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URBAN WASTEWATER QUALITY IN VINH LONG PROVINCE, VIETNAM

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Abstract

Along with the speed of industrialization and modernization, the problem of urban environmental pollution is also increasing. This study aims to assess the characteristics of urban wastewater in Vinh Long province, Vietnam in 2019. Nine parameters, including pH, temperature, TSS, BOD, NH_4^+ - N, NO_3^- - N, PO_4^{3-} - P, S^{2-} and coliform at 22 monitoring locations in Vinh Long province were collected and compared with threshold values of national technical regulation on domestic wastewater (QCVN 14:2008/BTNMT). Pearson correlation, principal component (PCA) and cluster analysis (CA) were used to analyze relationship of water quality parameters, pollution sources and key water variables resulting water quality variation and similarities in wastewater properties in the study area. The findings showed that urban wastewater was contaminated with organic matters, nutrients, microorganisms. Correlation analysis found that organic matters and nutrients were strongly correlated in the wastewater, with correlation coefficient ranging from 0.529 - 0.771 (TSS, BOD, NH_4^+ - N, NO_3^- - N, PO_4^{3-} - P). The PCA showed that about 88.1% of the variation in water quality was explained by 5 factors: living activities, market, industries, production and business establishments. CA classified properties of urban wastewater into different clusters because of organic matters, nutrients (Group IV) and microorganisms (Group I). Findings of this study revealed that direct discharge of urban wastewater will adversely affect surface water environment; thus, urban managers should have solutions to treat wastewater before discharging in order to avoid environmental pollution of the receiving source as well as reduce public health concerns.

Keywords: Nutrients; Organic matter; Coliforms; Urban wastewater; Vinh Long province.

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1. Introduction

In recent years, Vietnam is one of the countries with a rapid urbanization rate, but due to difficult economic conditions, investment in urban infrastructure engineering systems in general and water supply and drainage systems is not a priority. The lack of wastewater treatment infrastructure, many treatment systems with inappropriate technology

have led to untreated urban wastewater being discharged directly into the environment (the average recorded water loss rate was about 26 - 29 %), threatening the environment (Ministry of Natural Resources and Environment, 2016). This becomes a big challenge for cities in Vietnam. According to statistics of the Ministry of Construction (2019), the whole country has 43 concentrated urban wastewater treatment plants in operation with a total designed capacity of over 926,000 m^3/day; however, the percentage of collected and treated wastewater is only about 13 %. The drainage system in Vietnam's urban areas is mainly a common drainage system that collects and transports various types of wastewater and even rainwater. Municipal wastewater often contains high levels of organic and inorganic substances. Wastewater discharged into the environment without treatment or improper treatment and accumulated for a long time in the receiving environment will be a great burden on the environment (Cat, 2007). According to the Ministry of Natural Resources and Environment (2016), surface water pollution in rivers, lakes and canals is still a big problem in most provinces and cities, especially in areas receiving wastewater from domestic, production facilities, etc. without or inadequate treatment. Most parameters related to organic pollution and nutrients exceed the allowable limits of current regulations.

In the Mekong Delta, currently only a few urban areas have built the urban wastewater collection and treatment system. The majority of wastewater generated from urban areas without or inadequate treatment may lead to the serious pollution of surface water in rivers and canals. In which, urban areas in Vinh Long province do not have centralized wastewater treatment plants, so untreated wastewater is discharged directly into the environment. Vinh Long is a province in the Mekong Delta with the total area of 1,525.73 km^2, located between the two main tributaries of the Mekong River, the Tien and Hau rivers. Vinh Long province has 8 district administrative units (1 city, 1 town and 6 districts) with 109 administrative units. The population of the province is 1,050,241 people; in which, the population living in urban areas reaches nearly 169,862 people, accounting for 16.6 % of the province's population. Thus, urban wastewater may lead to significant impacts if it is not properly treated and managed.

In addition, most of the urban areas of the province have a common rainwater and wastewater drainage system. However, some common drainage routes are obsolete, causing slow drainage and local flooding in the rainy season. The common drainage system is mainly arranged on the main roads, so some households living on small roads or in alleys also discharge waste directly into rivers and canals, causing environmental impacts. The province's urban wastewater includes domestic wastewater, wastewater from companies and factories and rainwater. The complex composition, high concentrations of pollutants and untreated wastewater cause serious environmental pollution, especially affecting surface water, groundwater as well as water supply in the province. According to Ullah et al. (2013), wastewater from urban and industrial areas contributes to the degradation of water resources, reduces agricultural output as well as affects public health. The discharge of

untreated wastewater into receiving sources affects the environment and human health (Edokpayi et al., 2017). The effects depend on the composition and concentration of pollutants in the wastewater as well as the volume and frequency of the effluents entering the receiving source (Akpor and Muchie, 2011). However, studies on wastewater characteristics in Vinh Long province have not been carried out. Therefore, this study aims to determine the characteristics of wastewater in the province in order to provide basic information for pollution management.

2. Materials and methods

2.1. Study area

Vinh Long province has a fairly flat topography, with a relatively low elevation compared to sea level. With the topography of the floodplain of the river mouth, the sub-terrain of the province is in the form of a basin in the center of the province and gradually rises towards the banks of the Tien, Hau, Mang Thit rivers and along major rivers and canals. Although Vinh Long has a large area of acid sulfate soil, the alum layer is very deep and the percentage of alum is low. Locating between the two largest rivers in the Mekong Delta, an interlaced network of rivers and the large average annual rainfall, the province has favorable natural conditions for production and daily life of the people. In 2019, the province's economy maintained its growth momentum, with gross domestic product (GRDP) increased by 6.22 %. The index of industrial production (IIP) in 2019 increased about 15.04 % compared to 2018, the highest growth rate from 2015 to date. Exports also had a remarkable growth. The province's total export turnover in 2019 was estimated at 568.7 million USD, up 22.3 % over the previous year. Vinh Long has always been one of the leading provinces in Vietnam in term of attracting investment due to reasonable and open policies. In Vinh Long province, there are 2 industrial parks, 1 industrial route and there will be 3 new industrial parks with industrial clusters. In addition, the province is also famous for eco-tourism with a variety of specialty fruits. In parallel with the speed of urbanization and rapid population growth, the amount of domestic wastewater and the content of substances are increasingly complex, but the technical infrastructure system is not synchronized.

2.2. Water sample collection and analysis

The study on urban wastewater characteristics in Vinh Long province in 2019 was carried out through collecting data from the Department of Natural Resources and Environment of Vinh Long province. Wastewater samples were assessed at 22 locations (from U1 to U22) with a monitoring frequency of once a year, including one wastewater sample at each sewer in 1 town and 6 districts along with 17 wastewater samples in the city area of Vinh Long province (Fig. 1). Urban wastewater characteristics were evaluated through 9 environmental parameters, including pH, temperature, total suspended solids (TSS), biochemical oxygen demand (BOD), ammonium (NH_4^+ - N), nitrate (NO_3^- - N), orthophosphate (PO_4^{3-} - P), sulfide (S^2) and coliforms. pH and temperature are measured directly in the field. TSS, BOD, NH_4^+ - N, NO_3^- - N, PO_4^{3-} - P, S^{2-} and coliforms were analyzed in the laboratory according to standard methods (APHA, 2017).

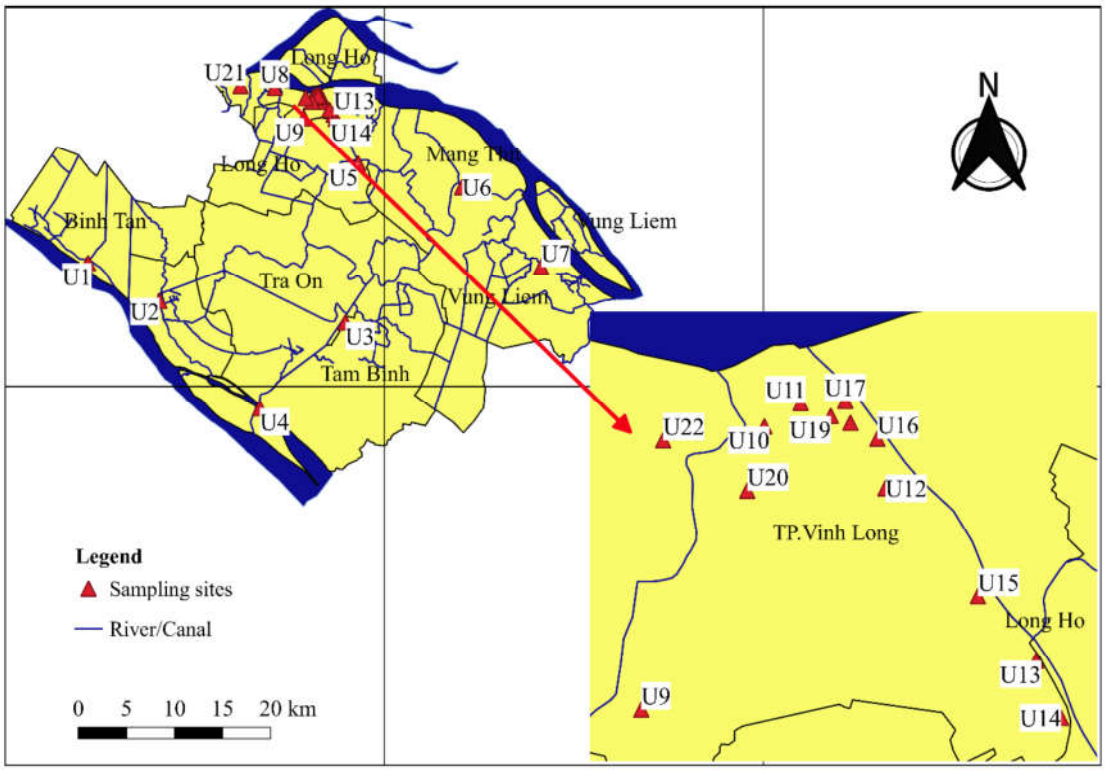

Figure 1: Location of urban wastewater monitoring points in Vinh Long province

2.3 Data analysis

The mean value of parameters in urban wastewater in Vinh Long province were compared with the maximum value. The maximum values of parameters were calculated according to the national technical regulation on domestic wastewater (QCVN 14:2008/BTNMT column A), as follows:

In which:

- C_{max} is the maximum allowable concentration of pollutant parameters in domestic wastewater when discharged into the receiving water source (mg/L);

- C is the concentration value of the pollution parameter specified in Table 1;

- K is the coefficient of the size, type of service facilities, public facilities and apartment buildings (with K = 1). This can be explained that the sluices are located near the market in the district area, so they are mainly near rivers and canals and the area is relatively large. While the residential areas/clusters are located in the city area; therefore, the number of households is relatively crowded.

Therefore, the maximum value of the parameters in wastewater in Vinh Long province was equal to the value specified in Table 1.

Correlation analysis (Pearson) was used to describe the relationship and interdependence between the analyzed criteria. Positive correlation means that two variables increase or decrease at the same time; while the negative correlation is a decreasing variable, an increasing variable (Gazzaz et al., 2012). Values greater than 0.5 showed a statistically significant correlation ($p < 0.05$) between the properties of wastewater indicators (Feher et al., 2016). All the above analyzes were performed using IBM SPSS 20.0 Windows statistical software.

Principal component analysis (PCA) was used to reduce from a large number of variables to a smaller number of factors, in order to select a small set of variables in a large set based on the original variables highly correlated with the principal component. The resulting PCA generates a new set of variables called principal components or principal factors (PC) (Olsen et al., 2012). The eigenvalue coefficient was considered as a measure of the principal component importance. The larger this coefficient, the greater the contribution that the principal component has to explaining the variability of the original data set. Cluster analysis (CA) was applied to the site survey group based on the wastewater environment monitoring components. CA groups objects (observation sites) into classes (clusters) on the basis of similarities within the same group and differences between different groups (Singh et al., 2005). Cluster analysis was performed using Ward's method (Salah et al., 2012). CA results were presented by a dendrogram. PCA and CA analysis were analyzed using Primer 5.2 software for Windows (PRIMER-E Ltd, Plymouth, UK).

Table 1. The value of pollution parameters

a	Parameters	Unit	Parameter values QCVN 14:2008/BTNMT
1	pH	-	5 - 9
2	Temperature	^oC	-
3	TSS	mg/L	50
4	BOD	mg/L	30
5	NH_4^+-N	mg/L	5
6	NO_3^--N	mg/L	30
7	PO_4^{3-}-P	mg/L	6
8	S^{2-}	mg/L	1
9	Coliform	MPN/100mL	3000

3. Results and discussion

3.1. Urban wastewater quality in Vinh Long province

pH in the sewers of the study area ranged from 6.70 - 8.00, with an average of 7.45 ± 0.32. The lowest and the highest pH were found at U19 and U17, respectively (Fig. 2a). The pH value of the study area is still within the allowable limit of QCVN 14:2008/BTNMT column A. The temperature at the monitoring discharge gates fluctuated from 28.20 - 32.40 ^oC, with an average value of 30.52 ± 1.09 ^oC. The lowest temperature was found at U20 and the highest temperature was found at U2 (Fig. 2b). This temperature is suitable for aquatic organisms to grow (Ty et al., 2018). In fact, the temperature in the wastewater is usually higher than that of the original clean water source. According to Hung (2009), the surface water in Vietnam ranged from 14.3 - 33.5 ^oC. The increase of water temperature will affect the dissolve of oxygen and the activity of bacteria in the wastewater.

TSS concentration in the sewers of the study area varied from 27 mg/L (U3) to 186 mg/L (U8), with an average of 73.91 ± 38.83 mg/L (Fig. 2c). According to Nga et al., (2012), TSS in domestic wastewater ranged at 30 - 120 mg/L. TSS concentrations in residential markets

fluctuated strongly from 13 - 330 mg/L with an average of 137 ± 0.13 mg/L (Da et al., 2018). In this study, only 6/22 locations had TSS content within the limits of the regulation; the others had TSS higher than the standard QCVN 14:2008/BTNMT column A from 1.02 - 3.72 times. High TSS has become a major concern for water quality in the Mekong Delta which is seen as the cause of poorer water quality, higher treatment costs and impacts on aquatic life (Giao, 2020). At the same time, high TSS in water could reduce the visibility of aquatic animals, the transmission of light into the water, hinder the photosynthesis of algae and reduce the oxygen content in the aquatic environment. BOD value indicated organic pollution in the aquatic system, which adversely affected water quality and biodiversity. From Figure 2d, BOD at 22 sewers in Vinh Long province in 2019 ranged from 29.80 to 178 mg/L (the lowest and highest at U14 and U4 sewers, respectively). The average value of BOD was 80.20 ± 44.03 mg/L. Canh et al. (2006) reported that organic matters in urban wastewater were higher than the current study area, ranging from 285 to 395 mg/L. Surface water of the Hindon River in Ghaziabad, affected by industrial and urban discharges, has BOD higher than the norm, with values of 27 - 51 mg/L (Suthar et al., 2010). The area of Chom Sao - Suoi Don canal in Vam Bung basin is significantly affected by untreated domestic wastewater from residential areas along the basin, leading to a high BOD and exceeding the permissible limit (Hung et al., 2019). Research results illustrated that only the U14 has BOD value within the allowable limit of the regulation, the remaining 21/22 locations all exceed the threshold specified by QCVN 14:2008/BTNMT column A from 1.06 - 5.93 times.

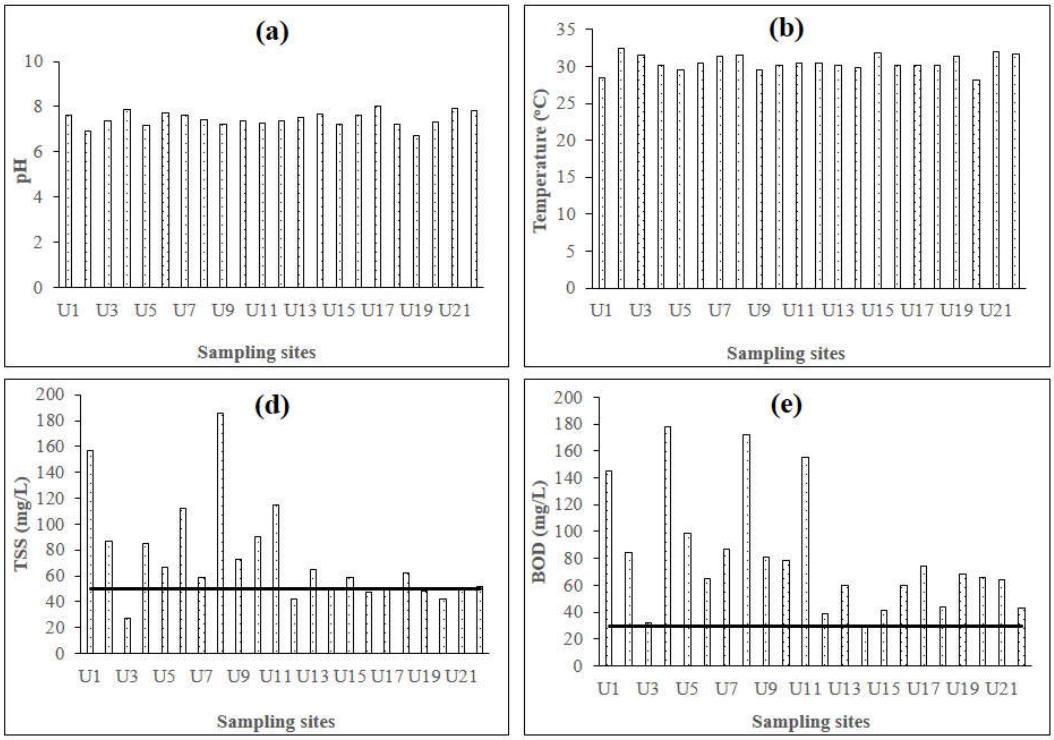

Figure 2: Urban wastewater quality in Vinh Long province

Note: (a) pH, (b) Temperature, (c) TSS and (d) BOD

Nitrogen is present in municipal wastewater, nitrogenous compounds as a result of the biodegradation of proteins. Nitrogen usually exists in the form of organic nitrogen, NH_4^+ - N, NO_2^- - N, NO_3^- - N. Organic N usually consists of natural components such as peptides, proteins, urea, nucleic acids and a large number of synthetic organic compounds. NH_4^+ - N is a natural component in wastewater, the first product of the decomposition of N-containing organic compounds and the decomposition of urea; NO_2^- - N is an intermediate product of nitrogen oxidation, which can enter the aquatic environment due to the use of industrial corrosion inhibitors; NO_3^- - N is the result of complete oxidation of ammonium. Ammonium concentration in natural surface water in unpolluted areas is less than 0.05 ppm. The ammonium concentration in wastewater from residential areas, chemical plants, food processing, dairy, etc. can be up to 10 - 100 mg/L. In the study area, NH_4^+ - N was relatively high, ranging from 15.7 to 76.5 mg/L, with an average of 40.74 ± 15.93 mg/L. NH_4^+ - N concentration was lowest at U14 and highest at U11 (Fig. 3a). In some urban rivers of Hanoi city, water sources are affected by domestic and production wastewater, hospital wastewater and stormwater runoff, causing NH_4^+ - N concentration to be high and exceed the standard with variable values from 24.71 to 52.39 mg/L (Hanh et al., 2016). Through research results, all monitoring locations have NH_4^+ - N in urban wastewater exceeding the allowable limit of QCVN 14:2008/ BTNMT column A from 3.14 to 15.3 times, showing that wastewater is in very dirty condition. If wastewater is not treated and discharged directly into the receiving environment, this will be a source of wastewater polluting the surface water environment, causing eutrophication, aquatic plants (Nga and Thu, 2005).

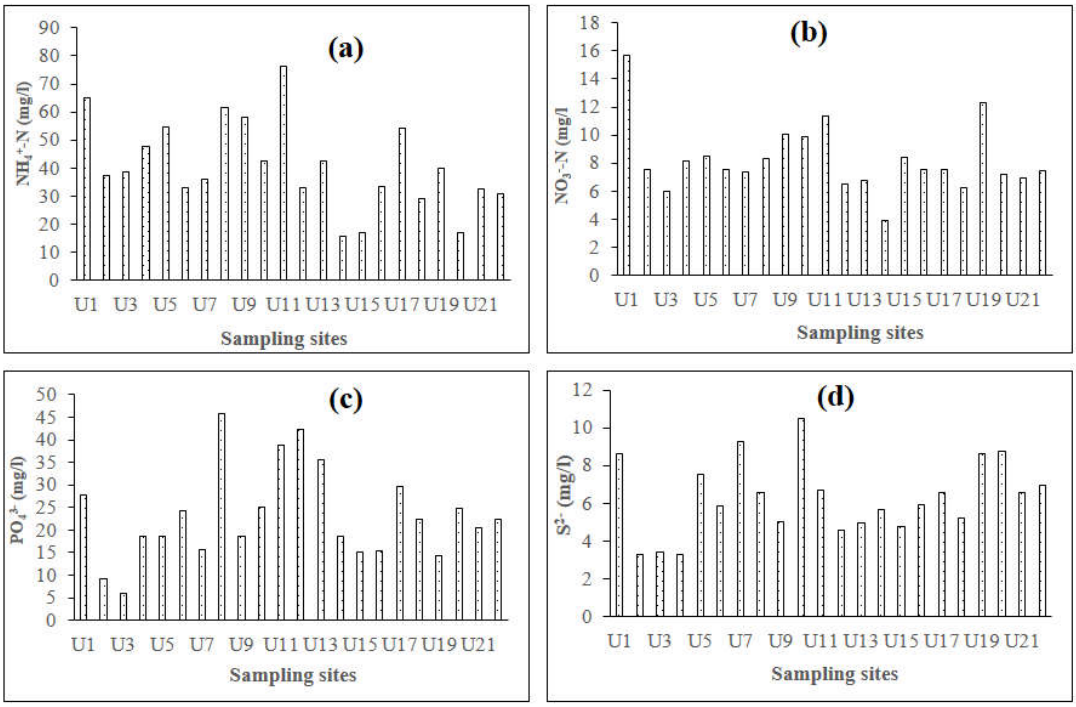

Figure 3: Urban wastewater quality in Vinh Long province

Note: (a) NH_4^+ - N, (b) NO_3^- - N, (c) PO_4^{3-} - P and (d) S^{2-}

Nitrates are the end product of the aerobic breakdown of nitrogenous substances found in human and animal waste. The concentration of NO_3^- - N at 22 sewers in the study area ranged from 3.92 to 15.7 mg/L (the lowest at U14 and the highest at U1), the average value was 8.25 ± 2.46 mg/L (Fig. 3b). The analysis results showed that the NO_3^- - N concentration in the study area was within the allowable limits of the national technical regulation on domestic wastewater QCVN 14:2008/ BTNMT column A. NO_3^- - N content low, due to the high BOD concentration and exceeding the standard as described above, due to the depletion of oxygen in the water, making it difficult for aerobic decomposition to occur, thereby low NO_3^- - N. The results were similar to the study of Nga and Thu (2005), the NO_3^- - N concentration was low with the average value ranging from 0.01 - 0.05 mg/L. This can be explained by the very high organic matter content (about 10 - 185 mg/L) which depletes dissolved oxygen, making nitrification difficult. According to Phuoc (2014), urban wastewater often contains phosphorus with concentrations from 10 - 20 mg/L, mainly derived from detergents. The study results indicated that PO_4^{3}-P concentration fluctuated from 5.9 - 45.9 mg/L (the lowest at U3 and the highest at U8), with an average of 23.18 ± 10.24 mg/L (Fig. 3c). In summary, the concentration of PO_4^{3-} - P in urban wastewater in the study area exceeded the limit value by 1.55 - 7.65 times (except for U3). High levels of nutrients when discharged directly into a receiving source could lead to eutrophication. Sulfur is released into the water mainly due to industrial, commercial and human activities. When the sulfide content exists in the water is high, it will affect the respiration and development of aquatic products. Wastewater often has a foul smell, but if the wastewater is contaminated, it will turn into a rotten egg smell due to the formation of H_2S in the water. Due to its acidic nature, H_2S is the cause of rapid corrosion of pipes in water supply and drainage systems. Due to the toxic nature of sulfide in water, the sulfide content in water has been strictly regulated in Vietnamese regulations. Figure 3d showed that the concentration of S^{2-} varied from 3.28 to 10.5 mg/L (with lowest and highest at U2 and U10, respectively), with an average of 6.30 ± 1.98 mg/L. The study area has the S^{2-} content exceeding the allowable threshold of QCVN 14:2008/ BTNMT column A from 3.28 to 10.5 times. The high S^{2-} content was consistent with high organic matter and nutrient analysis, which can lead to anaerobic decomposition (when oxygen content is low), producing a very strong odor and high odor intensity.

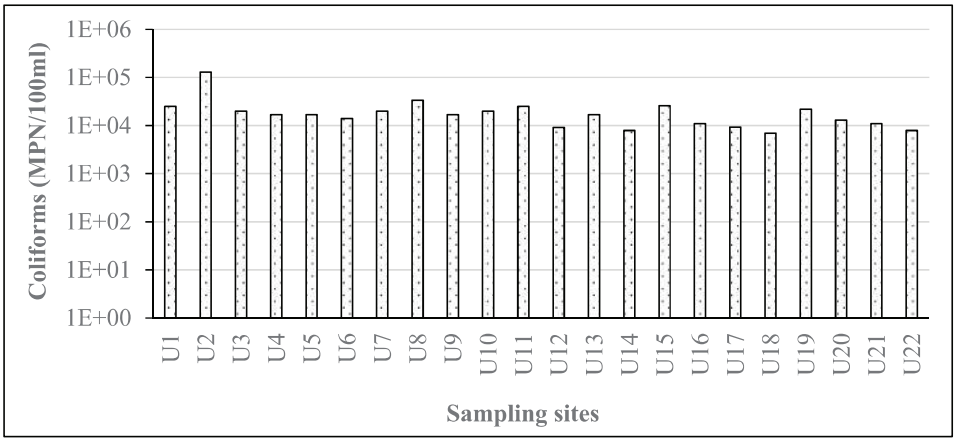

Figure 4: Density of Coliform in urban wastewater

As shown in Figure 4, the density of coliforms at 22 discharge sites in the study area of Vinh Long province varied from 7,000 to 130,000 MPN/100 mL (the highest at U2 and the lowest at U18), with an average of 21,831 ± 25,154.88 MPN/100 mL. The density of coliforms at Bung canal in the period 2015 - 2017 ranged from 59,000 to 97,000 MPN/100 mL, indicating the contamination of human and warm - blooded animal feces in the environment (Tri et al., 2020). According to Hanh et al., (2016), the coliform density in nine samples of river water in Hanoi, affected by mixed wastewater sources including domestic wastewater, production wastewater and hospital wastewater, all exceeded the permissible limit. The microbial contamination area with coliforms at all monitoring locations in this study exceeded the allowable limit of QCVN 14:2008/BTNMT column A from 2.33 to 43.33 times.

3.2. Correlation analysis of environmental components of urban wastewater in Vinh Long province

TSS was closely correlated with organic matters and nutrients. Specifically, TSS was strongly correlated with BOD (0.771), NH_4^+ - N (0.619), NO_3^- - N (0.529) and PO_4^{3-} - P (0.503). BOD was correlated with NH_4^+ - N (0.755) and NO_3^- - N (0.549). NH_4^+ - N was positively correlated with NO_3^- - N (r = 0.636), coexisting in wastewater (Tab. 2). In general, organic matters and nutrients were linearly correlated from moderate to good. This could indicate a significant increase in pollution for the receiving area because of the close correlation between the parameters.

Table 2. Correlation between environmental components in urban wastewater

Parameter	pH	Temp.	TSS	BOD	NH_4^+N	NO_3^-N	PO_4^{3-} - P	S^{2-}	Coliform
pH	**1**								
Temp.	-0.114	**1**							
TSS	0.008	-0.098	**1**						
BOD	0.067	-0.155	0.771	**1**					
NH_4^+-N	-0.024	-0.164	0.619	0.755	**1**				
NO_3^--N	-0.275	-0.265	0.529	0.549	0.636	**1**			
PO_4^{3-}-P	0.191	-0.249	0.503	0.371	0.411	0.130	**1**		
S^{2-}	-0.012	-0.321	0.161	0.122	0.117	0.448	0.156	**1**	
Coliforms	-0.461	0.411	0.256	0.190	0.095	0.098	-0.240	-0.278	**1**

3.3. Key indicators affecting urban wastewater quality in Vinh Long province

PCA was used to identify the sources leading to the variation in wastewater properties at the study sites. The correlation between the principal component and the baseline variables is explained by the weighted correlation data (Feher et al., 2016). The absolute value of the significant correlation coefficient greater than 0.75 means that there was a close correlation between the main components and the wastewater parameters; from 0.5 - 0.75 is the average and below correlation; and 0.5 is a weak correlation (Liu et al., 2003). The results showed that there are five main factors that explain 88.1 % of the variation of urban wastewater quality in Vinh Long province in 2019 (Tab. 3). Among the five eigenvalues, the first major component (PC1) has the highest

value and is the most important PC. With the variance value reaching 37.20 % of the variation of the original data set, PC1 is affected by a positive coefficient with the factors TSS (0.463), BOD (0.473), NH_4^+ - N (0.466), NO_3^- - N (0.42) and PO_4^{3-} - P (0.306) are at a weak correlation. PC1 focuses on the influence of organic matters and nutrients. PC2 explained 21.40 % of the variation in wastewater properties, weakly correlated with pH (0.442), temperature (-0.439) and moderately correlated with coliform (-0.644). PC2 is affected by microorganisms derived from human and animal feces. PC3 explained 14.50 % of the variation in the original data set, positively correlated with pH (0.507) and negatively correlated with S^{2-} (-0.54). In addition, PC3 was also weakly correlated with NO_3^- - N (-0.414) and PO_4^{3-} - P (0.336). PC4 explained 7.6% variation in municipal wastewater properties, correlated with moderate pH and PO_4^{3-} - P and weakly correlated with temperature and S^{2-}. PC5 explained 7.3 % of the variation in urban wastewater properties by a negative coefficient at the average correlation with temperature (-0.54), PO_4^{3-} - P (-0.514) and S^{2-} (-0.529). Through analysis, the factors pH, temperature, NO_3^- - N, PO_4^{3-} - P and S^{2-} were all affected by two or more PCs, these factors all affected PCs from weak correlation to medium. The factors TSS, BOD, NH_4^+ - N were affected by 1 PC at a weak correlation. Only coliforms are affected by 1 PC on average. In general, all environmental components have an impact on urban wastewater quality in Vinh Long province and should continue to be included in the monitoring program to monitor regional wastewater quality.

Table 3. Indicators that mainly affect urban wastewater quality

Variable	PC1	PC2	PC3	PC4	PC5
pH	-0.014	0.442	0.507	0.565	0.129
Temp.	-0.182	-0.439	0.274	0.439	-0.54
TSS	0.463	-0.129	0.202	0.007	-0.191
BOD_5	0.473	-0.108	0.198	0.181	0.193
NH4	0.466	-0.081	0.103	0.043	0.237
NO_3^-	0.42	-0.089	-0.414	0.185	0.13
PO_4^{3-}	0.306	0.262	0.336	-0.544	-0.514
S^{2-}	0.2	0.293	-0.54	0.349	-0.529
Coliform	0.041	-0.644	0.023	-0.037	-0.035
Eigenvalues	3.35	1.93	1.31	0.68	0.66
%Variation	37.2	21.4	14.5	7.6	7.3
Cum.%Variation	37.2	58.7	73.2	80.7	88.1

3.4. Classification of urban wastewater quality in Vinh Long province

CA is generated from wastewater quality data with the value of nine parameters to analyze the spatial similarity of monitoring locations. According to Figure 5, urban wastewater quality in Vinh Long province was divided into two groups of similar wastewater quality (black line, x = 0.6). Group I includes three monitoring locations (U2, U3, U15) and group II includes the remaining 19 monitoring locations (U1, U4, U5, U6, U7, U8, U9, U10, U11, U12, U13, U14, U16, U17, U18, U19, U20, U21, U22). In group II, most environmental components

in wastewater were higher than that in group I, except for coliform in group I which was 3.66 times higher than in group II (Tab. 4). In more detail, CA analysis grouped 22 monitoring locations into 4 groups of similar wastewater quality (red line, x = 0.4) with group I (U2), group II (U3, U15), group III (U12, U17, U18, U22) and group IV are the remaining monitoring sites. Group I had the highest coliform density of all wastewater groups with 130,000 MPN/100 mL and pH in this group was below 7.00. According to Pomeroy and Bowlus (1946), the optimal pH value for the formation of H_2S gas is 7.5 - 8.0; thus, the content of S^{2-} in group I was lower than that of the others (Tab. 4). Group I showed microbial contamination. Group II organic matters and nutrients were almost lower than the other groups, but the coliform density was only lower than that in group I. Group III had the lowest coliform density (Tab. 4). Group IV had the highest concentration of organic matters and nutrients along with suitable pH and temperature values to form H_2S gas, so S^{2-} in this group was also the highest (Tab. 4).

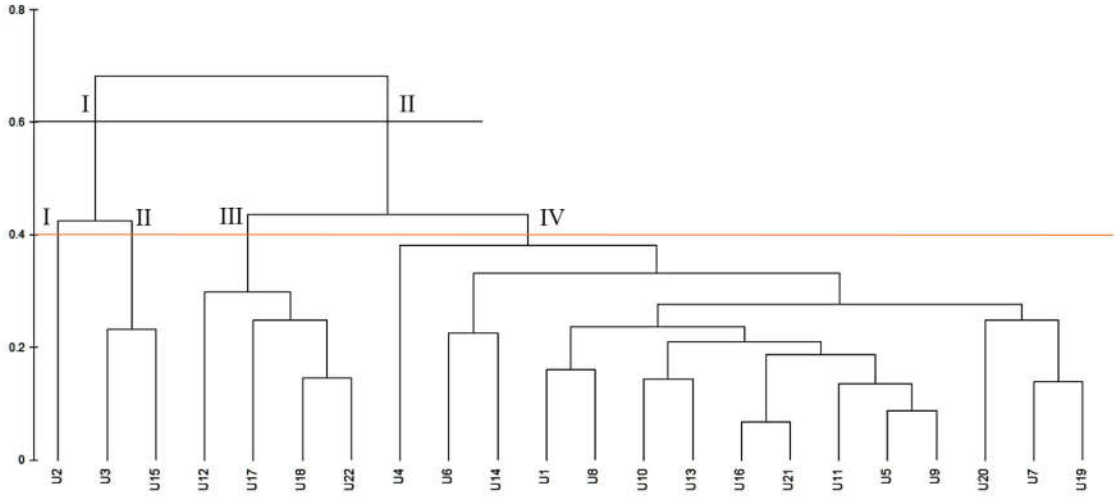

Figure 5: Urban wastewater quality cluster analysis

Table 4. Characteristics of wastewater groups through cluster analysis

	X=0.6		X=0.4				
Parameter	**Group I**	**Group II**	**Group I**	**Group II**	**Group III**	**Group IV**	**QCVN 14**
pH	7.16	7.49	6.90	7.29	7.59	7.46	5.0-9.0
Temp.	31.90	30.31	32.40	31.65	30.60	30.23	-
TSS	57.67	76.47	87.00	43.00	51.75	83.07	50
BOD_5	52.33	84.61	84.00	36.50	49.98	93.84	30
NH4	30.87	42.29	37.20	27.70	36.80	43.76	5
NO_3^-	7.32	8.40	7.56	7.20	6.96	8.78	30
PO_4^{3-}	10.13	25.24	9.30	10.55	29.28	24.16	6
S^{2-}	3.82	6.70	3.28	4.09	5.84	6.93	1
Coliform	58666.67	16015.79	130000.00	23000.00	8350.00	18060.00	3000

4. Conclusions

The analysis results showed that the urban wastewater of Vinh Long province has a high content of organic matters, nutrients, microorganisms. BOD at 21/22 monitoring locations exceeded the permitted standard from 1.06 - 5.93 times. The concentration of PO_4^{3-} - P at 21/22 monitoring points exceeded the prescribed threshold from 1.55 - 7.65 times. TSS concentration at 16/22 monitoring stations exceeded the standard from 1.02 - 3.72 times. The concentrations of NH_4^+ - N, S^{2-} and coliform at all monitoring points exceeded the allowable limit QCVN 14:2008/BTNMT column A. pH and NO_3^- - N were within the allowable limits. The temperature in domestic wastewater is suitable for the growth of organisms. Correlation analysis showed that organic matters and nutrients are linearly correlated with each other from moderate to good. Principal component analysis (PCA) showed that the observed environmental components all contribute to the influence of wastewater quality in the study area from a weak to moderate level, influenced by different sources (i.e. industries, households, production and business establishments, markets operating in the study area as well as rainwater runoff). Cluster analysis represents each group at each level of contamination with the content of microorganisms, organic matter, nutrients present in the urban wastewater. The results presented that the wastewater at the study sites has a high concentration of pollutants and pose potential risk to ecosystems and human health. The wastewater should be collected and treated through roughly.

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