



## **Sources and hydro-geochemical processes controlling the concentrations of nitrogen and phosphorus nutrients in the aquatic environment of the Cau River Catchment (Vietnam) as studied by isotopic and advanced statistic techniques**

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The aim of this study is to elucidate the sources of ammonium, nitrate, and phosphate in surface water of the Cau River - the second largest catchment in the Northern Part of Vietnam in order to develop a suited strategy for controlling the eutrophication in the region. 38 surface water samples within the catchment were collected in the dry and rainy seasons in 2017 to analyze for major water quality parameters such as pH, DO, TSS, COD, BOD, NH<sub>4</sub>, NO<sub>2</sub>, NO<sub>3</sub>, PO<sub>4</sub>, Cl<sup>-</sup>, Br<sup>-</sup>, Ca<sup>2+</sup>, Fe<sup>2+</sup>, total coliform density, uranium and thorium using appropriate analytical methods. Additionally, deltaNn-15 in nitrate and in ammonium (delta15Na), oxygen-18 in nitrate (delta18On) and phosphate (delta18Op), delta2H and delta18Ow in water were determined by CF IR MS technique. It was revealed that water in upstream of the Cau River is clean relative to the National Standard of surface water class A. However, water in the middle and downstream of the River where public residences and industrial zones are dense, is being contaminated with ammonium, BOD and coliforms as the water quality indicators in that regions are exceeded the National Standards for surface water of class B. The delta15Na and deltaNn ranged from -1.10 to 16.25‰ vs. AIR, the delta18On ranged from 3 to 30‰ vs. VSMOW and delta18Op ranged from 6.0 to 16.9‰ vs. VSMOW that overlapped the isotopic signatures of several possible sources of N- and P-nutrients. The delta18Op measured for phosphate in many water samples were higher than the equilibrium values expected for the temperature range and delta18Ow in the region implying the importance of the contribution of phosphate sources having high delta18Op, e.g. from water waste. On the other hand it was also observed that the delta18Op in several water samples were lower than that calculated from the temperature range and delta18Ow indicating on-going biological activities in cleavage of the P-O bond in phosphate originated from the anthropogenic sources.

The relationship between delta15Na and delta15Nn and concentrations of ammonium and nitrate revealed that denitrification and evaporation seem to be important processes controlling the concentrations of the two ions in the aquatic environment of the catchment. The low concentrations of phosphate in water was attributed to the precipitation of apatite at elevated concentrations of calcium in water as well as adsorption of dissolved phosphate ions onto surface of suspended matters (TSS) in the water column.

The computer code US EPA PFM 5.0 based on the "Receptor" model and "Positive Matrix Factorization, PMF" approach has apportioned 3 sources of nitrate and phosphate release in the region as follows: i) from agricultural activities that use inorganic (N-P-K) fertilizer; ii) from untreated domestic water waste; and iii) from atmospheric deposition. The contribution of each individual source varies by seasons.