IMPACT OF TRADITIONAL HANDICRAFT ON SURFACE AND GROUNDWATER QUALITY: A CASE STUDY IN SON DONG VILLAGE, VIETNAM

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SUMMARY
This study aims to analyze spatial and temporal changes of surface and groundwater quality from March to December 2019, in Son Dong commune, Hoai Duc district, Hanoi. A number of physicochemical parameters were sampled for analysis to give quantitative assessments, and spatial distribution as well as temporal variation were performed. Surface water samples were collected along the commune canal route at different depths (20 and 30 cm) and groundwater samples were taken from drill-wells. From March to December 2019, 10 groundwater samples and 5 surface water samples were collected. 7 surface water parameters including: Fe, NH_4^+, Mn, NO_2^-, Cu, TSS and pH, 8 groundwater parameters including: Fe, NH_4^+, Mn, NO_2^-, Cu, pH, TDS, and hardness were analyzed. Based on analyzed water quality findings, both surface and groundwater in Son Dong are heavily polluted compared to the standard of Ministry of Natural Resources and Environment. The indicators of pH, TSS, TDS and NO_2^-, were almost unchanged and lower than the permitted value. Water quality in the study area is contaminated with heavy metals. The analysis results of NH_4^+, Cu, Fe parameters are higher than the permitted standards QCVN 08: 2015/TNMT for surface water and 09: 2015/TNMT for groundwater. The groundwater quality index (GWQI) was calculated based on the analyzed criteria is higher than 200, which means it is not suitable for drinking. The most polluted areas are in the south and northwest of Son Dong commune. Therefore, in the face of poor water quality, it is necessary to have some suitable solutions to improve water quality in the study area.
Keywords: Groundwater, GWQI, Son Dong commune, surface water, traditional handicraft, water quality.

1. INTRODUCTION

Vietnam has a long tradition of handicraft, with the oldest village in the North is reported to age at least 1200 years old. According to the Vietnam Craft Villages Association, Vietnam has 2,790 craft villages, particularly in Hanoi there are 1,160 craft villages (VUSTA, 2010). Handicraft has played a cultural and economical role in the life of many ethnic communities across the globe (Connelly-Kirch, 1982; D.Nason, 1984; Soukhathammavong & Park, 2019). Many research has found the increasing demand in purchasing authentic and tradition product ("Food Souvenirs: Buying Behaviour of Tourists in Norway," 2016; Lin & Wang, 2012), hence the continuity, conservation, and even evolution of creation of numerous handicraft production.

Vietnam's craft villages contain many family-based businesses that specialize in traditional handicrafts as well as newer commodities such as recycled products. The economic benefits brought by recent and rapid growth in the number and size of craft villages are, however, diminished by water pollution and risks to health, agriculture, and other livelihood activities since. While these villages ensure the occupation for 30% of rural work force with significant rise of income, there has been rising concern over the production of handicraft villages because the techniques applied are usually out of date, with unproper or even lack of waste treatment system ("Mối lo ô nhiễm làng nghề," n.d.). The production is usually small in scale (family owned), scattered, and interwoven with the living area. The pollutants released spread in a wide spectrum and has impacts in many different environments: nutrient-rich water bodies due to waste from food production, thermal pollution, air pollution due to heavy metal dust. These phenomena usually carry the typical features of Vietnamese local products such as noodles, ceramics, silk, etc, which have impacts to local water footprint and quality (Liping Ye et al., 2018; Yiduo Yang et al., 2020).

In Vietnam, the impacts of handicraft production to water quality are being researched in some of the traditional handicraft villages in the North of Vietnam (Thi Hue, 2011; Thi

Tham, 2011; Thi Thu Tra et al., n.d.; Van Cuong et al., 2015). However, most of these studies focus on the quality of surface water, not to mention that the correlation between the production process and the water quality is under-researched. Son Dong is a long-existed handicraft village producing copper and wooden products in Hoai Duc district, Hanoi. With a population of 9,300 people and high density, water quality issues are a serious concern of indigenous peoples. Accordingly, this study aimed to evaluate the water quality in both surface and ground water of Son Dong commune, a place of a traditional handicraft village for over 600 years.

2. RESEARCH METHODOLOGY

Study site:

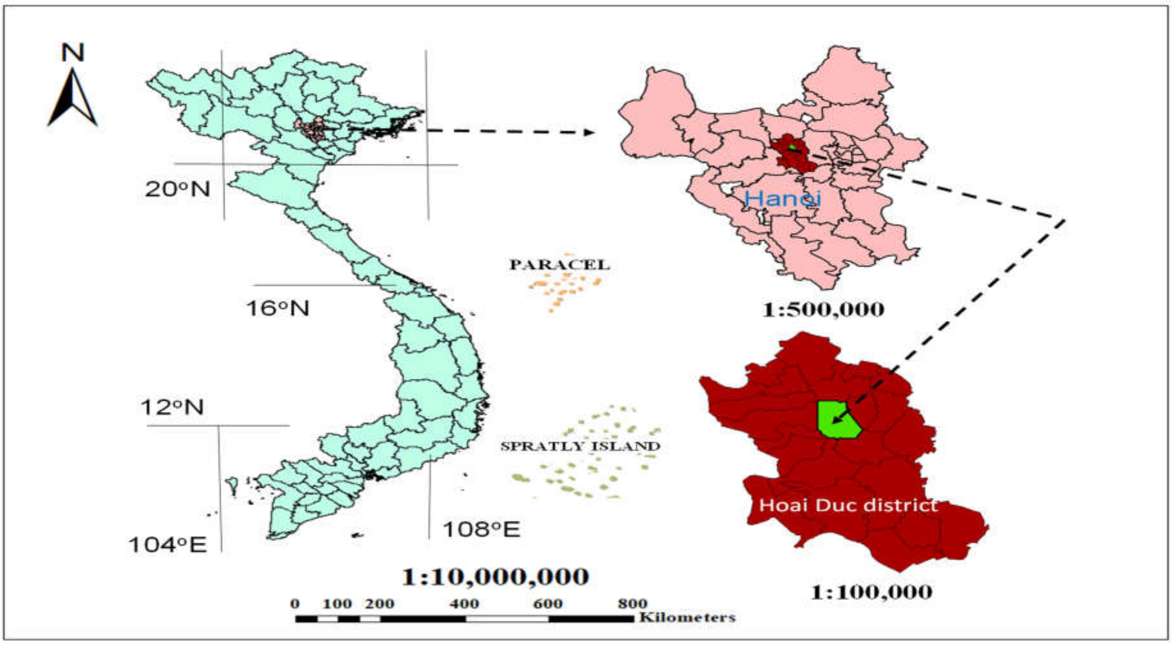

Figure 1. Map of Son Dong commune

Son Dong is a commune under the administration of Hoai Duc district, located in the West of the capital. Its coordination is around 21° 02′ 24″ N 105° 25′ 48″ E, surrounded by six other communes (Duc Giang commune in the north, Yen So, Dac So commune in the West, Song Phuong and Lai Yen commune in the Southern, Kim Chung commune in the East). Covering the area of roughly 328,000 ha on the transition zone of mountain and the Red river delta, this commune has many cultural, religious and historical sites. For such reason, there are many traditional villages in several fields that have long-lasting history in this region. In the proximity with Son Dong handicraft village (which focuses on building and painting spiritual and religious products), there are 4 other handicraft villages: a food processing village and a noodle making village in Duc Giang commune, an agricultural products processing village in Cat Que commune, and a picture making village in Van Canh commune (Fig.1). Son Dong has a dense population, most of which are workers in local companies and industrial zones, and craftsmen. Handicraft has become a major livelihood of many citizens in Son Dong because its contribution to the economy of the region is undeniable. This has been the mother land for the carpenters who specified in creating Buddhist statues and relating artifacts for at least 800 years. This has been not solely a livelihood, but also a historical and cultural symbol (Làng Nghề Truyền Thống Sơn Đồng - Hoài Đức, Hà Nội, n.d.).

Son Dong has a typical monsoon climate of Northern Vietnam. The annual rainfall is 1800 mm, mainly distributed from April to October, with the humidity is 76%. Surface water of Son Dong depends notably on Day and Nhue river pumping through the pumping stations and canal systems. Apart from that, there are also ponds and lakes located sporadically in the region. Ground water depth is quite stable at 5 to 7 meters.

Son Dong is located on the downstream area of Cat Que and Duc Giang commune. There is another small manmade canal branching from this stream aids in irrigation. Most of the densely populated village (inhabiting crafting households) in Son Dong gather in the center of this region and in proximity with the surface water. On the upper segment of the bigger river (within the border of Son Dong), there is a trash gathering spot.

Method:

Sampling method

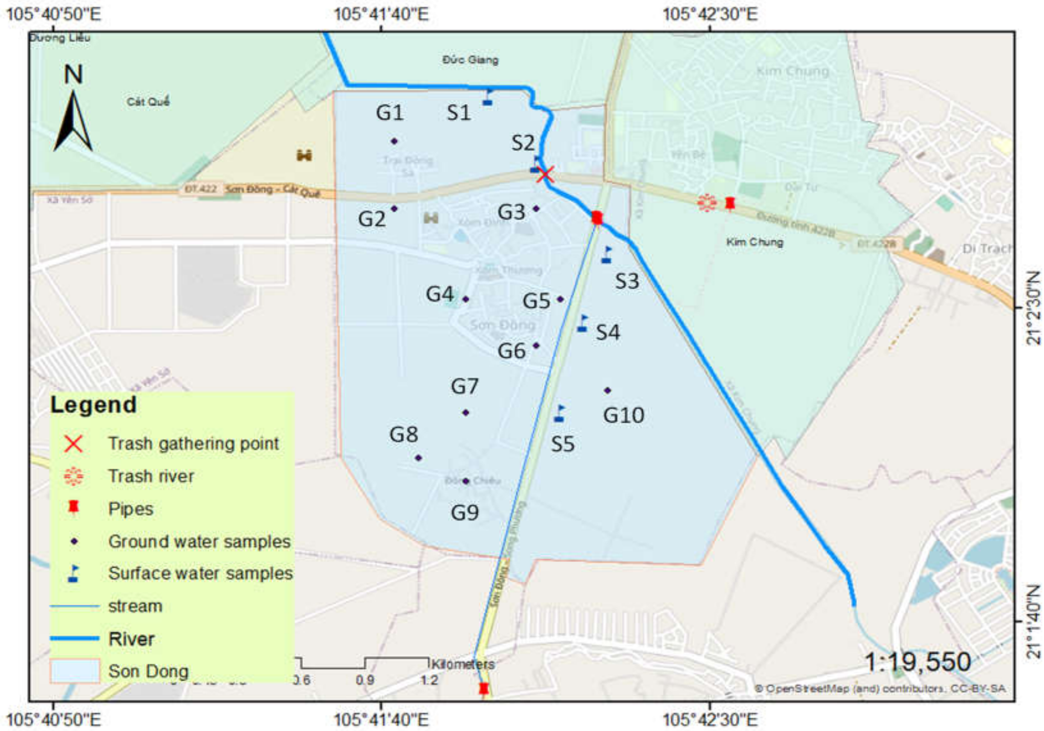

Figure 2. Sampling map

Surface was collected from March to December 2019 (except May) and groundwater samples was collected from March to December 2019 at fixed locations. There were 10 groundwater sampling locations (which are at the wells of households doing handicraft) chosen from five groups (the smallest administrative level) in Son Dong, in each group, there are two houses chosen randomly. The water samples were taken off from the wells at 40 m deep. In the meantime, five samples of surface water were randomly taken around the Cong Dam River (fig.2). The water samples were taken at the depth of 20 to 30 cm from the surface, with 1.5 to 2 meters from the riverbank.

- Examining water quality in laboratory

In this research, both surface water and groundwater quality were analyzed in the laboratory. The water indices used to analyze groundwater and surface water quality are among the most common physicochemical parameters (Dokou et al., 2015; Etteieb et al., 2017; K. Nag & Das, 2014; Mosaferi et al., 2014; Nasir et al., 2017; Slama & Sebei, 2020)

From March to December 2019, groundwater and surface water samples were collected in clean plastic containers with a volume of 500 ml. The samples were immediately taken to the lab and examination. The results from the laboratory then would be compared with the Vietnam standard 09:2015 and 08:2015/Ministry of Natural Resources and Environment (QCVN 09: 2015/BTNMT and QCVN 08: 2015/BTNMT) to define whether it was out of threshold.

In particular, 7 indicators: Fe, NH_4^+, Mn, NO_2^-, Cu, TSS, and pH for surface water, and 8 indicators: Fe, NH_4^+, Mn, NO_2^-, Cu, pH, TDS, and hardness for groundwater were analyzed.

The laboratory analytical methods are as follows:

Table 1. Methodology for indicators analysis

Parameters	Methods	
	Surface water	Groundwater
Fe	TCVN 6177:1996 (ISO 6332:1988) - spectrometric method using reagent 1,10 – phenanthroline	
NH_4^+	TCVN 6179-1:1996. Manual spectrometer method.	
Mn	TCVN 6002:1995 (ISO 6333:1986) - Photometric method with fomaldoxime	
NO_2^-	TCVN 6178:1996 (ISO 6777:1984). Molecular absorption spectrometry method	
Cu	TCVN 6193:1996 (ISO 8288:1986)	
TSS	TCVN 6625:2000 (ISO 11923:1997)	
pH	TCVN 6492:2011 (ISO 10523:2008)	
TDS		SMEWW 2540.C:2012
Hardness		SMEMW 2340.B:2012

Note: TCVN mean Vietnam standard; ISO means International Organization for Standardization; SMEWW mean Standard Methods for the Examination of Water and Waste Water.

- Groundwater quality index (GWQI)

The groundwater quality index is an important characteristic to evaluate water quality, which uses specific water quality parameters for the calculation. The formula for GWQI index was built by Vasanthavigar in 2010:

$$GWQI = \sum_{i=1}^{n} Sli \quad (1)$$

$$Sli = Wi \ x \ qi \quad (2)$$

$$Wi = \frac{wi}{\sum wi} \quad (3)$$

$$qi = \frac{Ci}{Si} x \ 100\% \quad (4)$$

Where:

GWQI: Water quality index;

Sli: the sub-index of i^{th} parameter;

wi: weight of each parameter;

Wi: relative weight values;

qi: The quality rating;

Ci: Concentration of indicator;

Si: Permitted level of QCVN09:2015/BTNMT.

Table 2. Weight of each parameter (wi) in GWQI equation

Indicators	Unit	Weight (wi)	QCVN 09:2015/BTNMT
Fe	mg/l	5	5
NH_4^+	mg/l	5	1
Mn	mg/l	5	0.5
NO_2^-	mg/l	5	1
Cu	mg/l	5	1
pH		3	8.5
TDS	mg/l	4	1500
Hardness	mg/l	3	500

After calculating, GWQI will be compared with the range to identify the status of groundwater. The GWQI range is as fllowed:

Table 3. GWQI range

GWQI range	Status
< 20	Excellent
20 – 50	Good
50 – 100	Poor
100 - 200	Very good
> 200	Unfit for drinking

3. RESULTS AND DISCUSSION

- Temporal variation of water quality

For surface water, pH, TSS and Mn are all in safe levels with average values of 7.98, 42.6, 0.2 mg/l, respectively. There are 4 indicators that have average values exceeding the allowable threshold according to B2 surface water in QCVN08:2015/BTNMT. The average Fe concentration of surface water is 5.21 mg/l, the maximum value is 9.39, nearly 5 times higher than the standard level. The average value of NH_4^+ and NO_2^- content is 1.42 and 0.27 mg/l, respectively, which is 2 times higher than the norm. The most severe pollution is recorded for Cu. Cu concentration at all 5 locations exceeded the allowable threshold, location S1 has the highest concentration was 59 mg/l, 59 times higher than the standard.

There are 3/7 criteria of groundwater exceeding the allowable threshold according to QCVN09:2015/BTNMT, including Fe, NH_4^+, and Cu. Concentrations of these substances are 8.41, 3.07, and 51.72 mg/l, respectively, exceeding the standard by 2.6, 3, and 52 times, respectively. Cu is the most serious pollutant with the highest concentration exceeding 168 times the norm. Comparing concentrations of pollutants to surface water found that groundwater was more heavily polluted. The reason can be explained that the wells are exploited from shallow aquifer, where it is connected to surface water, the water level in the well fluctuates from 3-5 m, so the water quality in the well will change over time similar to surface water.

Table 4. Descriptive statistics of water quality

	Surface water					Groundwater				
	Mean	**Max**	**Min**	**Sd**	**QCVN08**	**Mean**	**Max**	**Min**	**Sd**	**QCVN09**
Fe	5.21	9.39	2.87	1.40	2	8.41	16.34	5.19	3.29	5
NH_4^+	1.42	4.68	0.17	0.80	0.9	3.07	5.15	1.19	0.83	1
Mn	0.20	0.44	0.02	0.09	1	0.23	0.68	0.02	0.14	0.5
NO_2^-	0.27	0.46	0.10	0.09	0.05	0.14	1.08	0.01	0.22	1
Cu	43.27	59.00	31.00	8.58	1	51.72	168.00	8.00	37.67	1
TSS	42.60	62.00	30.00	8.51	100					
pH	7.98	8.30	7.70	0.14	5.5 - 9	8.02	8.30	7.50	0.14	5.6 - 8.5
TDS						598.40	780.00	505.00	68.96	1500
Hardness						159.98	1186.00	95.00	137.43	500

Concentrations of surface water pollutants fluctuate over time. It increases to the highest position in April and decreases gradually from May to September and increases again until December. It can be seen that the pollutant concentration is higher in the dry season and decrease in the rainy months. The reason can be explained that the amount of surface runoff in the rainy season is higher, and the flow is continuous, leading to improved water quality. In contrast, in the dry season, the amount of surface water is lesser, while the waste sources are continuously discharged into Cong Dam river, causing heavy pollution, especially in April.

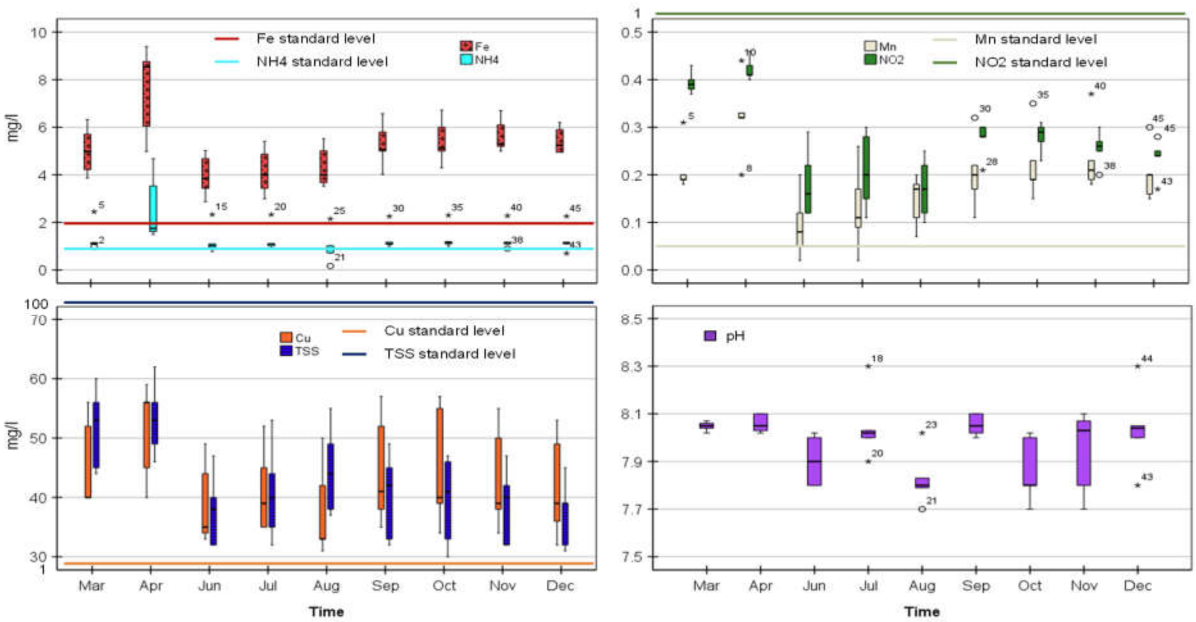

Figure 3. Box plot of surface water quality

There is a difference in groundwater quality between the dry season and the rainy season. Similar to surface water, the concentration of groundwater parameters reached the highest value in April and decrease in June, July and August.

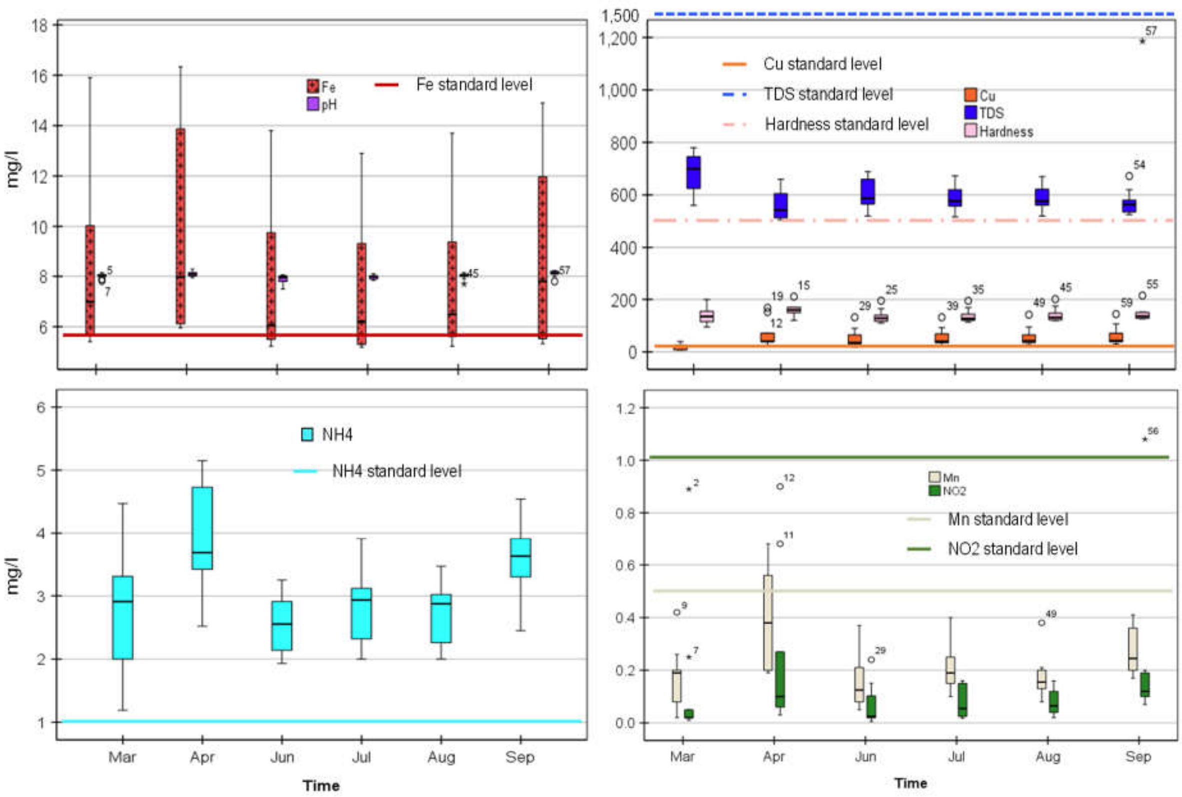

Figure 4. Box plot of groundwater quality

- Groundwater quality index

The GWQI of drill-wells fluctuates seasonally, increasing in the dry season and decreasing in the rainy season. The GWQI of all 10 drill-wells tended to increase to the highest position in April and gradually decrease in the following rainy season months. This index fluctuates in both space and time.

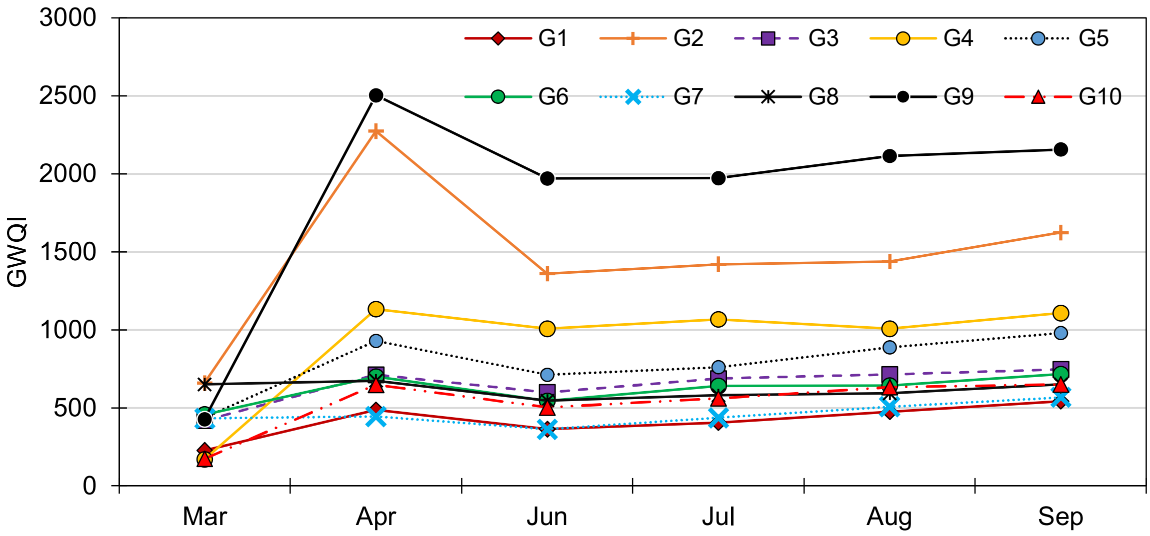

Figure 5. Temporal variation of GWQI

GWQI is calculated based on 7 indicators analyzed. In general, all 10 wells are heavily polluted. The mean of GWQI of all drill-wells is greater than 200 with the status for the groundwater is "Unfit for drinking" and cooking purposes. Drill-wells 9 and 2 are the two most polluted with GWQI values at 1857.28 and 1462.59 respectively. The remaining wells have GWQI values ranging from 417.08 to 915.49. The minimum value of wells 4 and 10 in March was less than 200, but in general, groundwater in this area is extremely polluted.

Table 5. Descriptive statistic of GWQI

	Mean	Max	Min	Sd	Status
1	417.08	542.92	228.34	111.94	Unfit for drinking
2	1462.59	2273.59	658.18	518.38	Unfit for drinking
3	646.63	746.39	418.53	122.35	Unfit for drinking
4	915.49	1132.89	170.63	368.49	Unfit for drinking
5	784.67	978.84	438.15	197.71	Unfit for drinking
6	617.37	717.27	458.17	98.39	Unfit for drinking
7	458.83	567.69	363.47	70.32	Unfit for drinking
8	616.56	674.11	547.94	49.44	Unfit for drinking
9	1857.28	2502.53	427.68	726.85	Unfit for drinking
10	528.74	650.22	174.52	183.08	Unfit for drinking

From the interpolation map of groundwater quality of Son Dong commune, it can be seen that the Northwest and the South with points 2 and 9 respectively are the most polluted places. In the center of the commune, spreading from East to West, the pollution level is lower. However, compared to the GWQI range, all groundwater in the area is harmful to drink

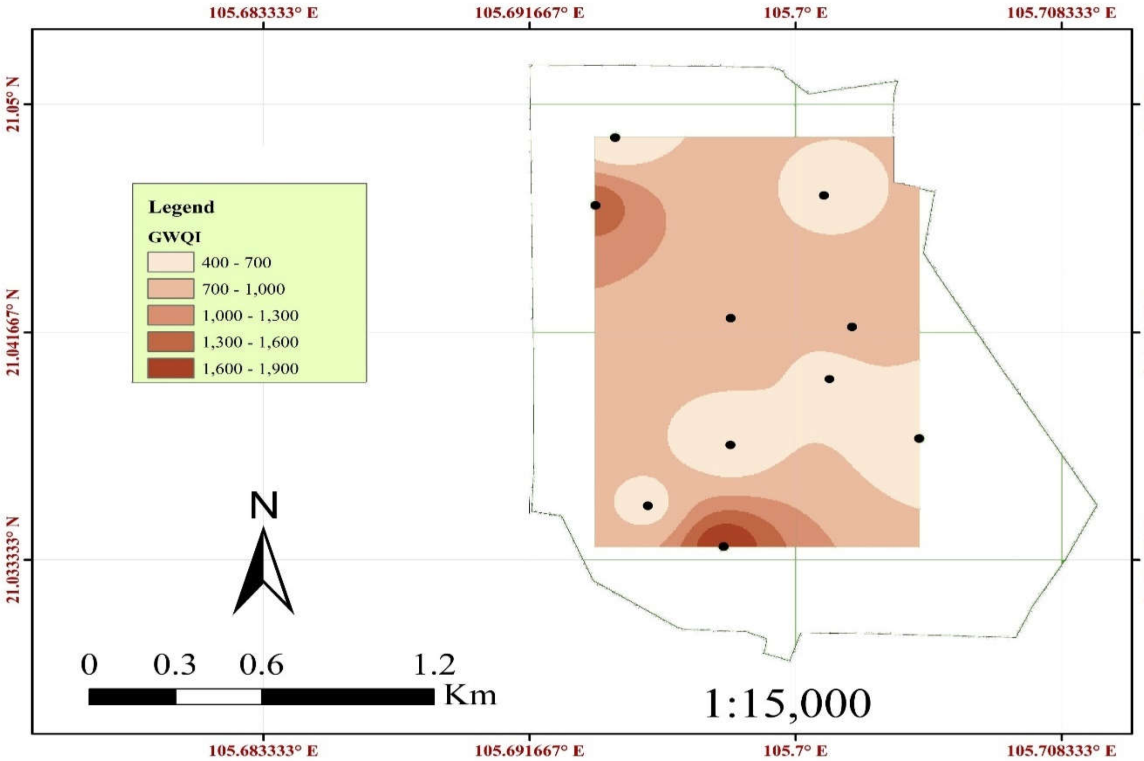

Figure 6. GWQI interpolation map

- Correlation

The correlation matrix between indicators of surface water quality shows that there is a strong correlation between NH_4^+ and Mn with R2 = 0.87. The pairs with average correlation are Fe-NO_2^-, NH_4^+-TSS, Mn-TSS, NH_4^+-pH, Mn-pH. For the remaining pairs in the matrix, there is weak or no correlation.

Table 6. Matrix correlation among surface water quality indicators

	Fe	NH4	Mn	NO2	Cu	TSS	pH
Fe	1	0.02	0.05	0.57	0.01	0	0.01
NH_4^+		1	**0.87**	0.04	0.12	0.52	0.56
Mn			1	0.23	0.15	0.52	0.61
NO_2^-				1	0.09	0.19	0.33
Cu					1	0.73	0
TSS						1	0.25
pH							1

For the indicators of groundwater, there is almost no cross-correlation between them. For GWQI, the strongest correlation is recorded for Cu with R2 = 0.99. Thus, it can be concluded that groundwater pollution comes mainly from severe Cu pollution. This is the only factor that is correlated with GWQI.

Table 7. Matrix correlation among groundwater quality indicators

	GWQI	Fe	NH_4^+	Mn	NO_2^-	Cu	TDS	pH	Hardness
GWQI	1	0.00	0.15	0.29	0.11	**0.99**	0.06	0.00	0.03
Fe		1	0.00	0.06	0.07	0.00	0.10	0.04	0.07
NH_4^+			1	0.12	0.02	0.16	0.01	0.00	0.04
Mn				1	0.13	0.29	0.04	0.07	0.01
NO_2^-					1	0.10	0.20	0.07	0.01
Cu						1	0.06	0	0.03
TDS							1	0.11	0.02
pH								1	0.47
Hardness									1

Comparing the water quality in Son Dong and Dai Bai copper craft village shows that the pollution situation in Son Dong is extremely serious. While the concentration of Cu in surface and groundwater analyzed at Dai Bai in 2013 was within the allowable range of Vietnamese standards, the level of Cu pollution in Son Dong was much higher. This was also observed for Fe concentrations in both surface and groundwater (Table 8). Pollution causes may be due to the process of copper production and wastewater treatment of each locality. The results of the study are intended to provide data on water pollution in craft villages, thereby promoting the implementation of solutions to improve water quality.

Table 8. Comparison of water quality of traditional copper craft villages Son Dong and Dai Bai, Bac Ninh province (Vu, 2013)

No.	Surface water			Groundwater		
	Son Dong, 2019	Dai Bai, 2013	QCVN08	Son Dong, 2019	Dai Bai, 2013	QCVN09
Fe	5.21	1.36	2	8.41	8.76	5
NH_4^+	1.42	3.32	0.9	3.07	0.28	1
Mn	0.20		1	0.23	0.28	0.5
NO_2^-	0.27		0.05	0.14	0.003	1
Cu	43.27	< 0.25	1	51.72	0.25	1
TSS	42.60	107.2	100			
pH	7.98	7.7	5.5 - 9	8.02	7.3	5.6 - 8.5
TDS				598.40		1500
Hardness				159.98	32	500

5. CONCLUSION

From the study, it can be concluded that the quality of surface water and groundwater in copper production villages in Son Dong commune, Hoai Duc district is polluted. Surface water is contaminated with indicators: Fe, NH_4^+, NO_2^- and Cu, groundwater is contaminated with indicators: Fe, NH_4^+ and Cu. The average concentration of Cu in surface water and groundwater is 43.27 and 51.72 mg/l, respectively, about 40 to 50 times higher than the permitted standard of the Ministry of Natural Resources and Environment. The quality of surface water and groundwater fluctuates with the seasons, the pollution gets worse in the dry season and improves in the rainy season. Groundwater quality index fluctuates in space and time, with the highest value in April. The Northwest and the South are the two places have the highest pollution levels. The cause of water pollution comes from the serious pollution of Cu in surface water and groundwater. It is advised that the groundwater in the area is not suitable for drinking.

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ẢNH HƯỞNG CỦA LÀNG NGHỀ TRUYỀN THỐNG ĐẾN CHẤT LƯỢNG MẶT VÀ NƯỚC NGẦM: NGHIÊN CỨU TẠI XÃ SƠN ĐỒNG, VIỆT NAM

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TÓM TẮT

Nghiên cứu này nhằm phân tích sự thay đổi theo không gian và thời gian của chất lượng nước mặt và nước ngầm tại xã Sơn Đồng, huyện Hoài Đức, Hà Nội. Một số chỉ tiêu hóa lý được lấy mẫu phân tích nhằm đánh giá biến động chất lượng nước theo thời gian và không gian tại khu vực. Các mẫu nước mặt được thu thập dọc theo tuyến kênh của xã tại các độ sâu khác nhau (20 và 30 cm). Từ tháng 3 đến tháng 12 năm 2019, 10 mẫu nước ngầm và 5 mẫu nước mặt được thu thập từ các giếng khoan và sông Cống Đầm. 7 chỉ tiêu nước mặt bao gồm: Fe, NH_4^+, Mn, NO_2^-, Cu, TSS và pH, 8 chỉ tiêu nước ngầm bao gồm: Fe, NH_4^+, Mn, NO_2^-, Cu, pH, TDS và độ cứng. Kết quả cho thấy cả nước mặt và nước ngầm ở Sơn Đồng đều bị ô nhiễm nặng. Các chỉ tiêu pH, TSS, TDS và NO_2^-, ít biến động và thấp hơn mức quy chuẩn. Tuy nhiên, các thông số NH_4^+, Cu, Fe cao hơn quy chuẩn cho phép QCVN 08: 2015/TNMT đối với nước mặt và 09: 2015/TNMT đối với nước ngầm. Chỉ số tổng hợp về chất lượng nước ngầm (GWQI) được tính dựa trên các chỉ tiêu đã phân tích đều cao hơn 200, có nghĩa là không phù hợp cho ăn uống. Các khu vực bị ô nhiễm nặng nhất ở phía Nam và phía Tây Bắc của xã Sơn Đồng. Do đó, trước tình trạng chất lượng nước ô nhiễm, cần sử dụng một số giải pháp phù hợp để cải thiện chất lượng nước khu vực nghiên cứu.

Từ khóa: chất lượng nước, chỉ tiêu nước ngầm GWQI, làng nghề truyền thống, nước ngầm, nước mặt, xã Sơn Đồng.

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