Journal of System Dynamics
Journal of System Dynamics
Volume 1 ● Number 1 ● June 2020 ● pp. 26-33

WATER CAPACITY MODEL OF POLLUTION LOAD IN KALIAJI RIVER

Ira Mulyawati[1], Erliza Noor[2]

[1] *Sahid University Jakarta, Environmental Engineering Study Program*
[2] *Agricultural Industrial Engineering, IPB University*

Corresponding author:
Universitas Sahid Jakarta
Jurusan Teknik Lingkungan
Jl. Prof.Dr. Soepomo 84, Tebet Jakarta 12870
phone: (021) 83785303
e-mail: iramulyawati@gmail.com

ABSTRACT
This research aims to analyze the water quality condition of Kaliaji river based on physical and chemical water river factors. The analysis was conducted on observation points in downstream by testing the water pollution parameters compared to the water quality standard of water Pollution Control for Class III. The parameters observed in this study were TSS, TDS, BOD, COD, Phosphat, Nitrat and Flourida. Determination of water quality status using pollution index method was compared to water quality standard Governmental Regulation No. 82/2001 class III. The water quality of Kaliaji river from downstream observation points generally had no decreased quality according to the parameters which fulfill the quality standard. The carrying capacity index of Kaliaji river was categorized as very good because the index value was still below 1. Prediction result of the simulation of carrying capacity index was increased along with increase in the number of industries. Further this situation will have already exceeded the ideal value in 2031. The implication of this conclusion will be the policy makers need to conduct environmental monitoring on a regular basis. The provision of green space in industrial areas needs to be directed at the flood retardant plant planting program.

KEYWORDS
Carrying capacity index, system dynamics, simulation, water pollution, water quality status

Introduction

Community development in the Kaliaji River watershed was followed by changes in the structure of life according to community needs. One of these impacts was discovered on the pattern of natural resource use around the river. The need for high water resources resulted in over-exploitation of the river. This has caused various negative impacts that will affect the sustainability of the river's function. In addition, the development of population and settlements have also led to changes in land use in the upstream area of the river. It is usually marked by changes of agricultural land to non-agricultural land, or forest areas to residential areas. The rapid development requires enormous natural resources. The economy of Kendal district is increasing quite rapidly. This is due to the existence of the Kendal Industrial Zones / KIZ (*Kawasan Industri Kendal* / KIK) which provides a multiplier effect so that boosts economic growth in both Kendal and Central Java districts [1]. In addition, Kendal district is also one of the Special Economic Zones / SEZ (*Kawasan Ekonomi Khusus* / KEK) based on KIZ. The Special Economic Zones (SEZ) is a policy plan to determine a region to be the center of the economy with a focus on the industrial sector. The impact of this SEZ will not only provide positive benefits to the development of the main SEZ, but will also provide a positive stimulus to increase regional economic activity around the SEZ [2]. To support this, infrastructure development [3] in Kendal district prioritizes the construction of roads and bridges to support various industrial and domestic activities. This situation has positive and negative impacts for Kendal district. One of the positive impacts is the increase of labor absorption which contributes to the income of Kendal district. On the other hand, this also has a negative impact on the environment if it is not managed properly, such as the increase of river pollution load. Contamination of the river can be identified by the levels of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand

(COD) in water, where the higher the BOD and COD, the more polluted river water [4]. The accumulation of BOD and COD from pollutant sources will cause a pollution load on the river's ability to recover [5][6]. The purpose of this study is to determine the value of the water capacity index for industrial zones and to determine environmental program priorities using system approach.

Methodology

The scope of the study area of water capacity to accommodate the load capacity of river pollutants is the Kaliaji Aji / Slembang river which is located in Kendal Regency where stretches along 20 km [7]. The data were collected from the site, primary data including data from observation and secondary data.

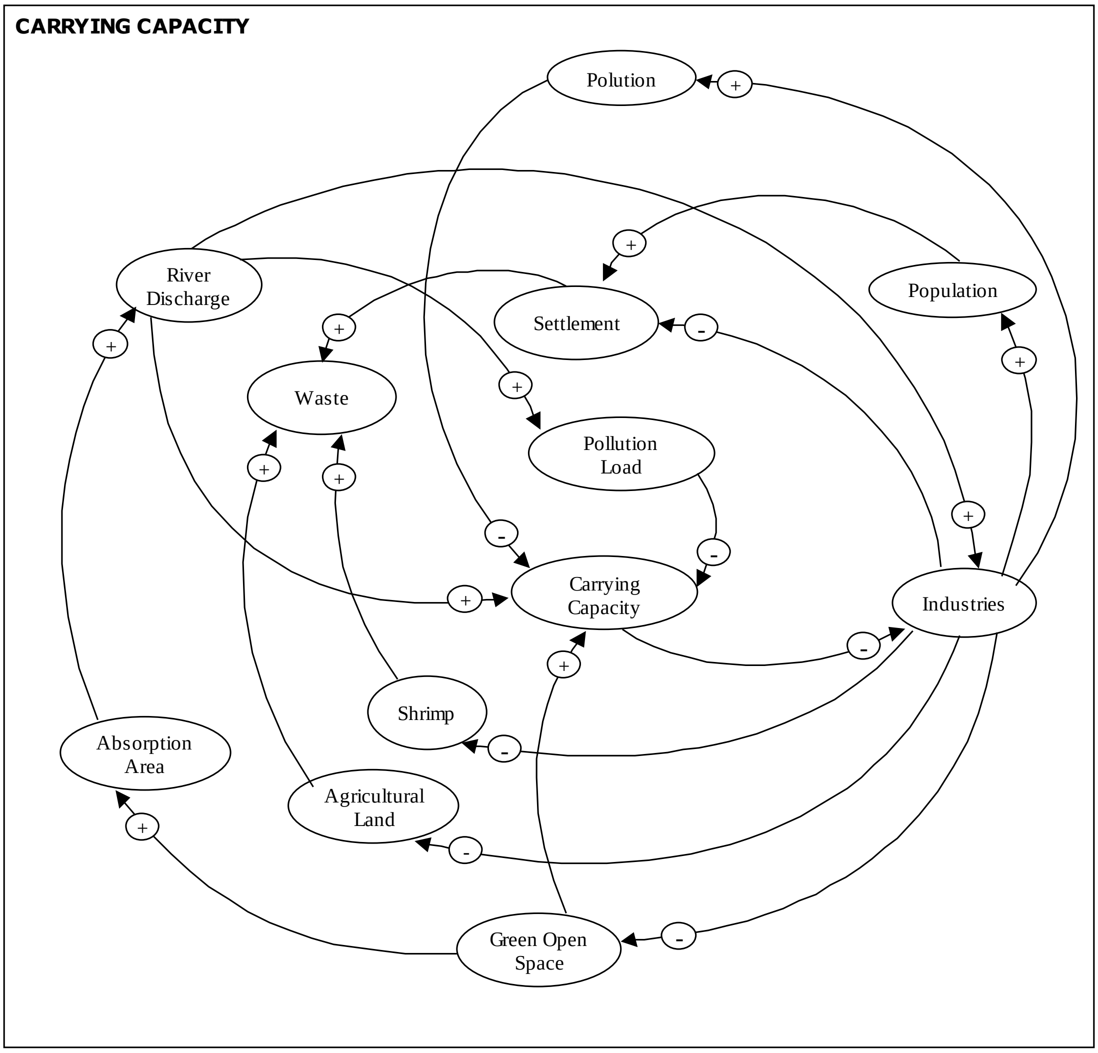

Fig 1. *Causal Loop Diagram* (CLD) Water Carrying Capacity Model

To understand the structure and behavior of the system that will assist the formation of formal quantitative dynamics models, it is used causal loops and flow charts. Causal diagram is created by determining the significant causal variables in the system and connecting them using arrows to effect variables, and the arrows can be applied in two directions if the two variables influence each other [8]. The relationship between the variables in the dynamic model of water carrying capacity is presented in Figure 1. The variables that are considered are the average index and the growth of pollution. The pollution load that enters the river and is calculated based on the multiplication of river discharge (debit) with the BOD parameter concentration which measured in the main river in each province, based on the following model [9]:

$$BP = Q \times C \times 3600 \times 24 \times 30 \times 12 \times 10^{-6}$$

Where : BP = Pollution load entering from drainage channels (tons / year)
Q = Drainage discharge (debit) (m^3 / sec)
C = Waste concentration (mg / L)

The assimilation capacity in the river is determined by making a graph of the relationship between the concentration of the waste parameter and the pollutant load. Then it is analyzed by cutting it with a quality standard line based on the specified quality standard. The assimilation capacity value is obtained from the intersection of the quality standard value for the BOD parameter [4][10].

Determination of the pollutant load of Kaliaji River (downstream) was carried out in 2017. The parameters used in this calculation are the key parameters of water pollution, namely TSS, TDS, BOD, COD, DO, Total Phosphate as P, NO3 as N and Fluoride. The water quality of the Aji River was analyzed descriptively by comparing the results of laboratory tests with the quality standard of PP. 82/2001 Class III and analysis of determining the quality status using the Pollution Index / PI (*Index Pencemaran* / IP) method [11][12].

Result and discussion

Determination of the pollutant load of Kaliaji River (downstream) was carried out in 2017. The parameters used in this calculation are the key parameters of water pollution, namely TSS, TDS, BOD, COD, DO, Total Phosphate as P, NO3 as N and Fluoride. The pollution load and assimilation capacity are presented in Table 1 and Fig 2.

Tabel 1. Pollution Load and Assimilation Capacity

Parameter	BP (Tons/year)	Assimilation Capacity
TSS	436,690	189,866
TDS	224,041	3,797,310
BOD	1,139	11,392
COD	4,557	94,933
DO	26,581	15,189
Total Fosfat sbg P	304	759
NO3 sbg N	28,480	37,973
Fluorida	721	5,696

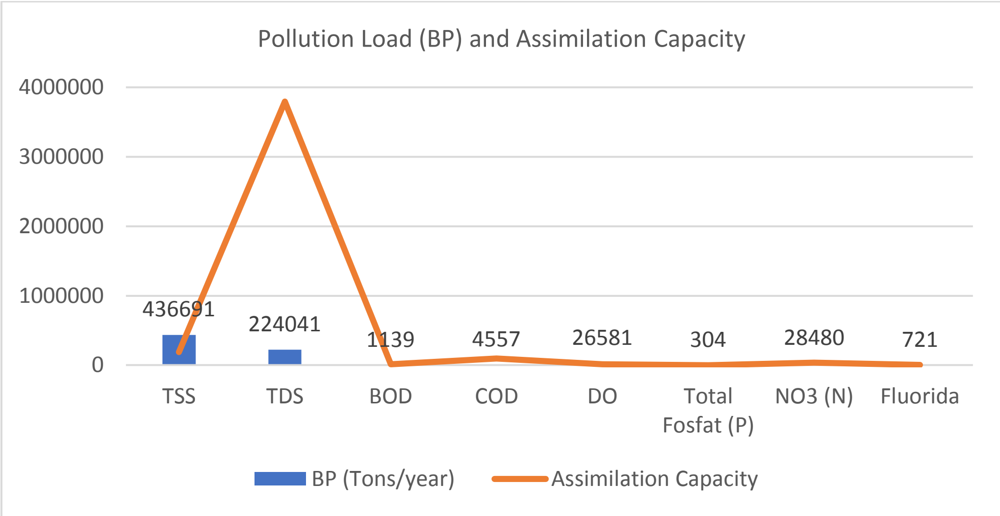

Fig. 2. Pollution Load and Assimilation Capacity

Based on Figure 2, the highest pollution load on the TSS parameter is 436,690.65 tons / year with an assimilation capacity of 3,797,310.00. The lowest pollutant load is Total Phosphate as P, which is 303.78 tons / year with an assimilation capacity of 3,797.31. According to the calculation result of the pollution load, it can be seen that the water quality condition of the Kaliaji River does not exceed the permitted river quality standard. Contaminated river water by pollutants is generally caused by the waste that entries into the water. Various development activities that can cause water pollution include human activities, agricultural activities, the industrial sector, and others, including natural emergence. The limited amount of waste processing in these various activities can cause the concentration of waste produced to exceed the assimilation (ability to neutralize) water. Water environmental services in 2031 will worth IDR 4,209,242,764.

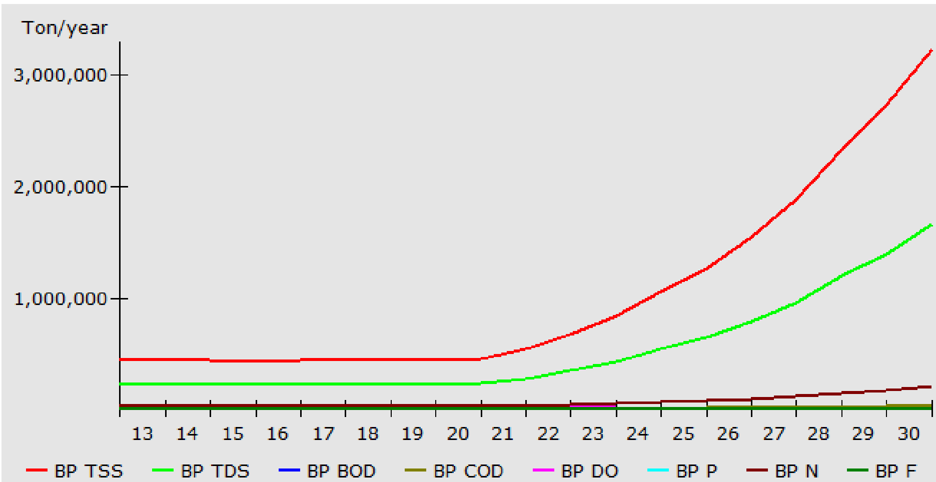

Fig 3. Water Pollution Load

Table 2. Pollution Load Prediction

Year	Discharge Aji River	BP TSS	BP TDS	BP BOD	BP COD	BP DO	BP P	BP N	BP F
13	125.00	447,120	229,392	1,166	4,666	27,216	311	29,160	739
14	122.25	437,283	224,345	1,141	4,563	26,617	304	28,518	722
15	122.25	437,283	224,345	1,141	4,563	26,617	304	28,518	722
16	122.10	436,759	224,076	1,139	4,557	26,585	304	28,484	722
17	125.75	449,818	230,776	1,173	4,694	27,380	313	29,336	743
18	122.99	439,922	225,699	1,148	4,590	26,778	306	28,691	727
19	122.99	439,922	225,699	1,148	4,590	26,778	306	28,691	727
20	122.84	439,394	225,428	1,146	4,585	26,746	306	28,656	726
21	126.51	452,532	232,168	1,181	4,722	27,545	315	29,513	748
22	123.73	442,576	227,061	1,155	4,618	26,939	308	28,864	731
23	123.73	548,610	281,461	1,431	5,725	21,733	382	35,779	906
24	123.58	677,864	347,774	1,768	7,073	17,546	472	44,209	1,120
25	127.28	861,513	441,994	2,247	8,990	14,644	599	56,186	1,423
26	124.48	1,036,592	531,817	2,704	10,817	11,641	721	67,604	1,713
27	124.48	1,270,601	651,873	3,315	13,258	9,497	884	82,865	2,099
28	124.33	1,548,621	794,510	4,040	16,160	7,773	1.077	100,997	2,559
29	128.04	1,935,801	993,150	5,050	20,200	6,596	1.347	126,248	3,198
30	125.23	2,283,165	1,171,363	5,956	23,824	5,349	1.588	148,902	3,772
31	125.23	2,732,732	1,402,010	7,129	28,515	4,469	1.901	178,222	4,515

Based on the prediction, the water quality pollution load will increase every year. The highest pollutant load on the TSS parameter in 2013 was 447,120 tons / year. It is predicted that it will increase in 2031 to 2,732,732 tons / year. The smallest pollution load in phosphate parameter of 311 tons / year in 2013 is predicted to increase in 2031 to 1.901 tons / year.

Kaliaji River water quality can be seen from the physical and chemical parameters of the water, which identifies no reduction in water quality. This can be seen from several parameters that there is no parameters which exceed the quality standards (QS) required in Government regulation (*Peraturan Pemerintah*) No. 82/2001 Class III. The carrying capacity index is categorized as very good because the index value is still below 1. The complete data is presented in Table 3 and the water quality kite diagram is presented in Figure 4.

Tabel 3. Water Carrying Capacity Index

Parameter	**Test**	**QS (III)**	**Discharge (m^3/sec)**	**constanta**	**BP (Ton/Tahun)**	**Assimilation Capacity**	**Index**
TSS	115.00	50	122.1	31.1	436,691	189,866	2.3000
TDS	59.00	1,000	122.1	31.1	224,041	3,797,310	0.0590
BOD	0.30	3	122.1	31.1	1,139	11,392	0.1000
COD	1.20	25	122.1	31.1	4,557	94,933	0.0480
DO	7.00	4	122.1	31.1	26,581	15,189	0.5714
Total Fosfat sbg P	0.08	0.2	122.1	31.1	304	759	0.4000
NO3 sbg N	7.50	10	122.1	31.1	28,480	37,973	0.7500
Fluorida	0.19	1.50	122.1	31.1	721	5,696	0.1267

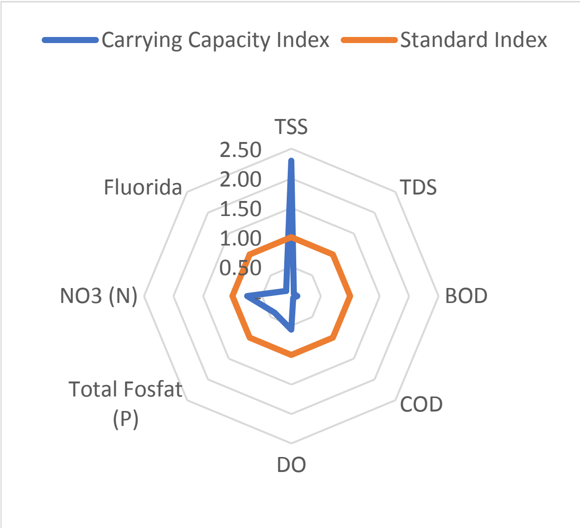

Fig 4. Water Quality Kite Diagram

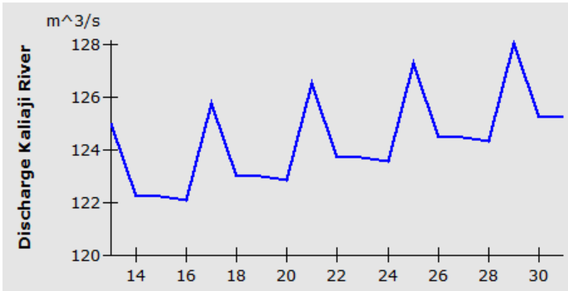

Fig 5. Discharge Kaliaji River

Based on the prediction, the Kaliaji River discharge (*debit*) has increased and decreased every year. In 2013 the Kaliaji River discharge was 125.00 m^3 / second, and it is predicted that it will increase in 2031 to 125.23 m^3 / second. The predictions are presented in Figures 5 and 4. The increase is not that significant, only the average increase of 0.23 m^3 / second in 15 years.

The water capacity / carrying capacity index in 2013-2019 is categorized as very good. It is predicted that in 2023-2031 it will increase but still in very good category. The prediction for COD and N index in 2027-2031 will increase and are categorized as quite bad. The prediction of the capacity index in detail is in Figure 6 and Table 5. The water capacity / carrying capacity for industrial zones is seen from water and air, where the value of the water capacity index is still good with a value of 0.17.

Table 4 Discharge Kaliaji River

year	Debit S Aji
13	125.00
14	122.25
15	122.25
16	122.10
17	125.75
18	122.99
19	122.99
20	122.84
21	126.51
22	123.73
23	123.73
24	123.58
25	127.28
26	124.48
27	124.48
28	124.33
29	128.04
30	125.23
31	125.23

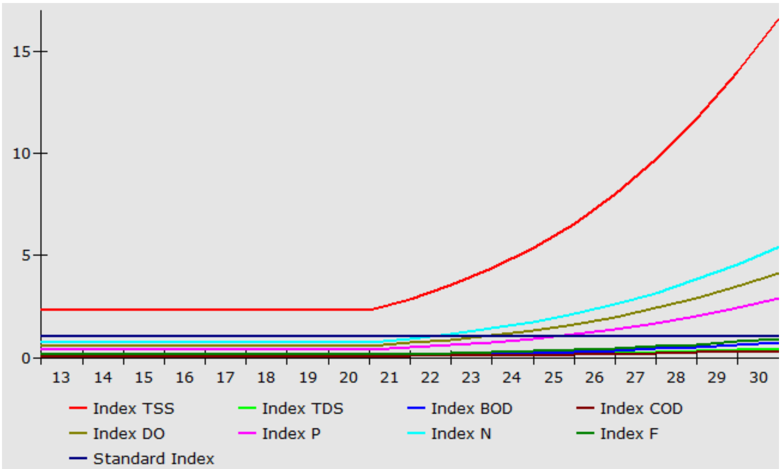

Fig 6. Water Carrying Capacity Index

Tabel 5. Index Daya Tampung Kualitas Air

Year	Index TSS	Index TDS	Index BOD	Index COD	Index DO	Index P	Index N	BP F
13	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
14	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
15	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
16	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
17	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
18	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
19	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
20	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
21	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
22	2.3	0.06	0.1	0.05	0.57	0.4	0.75	0.13
23	2.85	0.07	0.12	0.06	0.71	0.5	0.93	0.16
24	3.53	0.09	0.15	0.07	0.88	0.61	1.15	0.19
25	4.35	0.11	0.19	0.09	1.08	0.76	1.42	0.24
26	5.35	0.14	0.23	0.11	1.33	0.93	1.75	0.29
27	6.56	0.17	0.29	0.14	1.63	1.14	2.14	0.36
28	8.01	0.21	0.35	0.17	1.99	1.39	2.61	0.44
29	9.72	0.25	0.42	0.2	2.42	1.69	3.17	0.54
30	11.72	0.3	0.51	0.24	2.91	2.04	3.82	0.65
31	14.03	0.36	0.61	0.29	3.49	2.04	4.58	0.77

The average water capacity / carrying capacity of all parameters, which is seen as a whole in 2020 is still below the index value. It means that it has a good value with the acceleration and there will be an increase of pollution index value that exceeds the standard in 2031 of 3.94. The comparison of the index value between business as usual and the scenario as in Fig 7.

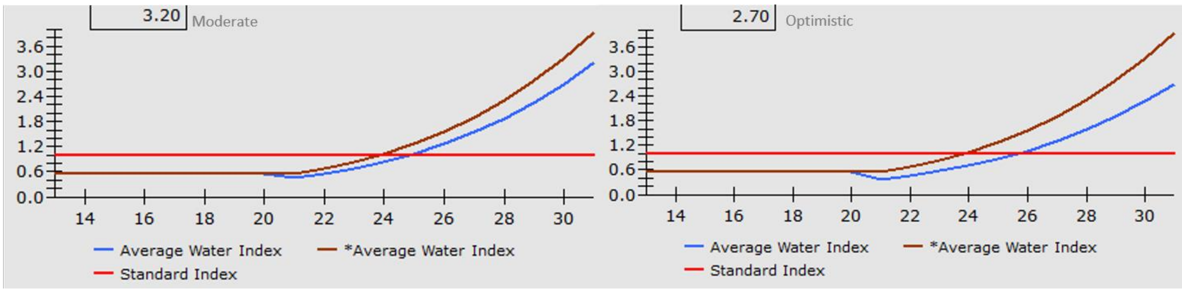

Fig 7. Water Carrying Capacity Index in Scenario Condition

Based on the simulation scenario graph, it can be seen that in the moderate scenario the decrease in the index value can be carried out until it reaches 3.20 in 2031. While in the optimistic scenario it can be further reduced to be even better of 2.70. In this condition, all scenarios still exceed the existing index standard value. Therefore it is still necessary to control the industrial area by 1) increasing the observation of the discharge and quality of the Kaliaji River intensively; 2) observing the quality of seawater around the watershed area in order to consider the ability of the water leaching and cleaning pollutants and to increase the ability of a better index; 3) making a water reservoir before being discharged into the river.

Conclusion

Based on the results of the study showing from water resources, the conclusion is that the capacity for industrial zones still obtains a good water capacity index value 0.17. It will increase as well according to the increase in the number of industries to 1.03, then this will have exceeded the ideal value in 2031. Whereas the value of environmental services from the water is Rp. 4.21 M. The implication of this conclusion is, in particular for the management of water and air quality in industrial zones, the policy actors need to carry out environmental monitoring regularly, considering that the simulation results show that there will be an increase in land demand every year along with the growth of the industrial sector. Provision of green open space in industrial areas needs to be directed at planting programs of flood-resistant plants, it also needs mangroves to reduce the minimization of abrasion from sea water [4, 13].

References

[1] KIK, *Dokumen analisis mengenai dampak lingkungan kawasan industri Kendal (KIK) tahap I*. Kabupaten Kendal, 2014.
[2] A. Aziz and E. Setyasih, "Evaluasi penentuan daerah kawasan ekonomi khusus (KEK)," *EKO-REGIONAL,* vol. 4, no. 1, 2009.
[3] T. Sukwika, "Peran pembangunan infrastruktur terhadap ketimpangan ekonomi antarwilayah di Indonesia," *Jurnal Wilayah dan Lingkungan,* vol. 6, no. 2, pp. 115-130, 2018.
[4] T. Sukwika and H. Putra, "Analisis sedimentasi dan konsentrasi atmosfer pada zona mangrove di Muaragembong, Bekasi," *Jurnal Pengembangan Kota,* vol. 6, no. 2, pp. 186-195, 2018.
[5] P. S. Sara, W. Astono, and D. I. Hendrawan, "Kajian kualitas air di sungai ciliwung dengan parameter BOD dan COD," presented at the Seminar Nasional Cendikiawan ke 4 Tahun 2018, Buku 1: Teknik, Kedokteran Hewan, Kesehatan, Lingkungan dan Landskap, 2018.
[6] U. O. Hasani, "Analisis kualitas air sungai Konaweha provinsi Sulawesi Tenggara," *Ecogreen,* vol. 2, no. 2, pp. 123-129, 2016.
[7] BPPP, *Kajian lingkungan hidup strategis review RTRW kabupaten Kendal*. Kabupaten Kendal: Badan Perencanaan Penelitian dan Pengembangan, 2017.
[8] I. Firmansyah, *Aplikasi powersim studio untuk sistem dinamik*. Bogor: Sistem Dinamik Center, Triwala Press, 2015.
[9] Y. Rahayu, I. Juwana, and D. Marganingrum, "Kajian perhitungan beban pencemaran air sungai di daerah aliran sungai (DAS) Cikapundung dari sektor domestik," *Jurnal Rekayasa Hijau,* vol. 2, no. 1, pp. 1-11, 2018.
[10] F. Idris, C. J. Koenawan, Jumsurizal, and A. D. Syakti, "Kapasitas asimilasi beban pencemaran di perairan teluk Riau," *Dinamika Maritim Coastal and Marine Resources Research Center,* vol. 6, no. 2, pp. 26-29, 2018.
[11] T. Lufiana, H. Haeruddin, and C. Ain, "Analisis beban pencemaran dan Index kualitas air sungai silandak dan sungai siangker, Semarang," *Management of Aquatic Resources Journal (MAQUARES),* vol. 5, no. 3, pp. 127-134, 2016.
[12] V. Djoharam, E. Riani, and M. Yani, "Analisis kualitas air dan daya tampung beban pencemaran sungai pesanggrahan di wilayah provinsi DKI Jakarta," *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan,* vol. 8, pp. 127-133, 2018.
[13] C. Kusmana and T. Sukwika, "Coastal community preference on the utilization of mangrove ecosystem and channelbar in Indramayu, Indonesia," *AACL Bioflux,* vol. 11, no. 3, pp. 905-918, 2018.