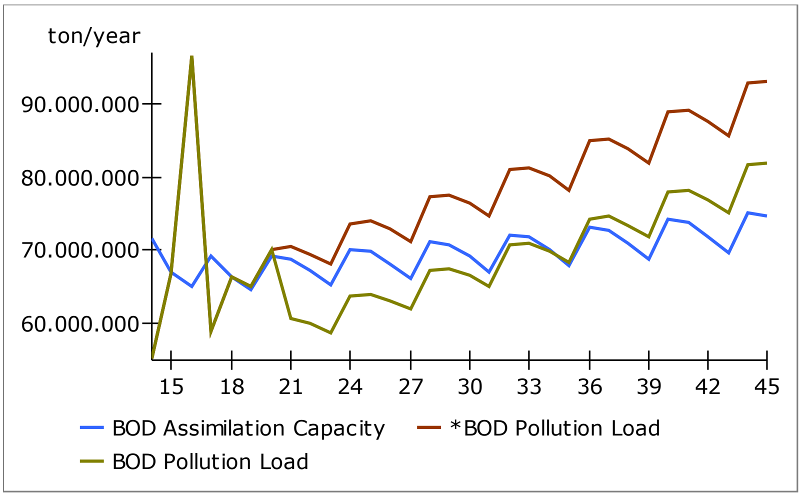

Fig 5. Differences in pollutant load values and assimilation capacity in the moderate scenario

The results of the moderate scenario showing that the value of pollutant load in 2014 was 55,217,415 tons/year, in 2017 it was 83,138,648 and in 2045 it was 83,138,648 tons/year. However, this value is still higher than the assimilation capacity of 75,791,534. The resulting capacity index is presented in Fig 6.

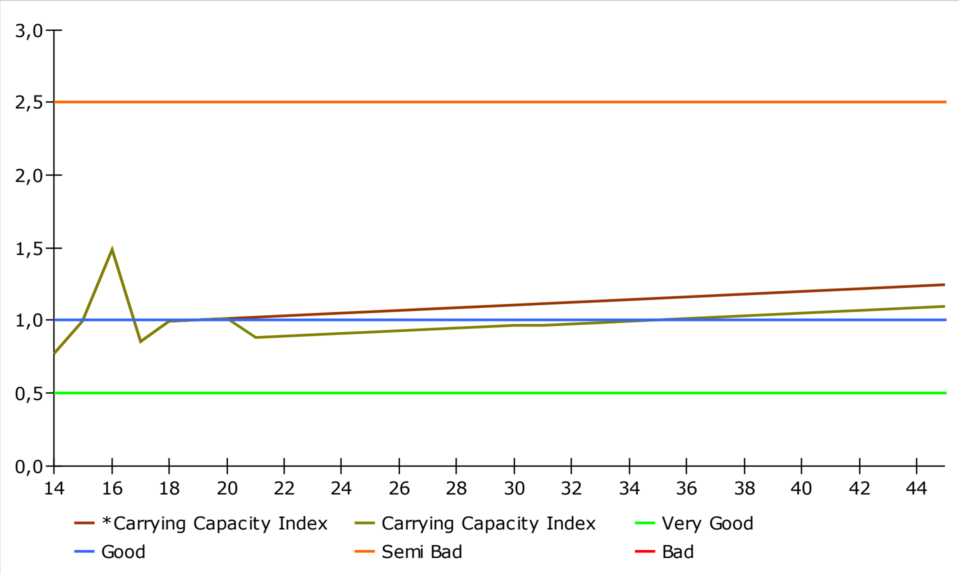

Fig 6. Capacity index moderat scenario

The figure above shows the capacity index after the scenario shown in gray, while the brown line is an index that has not been done in a moderate scenario. In gray, it shows the capacity index of 0.77 in 2014, 0.85 in 2017, and 1.10 in 2045. Whereas before a moderate scenario analysis, the index shows 1.25.

Optimistic scenario

In an optimistic scenario, waste minimization activities are 80%, use of organic fertilizer 50% industrial control and monitoring by 90% and reforestation by 200,000 hectares. Other technical efforts that can be used to reduce BOD levels in water include by giving lime to the waste before being discharged with an optimum lime content of 1.1%, giving ozonation treatment to the waste for 20 minutes [11] and chemically treating it for waste inlet like in a laboratory [12]. Simulation results show BOD in 2014 of 4.63mg / L in 2017 increased to 5.12 and after projected with an optimistic scenario to 5.80 mg / L in 2045. In that year the BOD load was below the standard that should be with a value of 5.80 from the default value of 6. The results of the BOD optimistic scenario projection are presented in Fig 7.

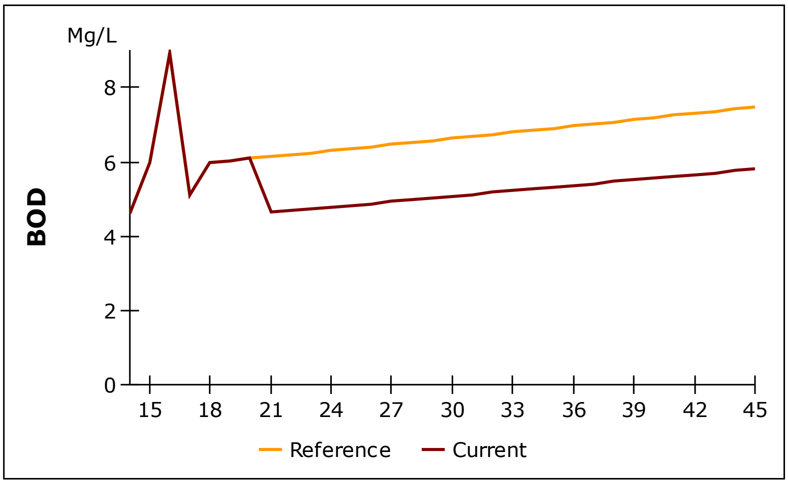

Fig 7. Optimistic scenario BOD

According to optimistic scenario analysis, the difference between the pollutant load value and the assimilation capacity value is presented in Fig 8.

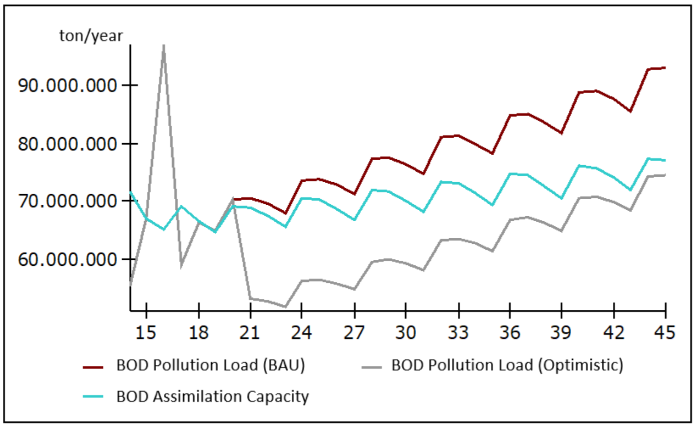

Fig 8. Differences in pollutant load values and assimilation capacity in the optimistic scenario

According to the picture, the optimistic scenario analysis results show that the value of pollutant load is 55,217,415 in 2014, 59,012,492 in 2017, and 74,601,647 in 2045. In 2045, the pollutant load shows a smaller value compared to the value of the assimilation capacity of 77,117,343. The resulting capacity index is presented in Fig 9.

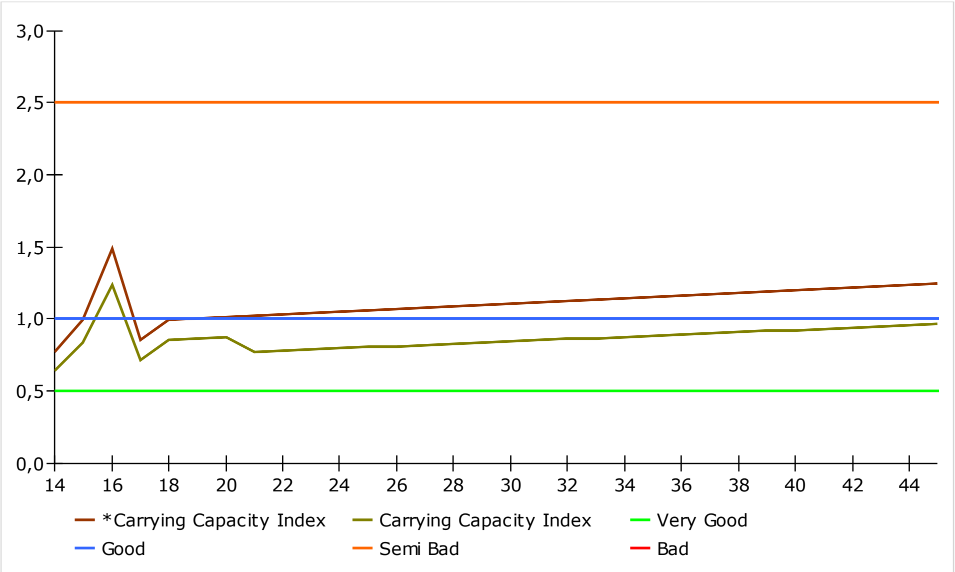

Fig 9. Capacity indeks scenario optimistic

Fig 9 shows the capacity index after an optimistic scenario which is shown in gray, while the brown line is an index that has not been done an optimistic scenario. The gray color indicates the capacity index of 0.77 in 2014, 0.85 in 2017 and 0.97 in 2045. While before a moderate scenario analysis, the index shows a 1.25 level.

Conclusions

The pollution load in Indonesia has exceeded its assimilation capacity. Around 58% of the river in Indonesia has a BOD pollution load that is more than its assimilation capacity. The BOD Capacity of 1.77 for the average of all regions in Indonesia, with developments in domestic, industrial and intensive agriculture will increase to 4.33 in 2045. The results of this study provide recommendations for improvement of BOD pollution in Indonesia including an emphasis on sources of household pollution, control of industrial areas and other activities, optimization of management of agricultural systems, control of regions or provinces that have exceeded their assimilation capacity, and integration of utilization organic waste, industrial and domestic activities for use in agricultural activities.

References

[1] Bank Dunia. 2003. Fokus utama mengurangi polusi. Pemantauan lingkungan Indonesia 2003. Hal 20-23

[2] Soedharma D, Adiwibowo S, Kawaroe M, Saputra S. Prosiding diskusi panel penangnan dan pengelolaan penemaran wilayah pesisir teluk Jakarta dan kepulauan seribu. 2005.PPLH-IPB, PKSPL-IPB, Bina Bahari Mandiri. Bogor

[3] Rizki Purnaini, Sudarmadji, Suryo Purwono. Permodelan Sebaran BOD di Sungai Kapuas Kecil Bagian Hilir Menggunakan WASP. 2019. *J. Tekno Sains* vol.8 no.2 pp.148-157

[4] Baigo Hamuna, Rosye HR Tanjung, Suwito, Hendra K Maury, Alianto. Kajian kualitas air laut dan indeks pencemaran berdasarkan parameter fisika-kimia di perairan Distrik Depapre Jayapura. 2018. *J. Ilmu lingkungan*. vol.16 no.1 pp.35-43

[5] Umbu A Hamakonda, Bambang Suharto dan Liliya Dewi Susanawati. Analisis kualitas air dan beban pencemaran air pada sub DAS Boentuka Kabupaten Timor Tengah Selatan. 2019. *J. Teknologi Pertanian Andalas* vol.23 no.1 pp. 56-67

[6] Sterman JD. 2000. Business Dynamic: System thinking and modelling for complex world. USA. The Mc Graw-Hill Companies

[7] Muhammadi, Aminullah Em Susilo B. 2001. Analisis Sistem Dinamis. Jakarta. UMJ Press

[8] Firmansyah I. 2016. Model pengendalian konversi lahan sawah, studi kasus di DAS Citarum, Institut PErtanian Bogor.

[9] Irman Firmansyah, Etty Riani, Rahmat Karunia Model pengendalian pencemaran laut untuk meningkatkan daya dukung lingkunga teluk Jakarta. 2012. J. Pengelolaan Sumberdaya Alam vol.2 no.1 pp:22-28

[10] Djajadinigrat T. 2001. Pemikiran, tantangan dan permasalahan lingkunganstudio tekno ekonomi ITB. Bandung

[11] Isyunarto Andrianto. Pengaruh waktu ozonisasi terhadap penurunan kadar BOD, COD, TSS dan Fosfat pasa limbah cair rumah sakit. 2008. J. Ganendra vol.12 no.1 pp. 45-49

[12] Eko Nuraini, Tantri Fauziah. Fajar Lestari. Penentuan nilai BOD dan COD limbah inlet laboratorium penguian fisis politeknik Yogyakarta. J. Integtated Lab Jurnal vol. 7 no.2 pp 10-15