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Impact of Urban Expansion on Water Quality of Sebeya River in Rubavu District, Rwanda

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Abstract

The water is a key important of natural resource which is very important to all ecosystems on the planet. Currently there is a less studies that look on water quality variation due to the growth that surrounds. Therefore, this research was conducted in order to assess the potential influence of urban increase on water quality of Sebeya river located in Rubavu district, western province of Rwanda. Five composite samples were collected in three sites located in 3 cells such as Mahoko. Musabike, and Kamuhoza located in Kanama sector. Samples analysis were conducted in laboratory located in Research Center for Natural Resources and Environment at UNILAK. Five water indicators comprising pH, Zinc, Total Nitrogen Total Phosphorous and Chromium have been analyzed and used as a test of significance for laboratory results. The human activities are negatively influencing the water quality indicator pH hence the increased human driven activities are decreasing the water body pH by 24 percent through absorbing the carbon dioxide resulted from these activities leading to the water body to become acidic consequently. Because urbanization is expanding very quickly in Kanama sector, the research found that there is an effect of urban increase on water quality of Sebeya River. Not only human activities can negatively affect the river, on the other side it is recommended that the water quality of the river can be preserved by the human activities resulting from the urban increase like soil erosion prevention and green practices.

Keywords

Water Quality, Urban Increase, Sebeya River Catchment, Water Pollution

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1. Introduction

Today, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050. Projections show that urbanization, the gradual shift in residence of the human population from rural to urban areas, combined with the overall growth of the world's population could add another 2.5 billion people to urban areas by 2050, with close to 90% of this increase taking place in Asia and Africa [15] and the expansion of urbanization affect the environmental sources including water quality.

According to Chinese city, Lianyungang Specifically, it has been realized the effects of the rate of urbanization on land water connections [4]. Catchment basins are degraded by the conversion of forests and natural pasture lands to agricultural uses [5], with the concomitant intensive application of pesticides, herbicides and fertilizers, moreover, the regulation of streams, rivers and the drainage of wetlands causing water pollution, stream bed erosion, reductions in water quality and quantity and other environmental and ecological problems [3]. Urban land expansion was recognized in all of the watershed. The central area of Guanyun County is the city that has the highest rate of urban increase. Measures of water indicators vary between urban districts and counties [1]. Urban land increase had higher negative influence on water indicators in reduced urban watersheds. urbanization has emerged as one of the important drivers of land use and environmental changes depleting

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natural resources and biodiversity, and disrupting natural drainage and ecosystem services; and increasing vulnerability of anthropogenically modified slopes to a variety of natural risks, particularly under climate change [9]. However, this growth also offers opportunities to break away from the past (inadequate) water management practices and adopt innovative approaches, which include the use of treated wastewater and by-products [14]. The disproportion may also clarify the higher sensitivity of water environment in results to urban increase in less-urbanized watersheds [17]

Rwanda's population is estimated to continue growing the rest of the century and reach 33.35 million people by 2099. The population, which currently sits at 12.95 million in 2020, is projected to surpass 20 million people in 2042 and 30 million people in 2076. Rwanda's population grew 2.58% from 2019 to 2020, adding about 325,000 people to the population. The fertility rate in Rwanda is 4.10 births per woman, which is boosting the population growth despite negative net migration [16]. Therefore, urban areas have the potential that generate ecological and environmental impacts at multiple scales. In City of Kigali, fast urban increase is recognized facts [6].

As we have seen in different researches, it has been identified that the speed or pace of urban expansion causes different problems especially in environmental sector whereby people depend on natural resources for the better living.

The population of the São Paulo Metropolitan Region has increased sevenfold since 1950 and its growth was not followed by a proportionate increase in domestic wastewater treatment levels [2]. The intense industrialisation process that occurred during that period also contributed to the increase of water pollution [13].

However, these practices result in a scarcity of drinking water and a number of viral diseases, soil erosion, release of phosphorus, ammonia and nitrates from agrochemicals applied, chemicals and waste from hospitals which in round influence the pollution of water and high levels of eutrophication in rivers [8]. The water quality of rivers may degrade due to the changes in the land cover patterns or land use practices within the catchment as human activities increase [11].

This research has an objective of assessing different effects of urban increase on water quality of Sebeya river and the study will measure the impact of urban increase on water quality.

2. Research Method

2.1. Model Specification

The impact of urban expansion on the water quality was analysed through regression analysis, the econometric model relating the independent control variables and the water quality indicators as dependent variables. As mentioned above, the chosen independent control variables are urban increase indicating the rate of the urbanisation in the chosen areas as the main variable of interest, human activities that are harming the water bodies especially Sebeya River, food packages indicating the municipality wastages from different economic sectors within the chosen areas, deforestation activities carried out in the chosen areas and whether the landslides and erosion took place in the areas chosen. The dependent variables chosen here to analyse the water quality are Ph, Zinc, Chromium, Total Nitrogen and Total Phosphorous.

$$\begin{pmatrix} PH, Zinc \\ Chromium \\ Nitrogen, Phosphorous \end{pmatrix} = \beta_0 + \beta_i \begin{pmatrix} human\ activities, deforestation \\ food\ packages \\ urban\ expansion, landslides\&erosion \end{pmatrix} + \varphi_i \quad (1)$$

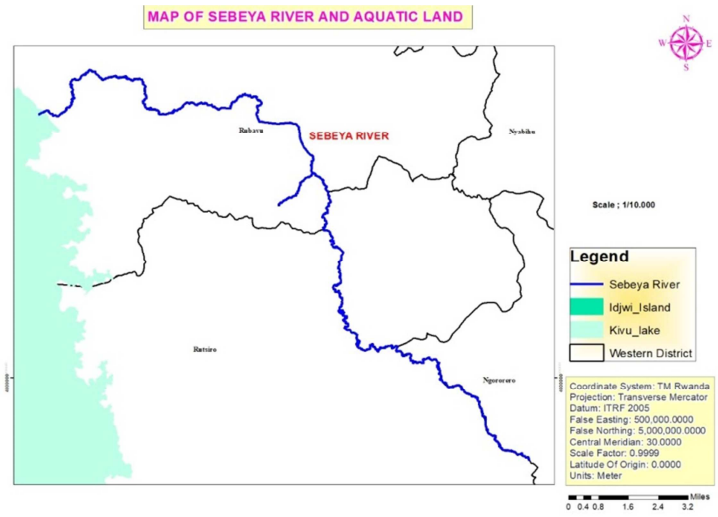

Figure 1. Geographic location of Sebeya river in Rwanda.

2.2. Description of the Area

Sebeya is a river located in Western Province, Rwanda that empties into Lake Kivu just south of the town of Rubavu [2]. It is among the main rivers in Rwanda that supply the Congo River basin [5].

In Rubavu district 51.7 % of the total population are females and 48.3 % are male. Total population in urban areas is 149,209 which makes 37% of the total district‟s population whereas 254,453 (63%) reside in rural areas. The district‟s population represents 3.8% of the total country‟s population and 16.3 % of the Western Province population (2,471,239 inhabitants). The average household size is 5.2 against 4.8 at national level [12].

2.3. Population

In the Sebeya catchment over 74% of the population live in rural areas, with the remaining 26% in urban areas. Gender statistics indicate a slightly higher female population (56% total), with 55% (both men and women) below 20 years old. There is a spatial variability of population density (people/km^2) in each administrative area, a significant urban population (25% of the total catchment population) located in the northern part of the catchment (sectors Rubavu, Nyakiliba, Rugerero and Gisenyi), with population densities ranging from 1,100 to 4,850 people/km^2. Sectors along the shores of Lake Kivu and the main road from Rubavu to Musanze are also very densely populated with more than 1,000 persons/km², while sectors in the highlands of the south-east have the lowest population density (260 to 600 persons/km²) [7]

The research will look at the changes on density of the population located in Kanama sector in different years. ArcGIS was used as a tool of mapping the study area.

2.4. Sampling and Laboratory Analysis

Analysis of samples follows the standards of Rwanda standard board (RSB). Samples was in a cooler box for preservation during transportation to the laboratory for analyzing the parameters planned in this research.

2.4.1. Laboratory Analysis

Water samples from Sebeya river were collected and analyzed in authorized laboratories. The main parameters to analyze was pH, Zinc, Chromium, Total Nitrogen, Total Phosphorous. These parameters were analyzed from water samples taken in the current period to discuss and demonstrate the characteristics of river water and effects of urban on water quality.

Table 1. Laboratory Test Parameters with methods.

PARAMETERS	TEST METHODS
Ph	EPA 180.1
Zinc	HACH 8009
Chromium	HACH 8023
Total Nitrogen (TN)	HACH 10072
Total Phosphorous (TP)	HACH 10209

2.4.2. Observation

The observation of this research was made on the field on Sebeya river in Kanama sector, Rubavu district. Here below are the parameters that have been used to analyze the quality of water.

Table 2. Parameters of Water quality.

PARAMETERS		
PHYSICAL	TOXIC METALS	INORGANIC CHEMICALS
pH	Zinc, Chromium	Total Nitrogen, Total phosphorous

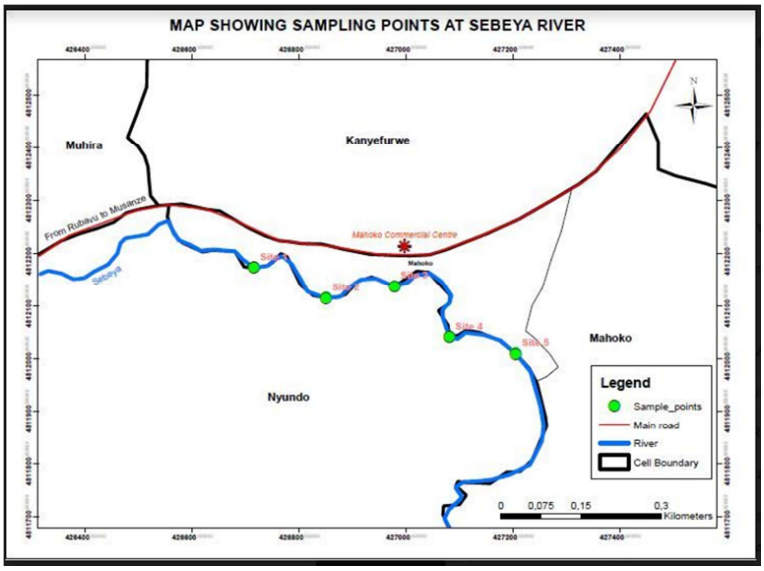

Figure 2. Map showing sampling points in Sebeya.

3. Data Analysis and Discussion

This chapter deals with presentation, analysis and interpretation of findings generated through water samples laboratory tests to study potential urban increase influencing water quality in Sebeya river. Five water-sampling points were selected basing on different cells that surround the river. Musabike, Kamuhoza and Mahoko are cells that are located in Kanama Sector of Rubavu District. Some of these cells has been selected because they are very close to the river and they are expanding in urbanization at a significant level.

3.1. Regression Analysis

Table 3. Statistical and analytical results.

VARIABLES	PH	Zinc	Chromium	Phosphorous	Nitrogen
Human activities	-0.24	0.158	-0.0307	-1.767	6.68
	(2.421)	(0.38)	(0.00519)	(6)	(4.842)
Deforestation	0.04	-0.308	0.0182*	0.022	-0.98
	(1.12)	(0.176)	(0.0024)	(2.776)	(2.24)
Urban increase	0.8	0.64	0.124*	5.84	-29.6
	(5.6)	(0.88)	(0.012)	(13.88)	(11.2)
Constant	6.1	-0.05	0.0175	-0.895	30.30*
	(1.435)	(0.225)	(0.00307)	(3.556)	(2.869)
Observations	5	5	5	5	5
R-squared	0.075	0.979	0.999	0.467	0.981

Notes Titles: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

From the table 3 reports that the human activities are negatively influencing the water quality indicator pH hence the increased human driven activities are decreasing the water body pH by 24 percent through absorbing the carbon dioxide resulted from these activities leading to the water body to become acidic consequently. The human activities in the chosen study area is influencing the zinc for the water body positively by 15.8 percent as the zinc concentration increase unnaturally due to additional of zinc through human activities and most zinc is added due to the market activities located in Mahoko cell and different factories. Surprisingly, the chromium in the water body of Sebeya River is reducing due to the human activities in the chosen area by 3 percent, and this result from the human exposed to the chromium and they absorb it, which lead to negative health effects. The human activities like industrial practices are positively influencing the nitrogen of the Sebeya water body resulting to high nutrient pollutions in the water bodies and the concentration of Total Phosphorous in the River Sebeya, originating from crop residue and mineralization as well as from atmospheric deposition on the land, is relatively high [10]. In this research, phosphorous is reducing due the reduction of sediments or organic matter in Sebeya river.

It reports that the deforestation practices are positively influencing the water quality indicator pH by 4 percent, 2.2 percent on the phosphorous respectively while it leads to increase in chromium concentration by 1.8 percent which significant at p<0.1 and the deforestation practices in the study area is negatively affecting the water quality indicators zinc, nitrogen by 30 percent and 98 percent respectively. In addition, from results revealed that human activities, deforestation are having a significant impact on the water quality indicators.

The urban increase in the study area is positively influencing the water quality indicator pH by an incline of 80 percent and this shows that the expansion of urban areas will have significant effects on the water bodies in the regions, the concentration of zinc as water quality indicator is increased by 64 percent due to growth of the urban area resulting to the disturbance of the water bodies through water quality indicators. The urban increase practices in the study area is positively affecting the concentration of the phosphorous as water quality indicator by an increase of 12.4 percent that is statistically significant at p<0.1. Interestingly, the nitrogen concentration in the water bodies will be affected negatively by 29.6 percent as result of the urban increase practices leading to decline in nitrous content like water consumed for activities of urban increase.

3.2. Urban Increase Trends in Sebeya Catchments

The analysis will show the status of water of Sebeya river taken within five samples in Kanama sector and the quality will depend on the rate of the indicators of Zinc, pH, Chromium, Total Phosphorous and Total Nitrogen found during the research.

Table 4. Water Quality status of Sebeya River.

VARIABLES	PH	Zinc	Chromium	Total Phosphorous	Total Nitrogen
Sebeya water sample	-0.05	-0.136**	-0.00750**	-0.293	2.020***
	(0.079)	(0.037)	(0.00145)	(0.216)	(0.225)
Constant	6.490***	0.692**	0.0835***	1.673	14.14***
	(0.262)	(0.123)	(0.00483)	(0.717)	(0.746)
Observations	5	5	5	5	5
R-squared	0.118	0.819	0.899	0.38	0.964

Notes_Titles:Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

(i). Status of PH on Different Samples Taken

In the findings, the sample taken from different Sebeya catchment, from sample 1 to another with the increasing rate of urban increase associated with the decline in Sebeya water quality indicator: pH by the percentage of five due to the increase of CO_2 in the water.

(ii). Status of Zinc on Different Samples Taken

In the table 4 there is an increasing rate of urban increase from sample 1 to another which affects the reduction of Zinc by 13.6 because the concentration of zinc in drinking water can often be higher than the concentration in the unprocessed water from Sebeya river.

(iii). Status of Chromium on Different Samples Taken

In the table 4 there is an increasing rate of urban increase from sample 1 to another (from Mahoko that is expanding the city moving to Musabike cell where the city is not yet available) which affects the reduction of Chromium in water by 0.7 percent due to the absorption of water taken from Sebeya river by the people surrounding the river.

(iv). Status of Phosphorous on Different Samples Taken

In the table 4 there is an increasing rate of urban increase from sample 1 to another which affects the reduction of phosphorous in water by 29.3 due to the irrigation done in agricultural activities found around the river in Kanama sector.

(v). Status of Nitrogen on Different Samples Taken

In the table 4 there is an increasing rate of urban increase from sample 1 to another which affects the increasing Nitrogen significantly in water due to the pollution of human activities, commercial food packages, soil erosions and other wastes from human bodies.

3.3. The Extent at Which the Urban Increase Contribute to the Water Quality Deterioration

Due to a rapid urban increase, rivers are affected by the urban increase new activities. The sediments brought by people surrounding the river and runoffs contribute to the deterioration of water quality of river. Different parameters of water quality will be analyzed to assess at which level urban increase deteriorates water quality.

3.3.1. Urban Increase on Indicator Zinc in Water of Sebeya River

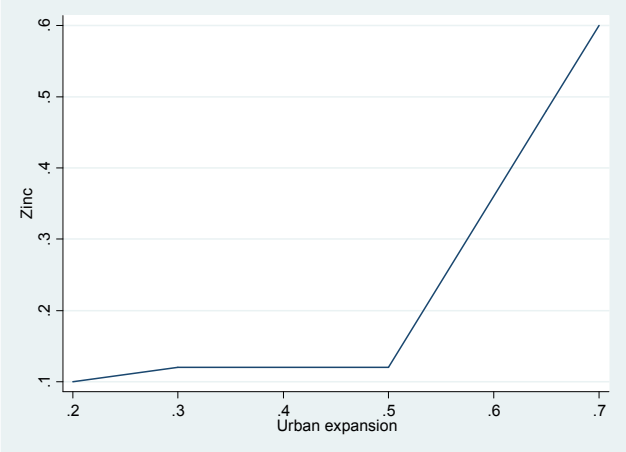

Figure 3. Variation of water quality indicator Zinc with urban increase.

The figure 3 reports that the concentration of the zinc in the water from Sebeya river increase with the urban increase rate with sloppy increase in from 0.2 to 0.3 with gradient of 0.25 and steep. increase from 0.5 to 0.7 urban increase rate with gradient of 2.375 while the concentration is kept almost flat from 0.3 to 0.5 with zero gradient. Moreover, this show that the urban increase has great significant influence on the concentration of the Sebeya river water quality indicator Zinc.

3.3.2. Extension of Urban on Water Indicator pH

The figure 4 reports that the concentration of the PH in the water from Sebeya river decrease with the urban increase rate with sloppy decrease in from 0.2 to 0.3 with negative gradient of 2.0 and steep increase from 0.3 to 0.5 urban increase rate with gradient of 0.5 and steep decrease from 0.5 to 0.65 with negative gradient of 1.33 while the concentration is subjected to tremendous increase from 0.65 to 0.7 with positive gradient of 12. Furthermore, this show that the urban increase has great significant influence on the concentration of the Sebeya river

water quality indicator PH.

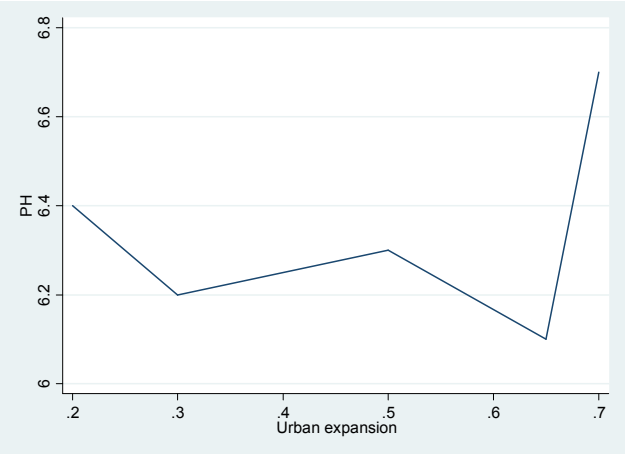

Figure 4. Variation of water quality indicator PH with urban increase.

3.3.3. Urban Increase on Indicator Phosphorous of Water in Sebeya River

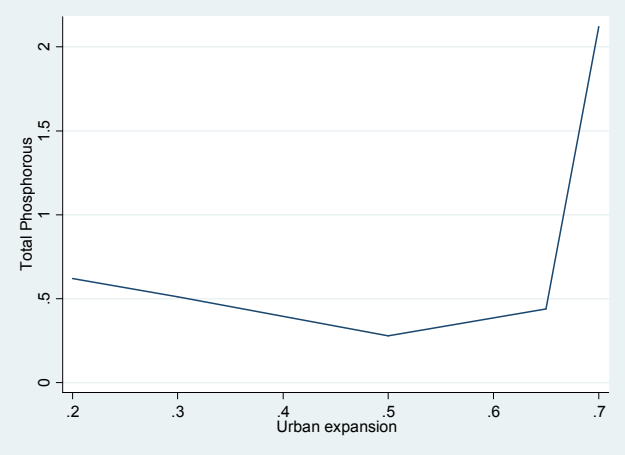

Figure 5. Water quality indicator of total phosphorous with urban increase.

The figure 5 reports that the concentration of the total phosphorous in the water from Sebeya river decrease with the urban increase rate with sloppy decrease in from 0.2 to 0.5 with negative gradient of 0.75 and steep increase from 0.5 to 0.65 urban increase rate with gradient of 0.5 while the concentration is exposed to tremendous increase from 0.65 to 0.7 with positive gradient of 30.4. Additionally, this show that the urban increase has great significant influence on the concentration of Sebeya river water quality indicator of total phosphorous.

3.3.4. Extension of Urban on Indicator Chromium of Water in Sebeya River

The figure 6 reports that the concentration of the chromium in the water from Sebeya river decrease with the urban increase rate with sloppy incline in from 0.2 to 0.3 with a positive gradient of 0.13 and sloppy increase from 0.3 to 0.5 urban increase rate with positive gradient of 0.0625 and flat increase from 0.5 to 0.65 with positive gradient of 0.003 while the concentration is subjected to tremendous rise from 0.65 to 0.7 with positive gradient of 0.1 Further, the results show that the urban increase has great significant positive influence on the concentration of the Sebeya river water quality indicator of chromium throughout the whole Sebeya river profile.

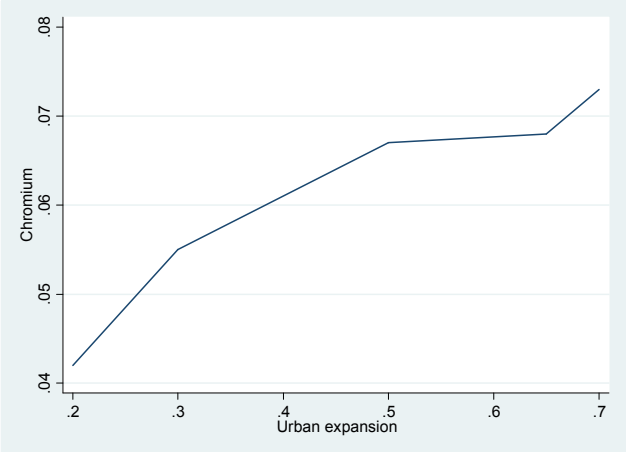

Figure 6. Water quality indicator of Chromium with urban increase.

4. Conclusion and Recommendation

4.1. Conclusion

The research found that there is an impact of urban increase on water quality of Sebeya River. Because urbanization is expanding very quickly in Kanama sector, this affect the water quality indicators to change accordingly.

The results from the field of study reports that different human activities like agricultural, animal husbandry, construction practices, terracing and other erosion prevention activities and some household related activities like poor management of household wastes, poor sewage systems carried out in the region near by the Sebeya river especially in Kanama sector are really affecting the chosen water quality indicators. Not surprisingly, the deforestation activities that took place in the region near Sebeya River had affected the quality of the water from Sebeya River throughout the River profile.

More interestingly, urbanization that is expanding in different regions of Kanama sector is significantly affecting water quality of Sebeya River due to expropriation and resettlement towards the improvement of infrastructure accessibility as a result of urban increase. Moreover, building settlements, industrialization, different activities done in the market, restaurants all the activities have a significant impact on water quality of Sebeya River and this can cause different diseases on the people who are surrounding the river.

4.2. Recommendations

Not only human activities can negatively affect the river, on the other side the water quality of the river can be preserved by the human activities resulting from the urban increase like soil erosion prevention and green practices.

Due to the urban increase, the quality of river is negatively affected so the leaders from Kanama sector should sensitize the citizens to do the community work once in a month around the Sebeya river in order to remove the solid wastes that can flow into the water to increase its quality.

From the findings deforestation affected the water quality through the increase of CO_2 in water which affects the water to become acid, so the citizens should be sensitize on reforestation in order to reduce the acidity of water in Sebeya river and also protect the river against erosion.

Because of urban increase, people started to live very close to the river so the government should create the buffer zones so that the river could be protected from human activities.

So, the government should preserve natural water resource through creation of buffer zones along water body profile.

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