Nitrate Contamination in Groundwater in Sugarcane Field, Suphan Buri Province, Thailand

Sorranat Ratchawang, Srilert Chotpantarat

Abstract: ***Due to the intensive agricultural activities, nitrate (NO_3^-) contamination is one of the problems for groundwater resource protection in Thailand, well-known as an agricultural country. Nitrate has no taste and odorless in water and can be detected by chemical test only. It was reported that Suphan Buri is considered as one of the provinces with intensive agricultural areas, especially sugarcane fields. In this study, NO_3^- concentrations were measured in 8 groundwater wells located in sugarcane fields in this province. NO_3^- concentration in the area was ranged from 2.39 to 68.19 mg/L with an average concentration of 30.49 mg/L which was a bit higher than the previous study by Department of Groundwater Resources or DGR, which found that NO_3^- was in the range of 0.53-66 mg/L with an average concentration of 24.15 mg/L. Moreover, there were two groundwater samples, which were found NO_3^- concentration higher than the Thailand groundwater drinking standard (45 mg/L). As a result, NO_3^- contaminated groundwater is common in the area with intensive use of nitrogen fertilizers and agricultural activities. People especially infants and babies living around the area have a chance to have health risks from NO_3^- by drinking and using water from the wells.***

Index Terms**:** ***Keywords: Nitrate, Groundwater, Nitrogen Fertilizer, Agricultural Area.***

I. INTRODUCTION

In a recent year, more than 1.1 worldwild billion people lack of safe drinking water [1]. In asia, this problem can cause over 500,000 infant deaths per year. Water quality around the agricultural areas has deteriorated by the leaching of fertilizers and pesticides due to the intensive agricultural practices [2]. Nitrate, considered as common agricultural contaminant, leading toxic algal blooms, decreasing dissolved oxygen (DO) leading to loss of fish and coral species in aquatic systems. It is found that NO_3^- lost from farm soils and eventually accumulates in groundwater which people use for drinking water due to intensive use of nitrogen fertilizers [3]-[5]. It is also found that drinking water with high NO_3^- concentration can cause methemoglobinemia infants and human birth defects [6], [7]. Nitrate (NO_3^-) is a chemical compound with one part nitrogen and three parts oxygen. This common form of nitrogen is usually found in water. In general, occurring concentrations of nitrate in groundwater are naturally less than 2 mg/L originated from natural sources such as decaying plant materials, atmospheric deposition, and inorganic fertilizers.

In Asia, nitrogen fertilizer application has increased dramatically approximately 17-fold in the last 40 years [8]. As comparing to other countries, it was found that average fertilizer application rates of Thailand are low (Thailand: 101 kg/ha; USA: 113 kg/ha; China: 321 kg/ha). Although an average fertilizer usage is low in Thailand, there is some evidence of increased consumption from an intensive agricultural system. Thai farmer applied nitrogen fertilizers with the rates of 1000 kgN/ha/yr in asparagus field in Nakorn Pathom province. It also was found that most of the applied nitrogen leached to soil and groundwater [9].

Nitrate in water is tasteless and odorless and can only be detected through chemical test. Due to the harmful effects of NO_3^- on water quality and human health, it has been concerned as international problem which require science-based asssessment [10]. In Thailand, it has been reported that NO_3^- concentration was found in surface water and shallow groundwater wells in Suphan Buri and Kanchanaburi province, which were located in the central plain of Thailand. Tirado [8] reported that 6 samples of 21 groundwater samples collected in these two provinces has greater NO_3^- concentration than the drinking water standard promulgated by World Health Organization (WHO) ($\leq$50 mg/L NO_3^-). Nitrate concentration was also found in groundwater collected from agricultural areas in Chiang Mai, located in the northern of Thailand, with the high concentration (290 mg/L) [11].

Monitoring for NO_3^- in groundwater is very important for protecting groundwater resources in Thailand. Suphanburi province, has intensive agricultural areas and leaks from household sewage systems that can increase NO_3^- concentration detection in groundwater. Therefore, the objectives of this study were to investigate the NO_3^- level in several sugarcane fields, construct the NO_3^- distribution and finally compare with the NO_3^- concentration derived from the previous work by Department of Groundwater Resources [12].

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II. MATERIALS AND METHODS

A. Study Area

The evaluation of NO_3^- concentration of this study was performed in sugarcane fields where is one of the most agricultural product growth in the area, located in U-thong and Song Phi Nong districts, Suphanburi province. Topography of the province is mainly mountainous area in the west and floodplain in the east. It has been reported that the average annual precipitation and average annual temperature are 975.4 mm and 28.1ºC. Most of the study area is occupied by agricultural land. The major field crops are rice and sugarcane, more than 50% of the study area. It has been reported that the area has several consolidated and unconsolidated aquifer. There are gravel, sand, and clay of deltaic plains, alluvial plains, and rolling terraces [13]. In general, the groundwater flow conforms the topographic elevation from high to low elevation. Nitrate concentration were tested from 8 domestic groundwater wells located in the study area. Moreover, water samples were analyzed for dissolved oxygen (DO) and pH.

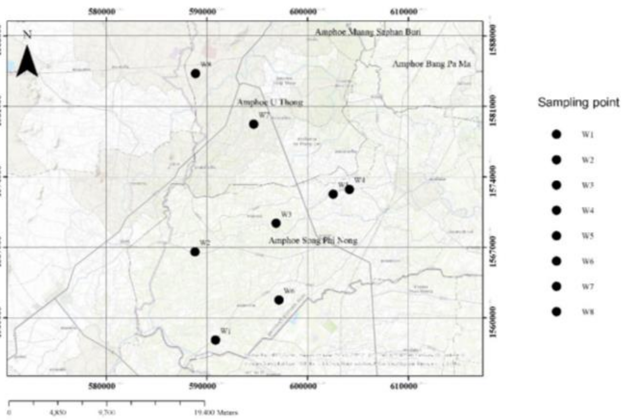

Fig. 1. Groundwater sampling wells in U-thong and Song Phi Nong districts, Suphan Buri province[12]

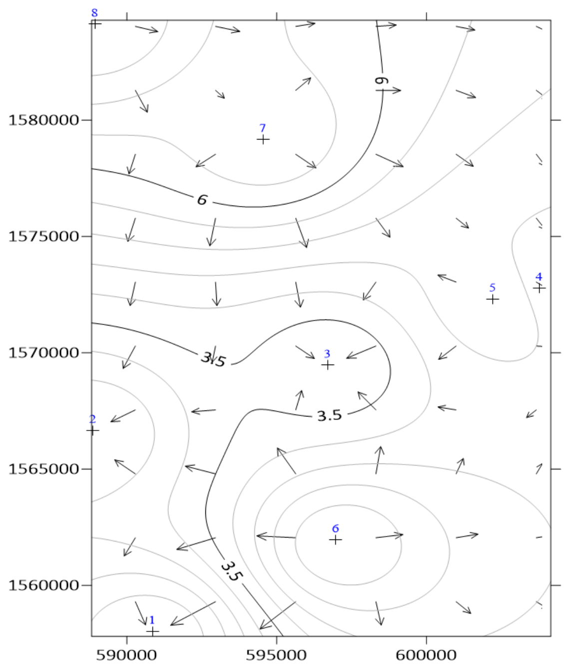

Fig. 2. Groundwater flow direction

B. Groundwater Sampling and Analytical Method

In this study, groundwater samples were collected from groundwater wells from 8 different areas in sugarcane field in U-thong and Song Phi Nong districts, Suphan Buri province, Thailand. Most of the wells were groundwater wells from farms and also nearby house with concrete casing for preventing from water pollution. These groundwater sources are mostly applied for agriculture, water use and consumption in households. The sampling bailer with rope was dropped into shallow groundwater well until it was full. Then, the bailer was pulled from the well and poured in the bucket. For deep groundwater wells, there was pumping system installed for groundwater consumption. Before collected, groundwater was pumped out for approximately 15 minutes (i.e. hand or electric pump). Groundwater samples were measured for pH and dissolved oxygen (DO) on site. Next, the samples were stored in a cool box prior to transportation.

For NO_3^- concentration detection, the samples were acidified by H_2SO_4 for making pH lower than 2 and measured NO_3^- using Ion Chromatography (IC) with the detection limit of 0.1 mg/L in duplicate.

C. NO_3^- concentration in groundwater data

The data of NO3- concentration contaminating in groundwater was derived from DGR [12]. In this study, NO3- concentration was classified into three levels as follows: the background level (< 10 mg/L NO3-), the acceptable level (10-45 mg/L NO3-), and more than the acceptable level (>45 mg/L NO3-).

III. RESULTS AND DISCUSSIONS

A. Nitrate Concentration in Groundwater

In this study area, NO_3^- concentration found in groundwater samples was ranged from 2.39-68.19 mg/L with an average concentration of 30.49 mg/L, and the median of 35.59 mg/L. The result indicated that there were two samples with NO_3^- concentration, which were higher than Thailand standard for drinking water (45 mg/L NO_3^-). One of them was higher than WHO safety limit (50 mg/L). The result also showed that 25% of the samples had NO_3^- level exceeding the acceptable level, 35% of the samples having NO_3^- level within the acceptable level, and 35% of the samples having NO_3^- level under the background level . In 2009, NO_3^- concentration in this area was in the range of 0.53-66 mg/L with an average of 24.15 mg/L, and the median of 12.80 mg/L [12].

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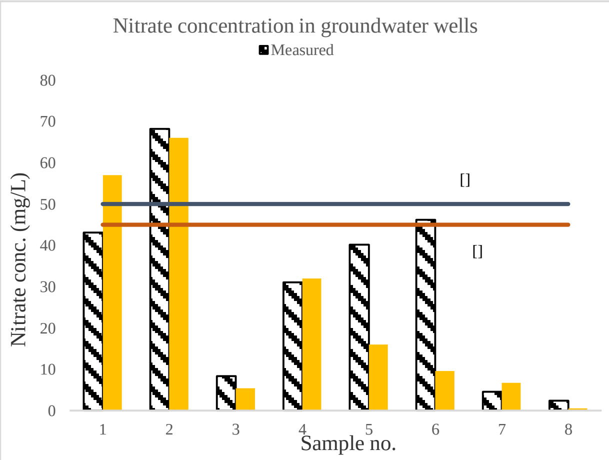

Fig. 3. NO_3^- concentration in groundwater samples during July 2018 (this study) and 2009 [12] in the study area

Table I: Chemical properties and groundwater levels of the eight groundwater wells during July 2018

Sample	**Nitrate (mg/L)**	**pH**	**DO (mg/L)**	**Depth to ground Water (m)**	**Ground Water level (m, asl)**
1	43.11	7.65	1.97	0.50	17.35
2	**68.19**	7.72	1.65	0.50	12.66
3	8.34	7.97	0.66	1.00	3.87
4	31.03	7.99	4.34	1.30	-2.10
5	40.15	7.12	1.63	0.65	6.42
6	**46.19**	7.8	2.9	0.90	4.01
7	4.53	7.23	1.96	2.50	12.25
8	2.39	7.75	2.03	N/A	N/A
Mean	30.49	7.65	2.14	1.05	10.27
SD	22.01	0.30	1.01	0.65	8.74
Max.	68.19	7.99	4.34	2.50	27.69
Min.	2.39	7.12	0.66	0.50	-2.10

From Table I, some groundwater samples had low NO_3^- concentration with a low DO. It can be reported that NO_3^- in the samples was reduced by microbe under hypoxic conditions (i.e. absence of DO) to N_2 via N_2O, also known as a denitrification process. There were some studies found denitrification in subsurface environment [14]-[18].

B. The Distribution of NO_3^- in the Study Area

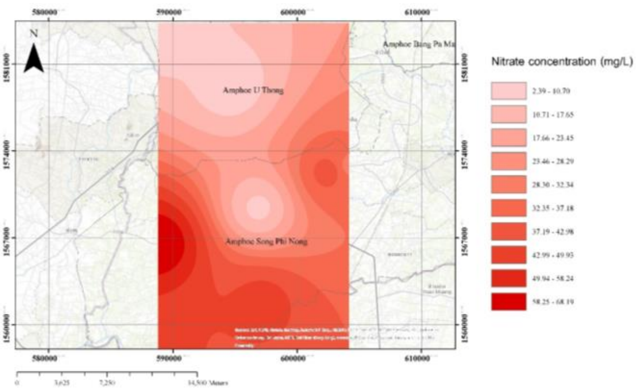

Fig. 4. the distribution of NO_3^- in groundwater samples during July 2018

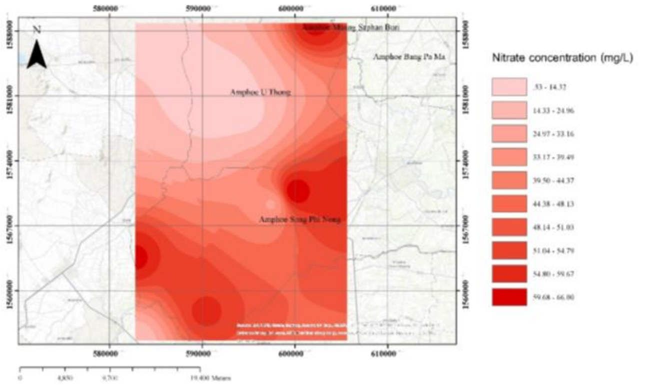

Fig. 5. the distribution of NO_3^- in groundwater wells collected during 2009 [12]

As seen from Fig.s 4 and 5, NO_3^- concentrations were high in the area with shallow depth to groundwter level. It implied that NO_3^- easily leached from the surface to groundwater [19], [20]. Moreover, for groundwater wells with deeper groundwater level, NO_3^- can potentially be sorbed by soils and microbial activity (denitrification) [5], [14]. It was found that groundwater wells with low groundwater elevation in the agricultural zone were reported to have high NO_3^- concentration due to impact of an intensive agricultural practice [21]. Considering soil property, such as hydraulic conductivity, plays an important role for leaching of nitrate concentration to groundwater [5]. It was found that the values of hydraulic conductivity of each soil in the study area were ranged from 0-5.0 m/day, indicating a high potential of NO_3^- leaching in the area [12]. In other hand, some areas with lower hydraulic conductivity showed lower NO_3^- contaminating in groundwater. Additionally, NO_3^- behaves conservatively under aerobic conditions [14].

IV. CONCLUSIONS

Nitrate contamination was one of the main problems to be concerned since the intensive use of fertilizers in Thailand, which is agricultural country. It can be detected by the chemical analysis. Suphan Buri province is considered as one of the provinces with intensive agricultural activity. One of the agricultural products mainly is sugarcane. Therefore, NO_3^- concentration was measured in 8 different groundwater wells in sugarcane field in this province. As a result, NO_3^- concentration in the area was from 2.39-68.19 mg/L with the average concentration of 30.49 mg/L and the median of 35.59 mg/L. Two of the groundwater samples had NO_3^- concentration which was greater than the Thailand standard (45 mg/L), and one of them exceeded WHO safety limit (50 mg/L).

As a result, NO_3^- contaminated groundwater is common in the area with intensive use of nitrogen fertilizers and agricultural activities. People especially infants and babies living around the area are the most vulnerable to health risks from nitrate by drinking and using water from the wells.

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Thus, it is recommended that nitrogen management should be implemented in the study area although most of the samples did not exceed groundwater standard for NO_3^- .

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