Risks assessment of water pollution at estuary area of red river (Vietnam)

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Abstract. This paper determined the state of the water quality in the estuary area of the Red River (Vietnam) and estimated the risk of population health from water pollution. When assessing the merits and demerits of each method, it was established that the generalized indicator of water quality (TWQI), which was first proposed by Pham N.H. in 2011 was more preferable for the conditions of Vietnam. In this paper, the author constructed the formulas for calculating the weight coefficients of the indicators in the classification of water quality in case of 10 selected parameters. Based on the results of the TWQI calculation, it was noted that the quality of surface water in the estuary area of the Red River during the flood of 2016 was in the IIId class, i.e. respectively, the water was contaminated. On the whole territory of the estuary area the average total carcinogenic risk from surface water contamination was 53.10-4, it means that there were 53 additional cases of malignant growth per 10,000 people. The increase in the risk to population health was inversely proportional to the increase in the value of TWQI. The greatest risk was observed in Hanoi and its suburbs, located in close proximity to large industrial areas in the north of Vietnam.

1. Introduction

The Red River is the largest river in Vietnam. In its basin are the largest industrial centers, settlements and cities in the north of Vietnam. A significant part of the organic and inorganic substances brought by the watercourses to the delta is deposited in the estuary area of the Red River. Due to the heavy anthropogenic load, the problem of pollution in the estuary area of the Red river becomes topically.

At present, in many countries of the world and in Vietnam, in particular, integral indicators of water quality have been used by various methods related to the 3 main groups [1-3].

- Water quality indicators without a weighting factor;
- Water quality indicators with a weighting factor of each indicator (WQI);
- Generalized water quality indicators with a weighting factor.

Each method of determining the integral indicator has advantages and disadvantages. To analyze these methods, 3 indicators from the above groups were compared in this paper.

A new generalized indicator of water quality (TWQI) was first proposed by Pham N.H. in 2011. This indicator largely eliminates the shortcomings of the integrated water quality assessment [1,3].

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Thus, the purpose of the research was to assess the quality of surface water in the estuary area of the Red River (Vietnam) by the method of TWQI and to determine the public health risk from water pollution

2. Research area and methods

The estuary area of the Red River is one of the largest estuary areas in Vietnam. Today it consists of the delta (14.6 thousand km^2) and the estuary seashore (1300 km^2) [4-6].

The top of the estuary area of the Red River, to which tides and storm surges extend, is 210 km from the sea, slightly below the mouth of the tributaries Da (right) and Lo (left). The top of the present delta is located 25 km below the top of the estuary area, here to the right of the river departs the first delta branch - Day [4,7]. The main branch, like the entire river, is called the Red (Hong Ha). The observation was conducted at 35 stations on delta waterways and the seaside in 2016 (Figure 1).

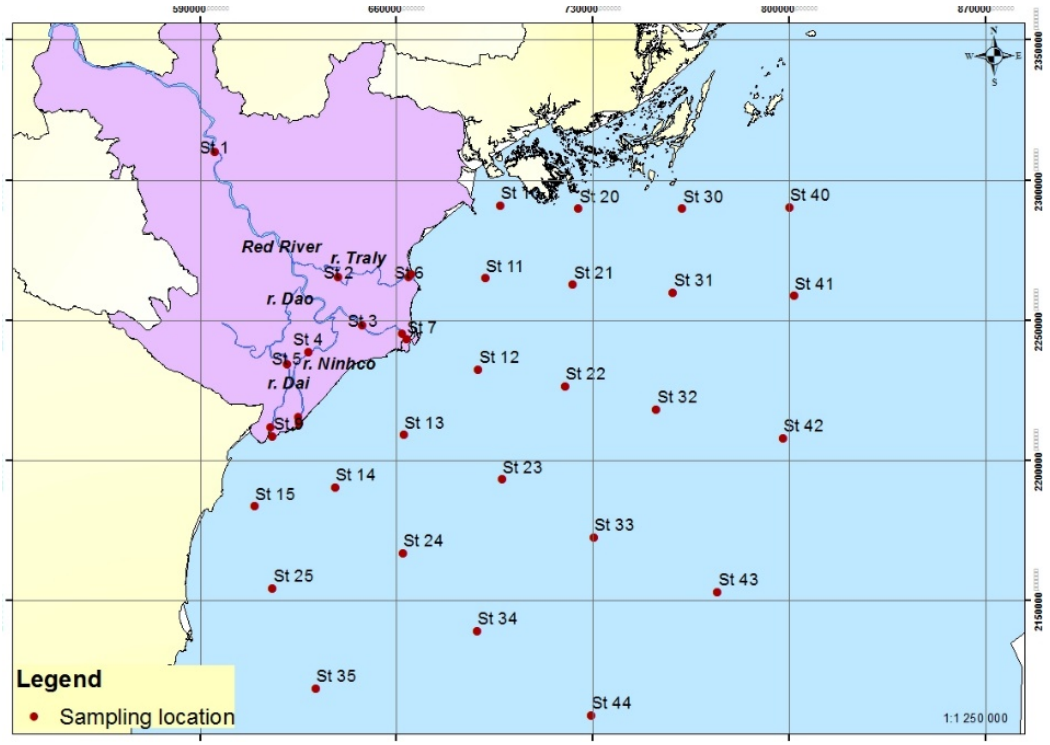


Figure 1. . Map-scheme of the estuary area of the Red River.

When applying WQI in Vietnam, it was adjusted. Pham N.H. and others [1] proposed a modified general water quality index (TWQI). The process of determining TWQI in the estuary area of the Red River can be divided into 4 stages [1,3]:

Step 1. Selection of water quality parameters.

At this stage, the research was carried out in the estuary area of the Red River during the flood period of 2016. 10 parameters were used in the research: 9 hydrochemical parameters - pH, dissolved oxygen in water (DO), BOD5, NO3-, PO43-, dry residue, Pb, Cd, Fe and the amount of E. coli [2,3,8].

Step 2. Determination of the individual quality indicators value for each ingredient (parameter).

The calculation was based on the formula [9-12]:

$$q_i = \frac{C_i}{C_0} \quad (1)$$

where, C_i – concentration of the i-th ingredient, *PDKi* - the maximum permissible concentration of the *i*-th ingredient.

Step 3. Calculation of the weight coefficients value of the Wi indicator according to the formula

$$W_i = \frac{W'_i}{\sum_{i=1}^{n} W'_i} \quad (2)$$

where, W_i - the weight coefficient of the indicator, W_i' – the partial weight coefficient of the indicator, n – the number of selected parameters.

Step 4. Calculation of the generalized indicator for water quality assessment in the estuary area of the Red River. The generalized indicator of water quality was calculated by the formula [1,3]:

$$TWQI = 100 \cdot \left(1 - \frac{\sum_{i=1}^{k} W_i (q_i - 1)}{\sum_{i=1}^{m_1} W_i q_i + \sum_{i=1}^{m_2} W_i (1 - q_i) + \sum_{i=1}^{k} W_i (q_i - 1)} \right) \quad (3)$$

where, W_i - the weight coefficient of the indicator, q_i – a particular quality indicator, m_1, m_2, k – the number of parameters respectively having qi is equal to less than and greater than 1.

Step 5. Create a water quality classification and water quality assessment and water quality assessment

From (3) it was noted that: the limit of water quality classes in the classification depended on the relation $\frac{k}{n}$ and was determined by the formula [1]:

$$T_k = 100 \times \left(1 - \frac{k}{n} \right) \quad (4)$$

where, k – the number of parameters having qi is greater than 1, n – the number of selected parameters.

To determine the change in water quality in the estuary area of the Red River by the time and sampling points, the same frequency of water contamination level f_{K3ij} is conducted. The value f_{K3ij} was calculated as a percentage of the number of samples, whose surface waters are in the same contamination class to the total number of sampling samples.

Calculations of the carcinogenic and non-carcinogenic risk to the health of the population at the estuary area of the Red River from the contamination of surface waters by chemical substances were carried out according to the formulas of the "Manual on Risk Assessment ..." [13-16]

3. Results and discussion

Using the method of Pham N.H. with 10 selected parameters: pH, dissolved oxygen (DO), BOD5, NO3-, PO43-, dry residue, Pb, Cd, Fe, the amount of E. coli indicator TWQI was determined for assessing water quality in the estuary area of the Red River.

Values of weight coefficients of indicators and particular water quality indicators were calculated for drinking purposes (A) and fishery purposes (B) [16,17]. The result of the determination on the basis of the TWQI for the 1st water sample and the weight coefficients values of WQI, which was developed by the National Sanitary Fund of the United States (W_i *) were presented in Table 1.

As can be seen from Table 1, the values of the weights coefficients of the indicators for the TWQI and WQI, developed by the National Sanitary Fund of the United States (W_i *) differ slightly. Since the values of the weight coefficients indicators for the WQI are the same for reservoirs of different purposes, and the values of the weight coefficients of the indicators for TWQI for drinking and fishery purposes are different [3]. The values of the weight coefficients of the indicators for the TWQI depend

on the relation of the concentration of the indicators to their C_0, i.e. the method of determining the value of the weight coefficients of the indicators according to the TWQI has a scientific basis and is not subjective [18-20].

Table 1. The weight coefficients of the indicators of TWQI and WQI.

No.	Parameters	C_i	C_0 (A)	C_0 (B)	q_i (A)	q_i (B)	W_i' (A)	W_i (A)	W_i' (B)	W_i (B)	W_i^*
1	pH	8,1	6-8,5	5,5-9	0,84	0,74	1,20	0,09	0,86	0,11	0,11
2	DO	6,8	5	4	0,74	0,59	1,11	0,08	0,89	0,11	0,17
3	BOD_5	8	6	15	1,33	0,53	1,75	0,13	0,70	0,09	0,11
4	NO_3^-	0,58	5	10	0,12	0,06	1,50	0,11	0,75	0,09	0,1
5	PO_4^{3-}	0,1	0,2	0,3	0,50	0,33	1,25	0,09	0,83	0,10	0,1
6	Dry residue	113	30	50	3,77	2,26	1,33	0,10	0,80	0,10	0,07
7	Pb	0,04	0,02	0,05	2,00	0,80	1,75	0,13	0,70	0,09	-
8	Cd	0,008	0,005	0,01	1,60	0,80	1,50	0,11	0,75	0,09	-
9	Fe	6,8	1	1,5	6,80	4,53	1,25	0,09	0,83	0,10	-
10	E. coli	2400	5000	7500	0,48	0,32	1,25	0,09	0,83	0,10	0,16

The definition of the water quality classification in the TWQI was determined by the formula (4). The resulting classification was proposed in Table 2:

Table 2. Classification of water quality in the TWQI.

Value of TWQI	Water quality class	Water quality assessment (characteristic)
$91 < TWQI \leq 100$	I	Conditionally pure
$71 < TWQI \leq 90$	II	Slightly contaminated
$51 < TWQI \leq 70$	III	Contaminated
$26 < TWQI \leq 50$	IV	Dirty
$0 < TWQI \leq 25$	V	Extremely dirty

The map of the water quality state in the estuary area of the Red River in accordance with TWQI was shown in Figure 2.

According to the results, the quality of surface waters in the 1st sampling range was related to the III-class, i.e. the water was contaminated and could not be used for drinking water.

As a result of the calculation of the recurrence frequency of water pollution, it was noted that: surface water in most stations sampling in the estuary area of the Red River was contaminated (the recurrence frequency of the III-class water quality was 75%). Due to the increase in the concentrations of pollutants during the flood period, the frequency of the IV-grade of water quality was 16.7%, i.e. the water quality in 16.7% of the investigated site was contaminated.

Based on the results of the calculations, the total carcinogenic risk from contamination of surface water was 53.10^{-4}, it means that 53 additional cases of malignant growth appear on the estuary area of the red River with a population of 10000 people. A high degree of risk was to Hanoi as a result of exposure to lead, arsenic and cadmium.

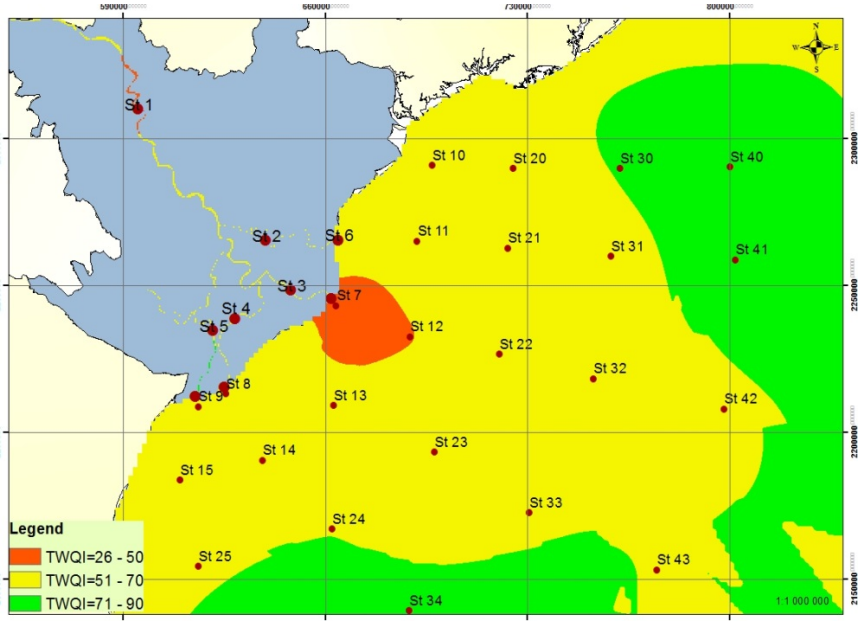


Figure 2. Map of water pollution in the estuary area of the Red River in 2016 by TWQI.

The greatest carcinogenic risk was observed as a result of lead effects, which was $2.73.10^{-2}$. This could be explained by the sewage of metallurgical enterprises at industrial centers in Viet tri, Thai Nguyen and Ha Noi.

Thus, the water in the estuary area of the Red River had an average level of risk to population health. The greatest risk was observed in Hanoi and its suburbs, located in close proximity to large industrial areas in the north of Vietnam. The increase in the risk to population health was inversely proportional to the increase in the value of TWQI, i.e. the worse the quality of water, the higher the risk to population health.

Conclusion

In the researches on assessing the quality of surface waters in the estuary area of the Red River (Vietnam), a TWQI was used with 10 selected parameters. Based on the results of the calculation, it was noted that the quality of surface water in the estuary area of the Red River during the flood of 2016 belonged to the third class - contaminated water, which was associated with an increase in population, urban development and industry in the Red River basin, especially the spread of iron deposits and development steelmaking enterprises. The water of the Red River in the estuary area could be used for fishery and other purposes of water use, except for drinking water use.

On the whole territory of the estuary area the average total carcinogenic risk from surface water contamination was 53.10-4, it means that there were 53 additional cases of malignant growth per 10,000 people.

It is necessary to organize more strict dynamic control for the content of such substances as lead, cadmium, iron, arsenic, chlorides, nitrates, nitrites and phosphorus common.

The increase in the risk to population health is inversely proportional to the increase in WQI. The greatest risk was observed in Hanoi and its suburbs, located in close proximity to large industrial areas in the north of Vietnam.

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