Water Pollution Factor Analysis and Management in Surabaya River - Indonesia

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Abstract—Surabaya river has severely polluted by both domestic and industrial activity according to the earlier studies result. This study was purposedly conducted to find what factors that significantly affect water quality of Surabaya river thus allowing for pollution management strategies to be made. The preventing action was made based on factor classification in which partial least square – structural equation modelling (PLS-SEM) method utilized. Historical monitoring data of Surabaya river in 3 parameters that are BOD, COD, and TSS from 6 location, domestic and industrial wastewater quality, and community participation were became the variables in the study. The result indicated that water quality along Surabaya river became the most dominant factor that affect its condition with the significancy value of 13.582. In addition to that, Surabaya river has also affected by domestic wastewater with significancy value of 2.801 based on PLS-SEM analysis. Strategic priority is determined by the *Analytical Hierarchy Process* (AHP). The results of the AHP analysis show that the main strategy plan was to establish communal wastewater treatment plant for domestic activity which gave 0.373 of significancy value.

Keywords--- *Surabaya river, Structural Equation Modelling, PLS-SEM, Analytical Hierarchy Process, pollution factor*

I. INTRODUCTION

The water pollution source could originally came from organic and inorganic matter of both industrial and domestic activity. Several industries in which producing paper, meat, textile, food, and leather were expected to deliver organic matter while those which produce ceramics, metal, and chemical were the inorganic one [1]. According to earlier studies, there were lead (Pb) as much as 0.393 ppm and 0.252 ppm in Rolak and Kali Mas respectively as part of the Surabaya river [2]. Other studies also stated the mercury (Hg) and Chrome (Cr) were above quality standard which listed in Perda Kota Surabaya No. 02/2004 for water classification. Other than heavy metals, Surabaya river has also polluted by detergent which came from daily activity of locals which later cause dilution of dissolved oxygen, eutrofication, and then followed by the death of aquatic biota [3],[4].

An effort to reduce pollution load has been executed. However, there were still no sign of improvement in terms of overall condition. The growth of domestic and industrial activity, lack of concern by the communities, and ineffective wastewater treatment suspected to be the causes. Analytic hierarchy process (AHP) was used to determine mitigation and improvement strategy by structurized complex hierarchy criteria [5]. The study on significant factor was accomplished by PLS-SEM method beforehand.

II. METHOD

A. Research Area

The study was conducted along segment mlirip-jagir of Surabaya river which approximately as long as 42.3 km and passing through 10 sub-district. The upstream has 30-35 m of width, 2-3 m of center depth, and 0.5-1 m of depth on the edge whilst the downstream has 50-60 m, 3.5-7 m, and 0.9-1.5 m of width, center depth, and depth on the edge respectively. The flow was relatively uniform throughout the year with 40-90 m3/second on the first half and 10-30 m3/second the second half. As for the temperature and wind velocity, it was around 22-31C and 30-35 km/hour respectively [6].

B. Determination of Pollutant Factors with Partial Least Square Structural Equation Modelling (PLS-SEM)

The initial stage of structural equation modelling was to create a model conceptual by determining latent variables and indicators as seen at the Table 1. Pollution level at the downstream which determined by the pollution index method was the dependent (endogen) variable, whereas Surabaya river water quality which measured by 3 parameter which are BOD, COD, and TSS was the independent (exogen) variable. The second and third independent (exogen) variable were Industrial wastewater quality which obtained from department of environment and community participation which measured by questionaire to riverside locals respectively. In addition to 3 variables that previously stated, there is also domestic wastewater quality which role as both endogen and exogen within the model. Furthermore, this theoretical model is tested to observe logical relationship between latent variables and indicator variable is an observed one.

The test used in this step is the indication test and the causality test. These tests are performed to ensure that the indicator(s) really indicate the latent variable. An indicator can be accepted if: (a) The indicator is an indication, sign, or the definition of latent variables; (b) The indicator should not have a causality relationship with latent variables to be formed [7]. The path diagram was subsequently being illustrated after all variable had been classified. The variables in the SEM diagram are shown in Fig. 1.

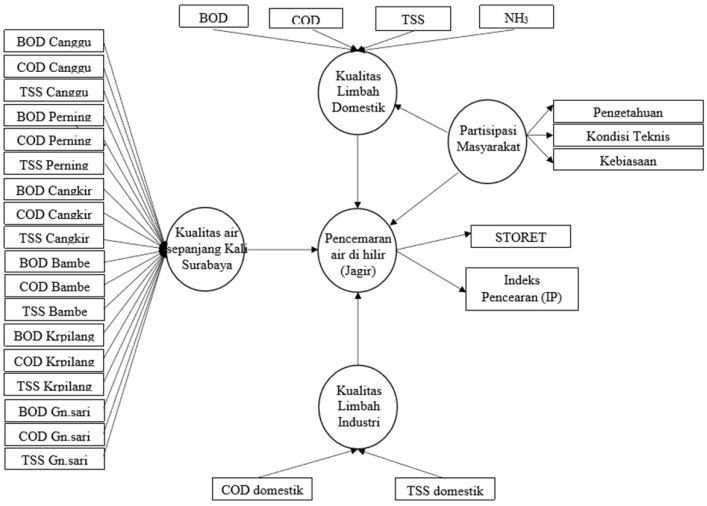

Fig. 1. *Structural Equation Modelling* (PLS-SEM) path diagram

C. Strategy Determination

The classification of pollution factor was furthermore be appointed as reference on management strategy making in which divided as technical, social, and institutional aspect. The questionaire result then inputed to the Expert Choice 11 software. The result is stated as valid if the inconsistency value was less or ≤10% [8].

III. RESULT AND DISCUSSION

A. Evaluation of Outer Model

Outer model evaluation was conducted to verify if the indicators had valid in which determined by the loading factor value of ≥ 0.5 [9]. there are 3 formative construct latent variables which divide into Surabaya river Water Quality, Domestic Wastewater Quality, and Industrial Wastewater Quality and 1 of a reflective construct which was Community Participation. The reflective construct latent variable had to be verified for its validity whereas for formative construct the same procedure was not necessary in assumption that all indicators in this construct were already calibrated in the first place. The validation result was illustrated in Fig. 2 and Table 1.

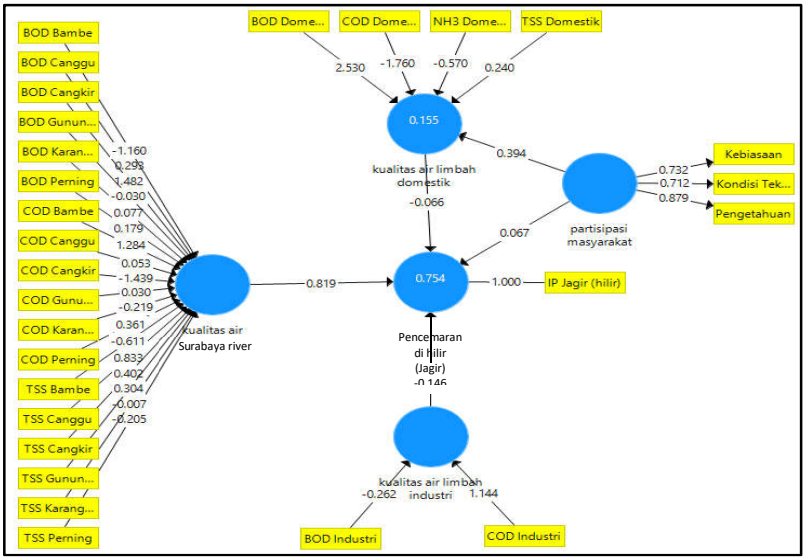

Fig. 2. PLS-SEM pathway construct diagram in validity test

TABLE 1
Convergent Validity Result (*Loading Factor*)

Latent Variable / Indicator Variable	Surabaya river water pollution	domestic waste water quality	industrial waste water quality	Society participation
BOD Perning	0.179			
COD Perning	0.361			
TSS Perning	0.205			
BOD Cangkir	1.482			
COD Cangkir	-1.439			
TSS Cangkir	0.402			
BOD Bambe	-1.16			
COD Bambe	1.284			
TSS Bambe	-0.611			
BOD Canggu	0.293			
COD Canggu	0.053			
TSS Canggu	0.833			
BOD Karangpilang	0.077			
COD Karangpilang	-0.219			
TSS Karangpilang	-0.007			
BOD Gunungsari	-0.03			
COD Gunungsari	0.03			
TSS Gunungsari	0.304			
BOD Domestic		2.53		
COD Domestic		-1.76		
TSS Domestic		0.24		
NH_3 Domestic		-0.57		
BOD Industri			-0.262	
COD Domestic			1.144	
knowledge				0.879
Conditions				0.712
Habit				0.732

According to the results of the convergent validity test the reflective indicators in Table 1 have no indicator variables that have values below 0.5 so there are no indicators that must be omitted because the value is valid.

Another validity check on latent variable was to look for their AVE (Average Variance Extracted) that has to meet the value of ≥ 0.5. in addition to validity, reliablity check which determined by composite reliability was required. This procedure was purposedly conducted to discover the correlation amongst each variable where > 0.7 was the desired value in terms of composite reliability. According to the result, the value of 0.605 and 0.820 were obtained for AVE and composite reliability respectively, which sufficiently passed the minimum for each criteria. The results were showed in Table 2.

TABLE 2
AVE test results, Composite Reliability, Cronbach's Alpha, and R^2 on Reflective Variables

	AVE	*Composite Reability*	*Cronbachs Alpha*	R^2
Downstream water pollution (Jagir)	1.000	1.000	1.000	1.000
Society participation	0.605	0.820	0.682	0.795

B. Evaluation of Inner Model

Inner model evaluation was conducted to look for t-value (significancy) and Rsquare from the model. T-value of 1.96 was considered as significant. The terminology of this particular process was named bootstrapping in smartPLS 3.0 software. Inner model evaluation result can be seen in Fig. 3 and Table 3.

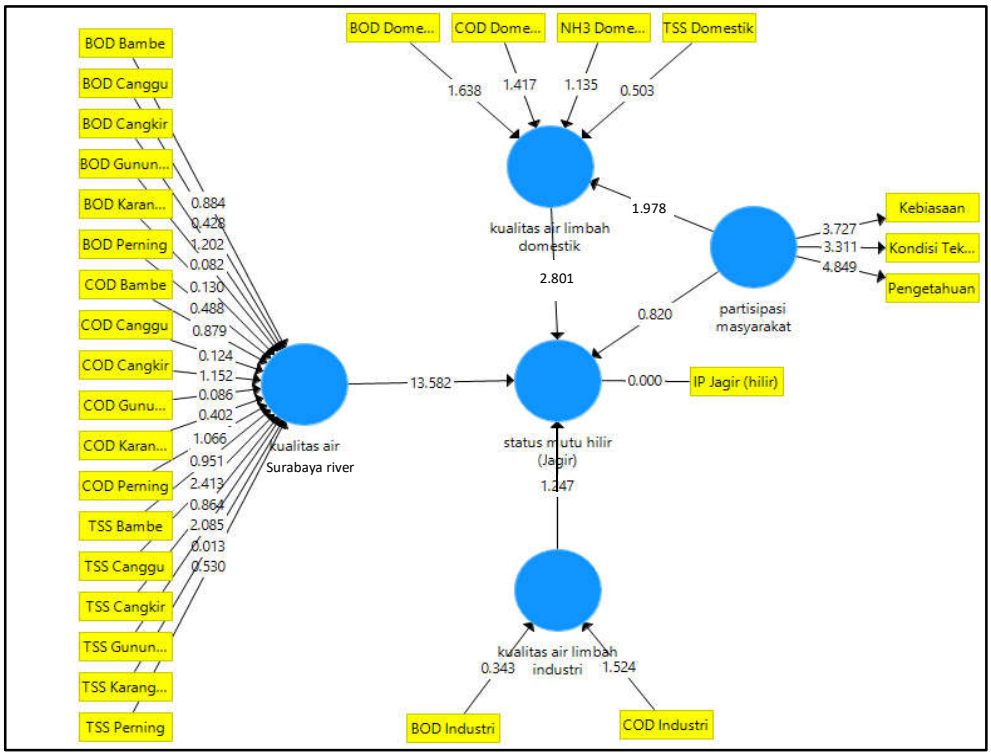

Fig.3. PLS-SEM output model of Bootstrapping Result

TABLE 3.
Significance Test Result

	Original Sampel O	*Sample Mean* M	*Standard Error* STERR	*t- statistics* |O|STERR|
Surabaya river water quality → downstream water pollution (Jagir)	0.819	0.877	0.06	13.582
Domestic waste water quality → downstream water pollution (Jagir)	-0.066	-0.044	0.082	2.801
Industrial waste water quality → downstream water pollution (Jagir)	-0.146	-0.076	0.117	1.247
Society participation → Domestic waste water quality	0.394	0.28	0.343	1.978
Society participation → downstream water pollution (Jagir)	0.067	0.052	0.081	0.82

According to Fig. 3 and Table 3 the results were as follows

a. The t-value obtained from "Surabaya river Water Quality" and "Downstream Pollution" correlation was 13.582, higher than 1.96 which could appropriately be stated as significant.
b. The t-value obtained from "Industrial Wastewater Quality" and "Downstream Pollution" correlation was 1.247, less than 1.96 which could not be stated as significant.
c. The t-value obtained from "Domestic Wastewater Quality" and "Downstream Pollution" correlation was 2.801, higher than 1.96 which could appropriately be stated as significant.
d. The t-value obtained from "Community Participation" and "Downstream Pollution" correlation was 0.82, less than 1.96 which could not be stated as significant.
e. The t-value obtained from "Community Participation" and "Domestic Wastewater Quality" correlation was 1.978, slightly higher than 1.96 which could appropriately be stated as significant.

C. Determination of Strategies for Control of Surabaya river Water Pollution

The confirmation of prioritized strategy in controlling Surabaya river pollution level was conducted by AHP method which Expert Choice 11 software was being utilized. This analysis divided through 3 stages where the first one was to determine the objectives, following by the second one which reviewed the aspects, and the last one was to decide which strategy executed in correspond to the interview.

According to interview the strategy alternatives were as follows:

a. To stringent the permission of domestic waste disposal
b. Periodically domestic waste disposal monitoring
c. Prevention approach socialization
d. Law enforcement
e. Retribution fee for Surabaya river Management program
f. Controlling the settlement alongside Surabaya river
g. Communal WWTP establishment

The hierarchy model was then illustrated in illustration 4.12 in which pairwise comparisson value of each criteria be assigned. The result was stated as consistent if the inconsistency ratio ≤ 0.1 and showed in the Table 4.

TABLE 4.
Inconsistency Ratio in the AHP method

Respondents	***Inconsistency Ratio***
Immanuel (DLH Jatim)	0.051
Sutardi (PJT I)	0.050
Septa (BBWS Brantas)	0.008
Andhika (DLH Kota Surabaya)	0.051
Ngesti Kinasih (DLH Kabupaten Mojokerto)	0.050
Hasil kombinasi	0.039

the analytical hierarchy process result indicates technical aspect to be the most significant factor in Surabaya river Pollution Control with eigen value of 0.530, then followed by 2 other aspects in which Social and Institution with 0.300 and 0.170 for each respectively. Criteria ranking arrangement was based on priority weight produced by comparison matrice where the main factor was determined by which has the most weight. The priority weighing based on eigen value illustrated in Fig 4.

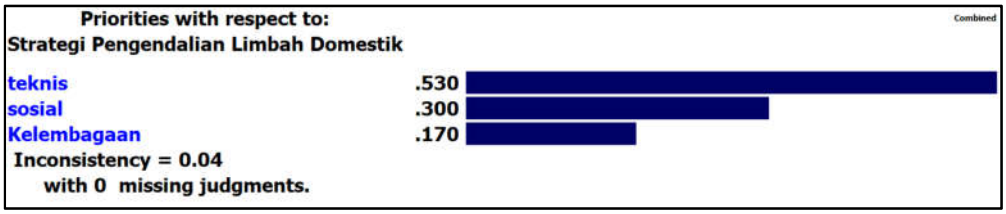

Fig 4. Priority weighting results of criteria with AHP Method

According to the interview, experts contended that technical aspect was considered to be the most important criteria in Surabaya river Pollution Control because of its significant impact. An appropppriate wastewater treatment facility had proven to reduce the pollution level. The second most important was social aspect which had been long believed affect pollution level in Surabaya river as community participation also dictate how the waste was treated. However, culture, habit, and education play a huge role hence this would take very long time for the implementation to be occurred. As for the institutional aspect, experts believe that it would only work if both technical and social approach had been efficiently be implemented as this was considered as supporting aspect for the other two mentioned previously. Therefore, technical approach was still being the most relevant choice albeit cost related problem become the main obstacle.

The results of weighting alternative strategies are known that the biggest value is the making of communal WWTP with a value of 0.373. The next priority priority sequence is to control the settlement of river border areas (0.235), tighten domestic waste disposal permits (0.158), periodic supervision of domestic waste disposal (0.100), payment of voluntary contributions for the Surabaya river water pollution control program (0.066), sanctions if they occur disposal of waste (garbage and black water) directly into the river (0.040), and the last priority is counseling and an appeal not to dispose of waste (garbage and black water) directly into the river (0.028). Based on the weighting of the above values, the strategic alternative that is considered to be the most effective in reducing Surabaya river water pollution according to experts is the manufacture of a communal WWTP in one city. The results of weighting alternative strategies with *Expert Choice* software 11 can be seen in Fig. 5.

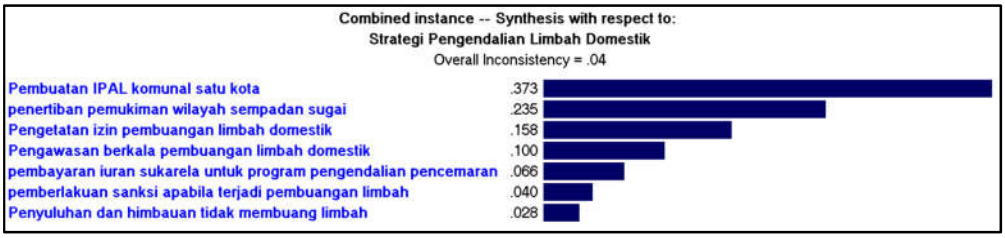

Fig 5. Priority weighting results of alternative with AHP Method

According to the result, the strategy priority were as follows:

1. Making communal WWTP

According to the analysis, communal WWTP was prioritized in consideration of its multiple function where aside of being able to treat domestic wastewater, it can also be used as drainage and sanitation system which work integratedly. Up until the study was conducted, department of environmental has established communal WWTP in Kelurahan Karah and Kelurahan Warugunung. The WWTP was consist of 9 infiltration wells. The first compartment was functionate to collect wastewater before it purified through filtration process on the second chamber. This process went all the way up to the final one before disposed to the stream. Communal WWTP establishment was one of many efforts to minimize the effect of waste disposal alongside Surabaya river. Communal WWTP establishment has yet to met the target of 74 clusters. The expectation of the program was to significantly reduce the amount of pollution that enter Surabaya river.

2. Controling river side areas and tightening permits for domestic waste disposal

Pollution control policies can be taken by optimizing land use through the concept of spatial planning. Spatial planning is a system of spatial planning processes, space utilization, and control of spatial use. The application of spatial concepts of various types of activities can be arranged according to their designation so that they do not disturb the existence of the surrounding ecosystem. The application of the spatial concept is closely related to the control of the river border area. According to Government Regulation, concerning the Implementation of Spatial Planning, in the utilization of space everyone is required to have a permit to use space. Permission to use space can be in the form of:

a. Principle permit
   Principle permit is a permit granted by the government / regional government to state that an activity is in principle permitted to be held or operating.
b. Location permission
   Location permit is a permit granted to the applicant to obtain the space needed to carry out his activities. Location permits are needed for the utilization of more than one ha of space for non-agricultural activities, and more than 25 ha for agricultural activities.
c. Spatial / Block Plan Permit is a technical permit regarding the layout of buildings and environmental arrangements given by the Regional Government to business entities or individuals to arrange the structure and patterns of use of space.
d. Building Construction Permit (IMB)
   Building Construction Permit is the basis for constructing buildings in order to use space. IMB is given based on zoning regulations as a basis for holders of building permits according to their assigned functions, and plans for building structures that have been approved by the district / city government.
e. Other permits are based on statutory provisions (including Permit to Change Space Utilization, Disturbance Permit).
   Issuance of licenses focused only on one agency requires good coordination with other agencies, namely the Regional Development Planning Agency, National Land Agency, Office of Public Works and Spatial Planning. In relation to the use of space in the border area of Surabaya river, technical recommendations from the Brantas Central Region (BBWS) are needed. The lack of smooth coordination and the provision of technical recommendations from other technical agencies has led to uncontrolled use of space, because developments in the field are faster than the licensing process. BBWS has the authority to control the use of space in the Surabaya river border area, but it cannot execute through licensing and control because it is not its authority. Likewise, if there is a building construction in a river border area, BBWS is not authorized to carry out legal action.

3. Supervision of periodic disposal of domestic waste water quality

Monitoring the quality of industrial waste must be carried out continuously and provide strict sanctions for the violator industry. An urgent inspection effort also needs to be carried out by government agencies that are authorized to give administrative sanctions in the form of fines to close down industries that have been proven to be polluting. The Regional Government also needs to supervise the disposal of industrial waste water into river water bodies or canals by means of installing water meters to avoid excessive disposal of wastewater. In addition, the regional government also needs to carry out a target water quality program to improve the status of water quality gradually to fulfill first-class water quality standards. Environmental management institutions must have strong authority in supervising and sanctioning industries that pollute Surabaya river.

4. Payment of voluntary contributions for pollution control programs

In addition to having to have permission to dispose of waste to Surabaya river, the industry should also have to pay a waste disposal tax to finance the rehabilitation of polluted parts of the river and finance monitoring and monitoring of waste. The imposition of pollutant waste tax is one way that must be tried to reduce the level of pollution of rivers in Indonesia, especially Surabaya river. The implementation of a waste disposal tax is imposed on every industry that dumps its waste into Surabaya river. Industries, hotels and hospitals that dispose of their waste into Surabaya river must pay a tax on waste disposal which depends on the amount of waste, the amount of content and the toxicity level of pollutants in the waste disposed. The tax results of industrial waste disposal can be used as operational costs for DLH in managing the river environment

5. Enforcement of domestic waste disposal sanctions

In the context of reducing pollution and environmental damage in addition to preventive efforts, repressive measures must also be taken in the form of effective, fair and consistent enforcement of environmental law against pollution and environmental damage that has occurred. The environmental legislation must be enforced. The need to issue a regulation concerning restrictions on the disposal of domestic waste into rivers in order to achieve river quality standards. Anyone who is proven to damage the environment must be punished according to the applicable provisions in the perfection of the sense of justice of the community. For example, there are those who dispose of black water waste directly into the river can be subject to social sanctions in the form of photographic evidence when disposing of waste and published in the village office. All law enforcement officers from the police, prosecutors and judges must have an environmental sense to better consider the impact of their policies on the lives of future generations who also need a clean and healthy environment. Industries, hotels, hospitals and various forms of businesses / activities that dispose of liquid or solid waste that do not meet the quality criteria must be given a strict and consistent penalty in accordance with Law No. 32/2009 concerning Environmental Protection and Management (PPLH) to ensure legal certainty for the protection and management of Surabaya river on an ongoing basis

6. Extension and appeal not to dispose of domestic waste to Surabaya river

In controlling the pollution of Surabaya river water, extension activities primarily for communities around the banks of the Surabaya river need to be carried out. Counseling is carried out not only in the form of training or socialization, but there are aspects of other activities that are able to empower communities around the river. The community extension and empowerment activities include information dissemination, non-formal education, community explanation and strengthening with the aim of education, dissemination of innovation, facilitation, consultation, supervision, monitoring and evaluation. In Law No. 32/2009 concerning Environmental Protection and Management (PPLH) [9]. In paragraph (1) the article states that the community has equal and equal rights and opportunities the extent to play an active role in environmental protection and management. The forms of roles are regulated in paragraph (2) in the form of social supervision; giving suggestions, opinions, suggestions, objections, complaints; and / or delivery of information and / or reports. While the purpose of the role of the community in accordance with paragraph (3) is to raise awareness in the protection and management of the environment, improve independence, community empowerment, and partnerships, develop community capabilities and pioneering, develop community responsiveness to conduct social supervision, and develop and maintain culture and wisdom local in order to preserve environmental functions.

IV. CONCLUSION

The factor that has the most significant influence on pollution in the lower reaches of Surabaya river (Jagir) is the water quality factor in the Surabaya river stream with a significance value of 13,582. Another variable that is also significant for pollution in the lower reaches of Surabaya river is the variable quality of domestic wastewater with a significance value of 2,801.

The priority order of the alternative strategy for controlling Surabaya river water pollution originating from the first domestic waste is the making of a communal WWTP of one city with a significance value of 0.373. The second priority is to control the settlement of riverine boundaries (0.235), thirdly tighten domestic waste disposal permits (0.158), fourth periodic supervision of domestic waste disposal (0.100), fifth payment of voluntary contributions for the Surabaya river water pollution control program (0.066), sixth sanction if there is direct disposal of waste (garbage and black water) into the river (0.040), and the last priority is counseling and an appeal not to dispose of waste (garbage and black water) directly into the river (0.028).

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