วารสารวิทยาศาสตร์บูรพา ปีที่ 26 (ฉบับที่ 2) พฤษภาคม – สิงหาคม พ.ศ. 2564
BURAPHA SCIENCE JOURNAL Volume 26 (No.2) May – August 2021 บทความวิจัย

การตรวจสอบติดตามคุณภาพน้ำและปริมาณโลหะหนักของแม่น้ำพอง ในเขตภาคตะวันออกเฉียงเหนือ ประเทศไทย

Water Quality and Heavy Metal Monitoring of the Pong River in Northeast Thailand

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Received : 19 May 2020
Revised : 6 July 2020
Accepted : 7 August 2020

บทคัดย่อ

แม่น้ำพองเป็นแม่น้ำสายใหญ่ในเขตพื้นที่ภาคตะวันออกเฉียงเหนือของประเทศไทย แม่น้ำสายนี้มีบทบาทสำคัญในด้านเป็นแหล่งทรัพยากรน้ำสำหรับการเกษตรกรรม ผลิตไฟฟ้า เพาะเลี้ยงสัตว์น้ำ ใช้อุปโภคบริโภค อุตสาหกรรมและการสันทนาการ ซึ่งในปัจจุบันคุณภาพน้ำของแม่น้ำพองมีการเปลี่ยนแปลงและปนเปื้อน งานวิจัยนี้จึงมุ่งเน้นศึกษาการตรวจติดตามค่าโลหะหนักในน้ำร่วมกับการตรวจวัดคุณภาพน้ำจาก 6 จุดสถานีของแม่น้ำพองใน 3 ฤดูกาลที่แตกต่างกัน ได้แก่ ฤดูร้อน (มีนาคม 2559) ฤดูฝน (สิงหาคม 2559) และฤดูหนาว (มกราคม 2560) ในช่วงไหลผ่านจังหวัดขอนแก่นของประเทศไทย ผลการศึกษาพบว่า กิจกรรมการเลี้ยงปลาในกระชังและฤดูกาลมีผลต่อการเปลี่ยนแปลงของคุณภาพน้ำ โดยคุณภาพน้ำส่วนใหญ่ตลอดปีมีค่าไม่เกินมาตรฐานคุณภาพน้ำผิวดิน ยกเว้น ค่าบีโอดี ที่มีค่าเกินมาตรฐาน 3.55-4.48 มิลลิกรัมต่อลิตรในเกือบทุกสถานี ซึ่งน่าจะเป็นผลมาจากการสะสมของอาหารปลาและของเสียจากปลาที่เลี้ยงที่ยังคงอยู่ในน้ำ ส่วนค่าโลหะหนักในน้ำที่ตรวจวัดได้แก่ สังกะสี ตะกั่ว ทองแดง แคดเมียมและปรอท นั้น พบว่าปริมาณของ สังกะสีและทองแดงอยู่ในระดับเกินมาตรฐานคุณภาพน้ำผิวดิน จากการสะสมของโลหะหนักในตะกอนดินจากการเลี้ยงปลาในกระชัง ในขณะที่ปริมาณสูงสุดของ ตะกั่ว แคดเมียม และปรอทที่พบคือ 0.1530 0.0586 และ 0.0079 มิลลิกรัมต่อลิตร ตามลำดับ โดยมาตรฐานคุณภาพน้ำผิวดินของโลหะหนักทั้งสามชนิดไม่ควรที่จะเกิน 0.05 0.005 และ 0.002 มิลลิกรัมต่อลิตร ตามลำดับ

คำสำคัญ : คุณภาพน้ำ ; โลหะหนัก ; การติดตามตรวจสอบ ; แม่น้ำพอง ; ประเทศไทย

Abstract

The Pong River is the largest basin located in the Northeast of Thailand. The river plays an important role as the water resource for agriculture, electricity generation, aquaculture, domestic uses, industrial and recreational purposes. Nowadays, the water quality of the Pong river has been changed and contaminated. This research aimed to study heavy metal monitoring in the water, and measuring water quality of the six different sites along the Pong River in three different seasons including summer(March 2016) , rainy(August 2016) and winter(January 2017) in Khon Kaen Province, Thailand. The results revealed that cage fish farming and seasons affected the change of water quality. Most of the water quality parameters from all the three seasons did not exceed the defined surface water quality standards, except the Biochemical Oxygen Demand (BOD) of 3.55-4.48 mg/L which was over the standard value for most stations, possibly due to the accumulation of fish food and fish feces remained in the water. The heavy metals measured in the water in each station were Zinc (Zn), Lead (Pb), Copper (Cu), Cadmium (Cd), and Mercury (Hg). It was found that the levels of Zn and Cu exceeded the standard values of surface water quality owning to heavy metal accumulation in the sediment from cage fish farming. In addition, while the defined surface water quality standard values for Pb, Cd and Hg must not be over 0.05 mg/L, 0.005 mg/L, and 0.002 mg/L, respectively, The highest levels of Pb, Cd, and Hg found were 0.1530 mg/L, 0.0586 mg/L, and 0.0079 mg/L respectively.

Keywords : water quality ; heavy metal ; monitoring ; Pong river ; Thailand

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Introduction

Thailand has experienced a rapid growth in population, industries, and agriculture in recent years (Molle, 2002). The growth has also brought the concerns for environmental issues, especially pollution. Water pollution is one of principal environmental and public health problems in Thailand (Kruawal *et al*.,2005). Wastewater discharges emit several kinds of pollutants including household chemicals, such as surfactants, pharmaceuticals and insect repellents, agricultural chemicals, such as pesticides and industrial chemicals, inorganics, and heavy metals (Kruawal *et al*.,2005).

The Pong River is the largest basin located in the Northeast of Thailand. The river plays an important role as water resource for agriculture, electricity generation, aquaculture, domestic uses, industrial and recreational purposes (Sangsurasak *et al*., 2006). Unfortunately, more than a decade, this river has been polluted from various sources such as agricultural runoff and remnants of past untreated effluent's spill. The previous study reported the sporadic occurrence of fish kills, particularly in the summer (Sangsurasak *et al*., 2006). Nowadays, the water quality of Pong river has been affected by the contaminants from several polluted sources of in the River. During the rainy season, topsoil runoff had been more intense in the relation to the changes of land use for agriculture or various deforestation activities etc. The volume transference of Pong River resulted in the change of water quality. Besides, Pong River flows along the area of continued expansion of the city which do not have a suitable wastewater treatment system; moreover, the area is the large industrial drainage basin (Mekong River Commission, 2011). In addition, the increasing number of pig farms and cage fish farming led to the extensive runoff and drainage from the agricultural area which took up 90% of Pong river. (Office of natural resources and environmental policy and planning, 1998; Regional Environment Office 10, 2017). Furthermore, the accumulation of various substances from the water source flowing into the Ubol Ratana Dam could affect the water quality in the dam and the lower Pong River. Therefore, the water quality deterioration inevitably occurred. For instance, SS, TDS, PO_4^{3-}, BOD, and TCB (Total Coliform bacteria) levels elevated in rainy season while DO level decreased in winter and summer. Furthermore, during the fluctuation of flowrate and rainy season, the levels of BOD, DO, PO_4^{3-} did not meet the standard values (Regional Environment Office 10, 2017).

Heavy metals are one of environmental issues because of their non-biodegradability and persistence. Most heavy metals affect human health differently based on levels of exposure and absorption; they are still toxic even though it is low in concentrations. They could affect people's health, environment, water, food, air, and products made in Pong river area. The mechanism which metals are accumulated to higher levels and move through the food chain is called biological magnification. It has been stated that Pong river is contaminated by accidental releases of chemical contaminants from the factories along the river. There were some studies on heavy metal contamination in Pong River; Natsima et al. 2012 reported that heavy metal accumulation in the sediment in Pong river was Zn>Cr>Pb>Cu>As>Cd. Correspondingly, another study also showed that in the sediment of Pong river, Zn level was the highest while Cd level was the lowest (Uraiwan et al., 2001). The levels of heavy metals in the water of Pong River had been reported since 1989, Cu and Zn levels were in the range of 0.00-0.22 and 0.00-2.84 mg/L. respectively, while Pb, Cr, Hg could not be detected. Although agricultural and industrial activities such as cage fish farming, pulp and paper mills around Pong river can cause the release of heavy metals into the river (Natsima et al. 2012; Mekong River Commission, 2011), the study and the reports on heavy metals in water of Pong River are still considerably limited.

Therefore, it is interesting and important to investigate the heavy metal levels in the water of Pong river which have not been regularly reported or monitored. For this reason, the objective of this research is to monitor the water quality and heavy metal levels near the aqua cultural area, namely cage fish farming which is currently the major land use of Pong River located in Khon Kaen province in order to identify the changes of water quality and heavy metal levels in the water samples collected throughout the years and also define the influence of cage fish farming on water pollution in Pong river.

Methods

1. Study area and sampling method

The study focused on Pong river, which flows through Khon Kaen Province in the Northeastern region of Thailand. Six different sampling sites were selected along the whole course of the Pong river and near the cage fish farming sites as shown in Table 1 and Fig.1. The samples were collected in three different months in three different seasons including March in summer, August in rainy season, and January in winter respectively in 2016 to 2017. Water samples were collected by grab sampling method using water sample bottles.

Table 1 Sampling sites

Sites	Detailed points
1	Nongtao village, Khoksung sub-district, Mueng district
2	Dongphong village, Sila sub-district, Mueng district
3	Napiang village, Samran sub-district, Mueng district
4	Khamkaenkoon village, Muang Wan sub-district, Nam Pong district
5	Huai Sua Ten village, Nam Pong sub-district, Nam Pong district
6	Khambon village, Khoksung sub-district, Ubolratana district

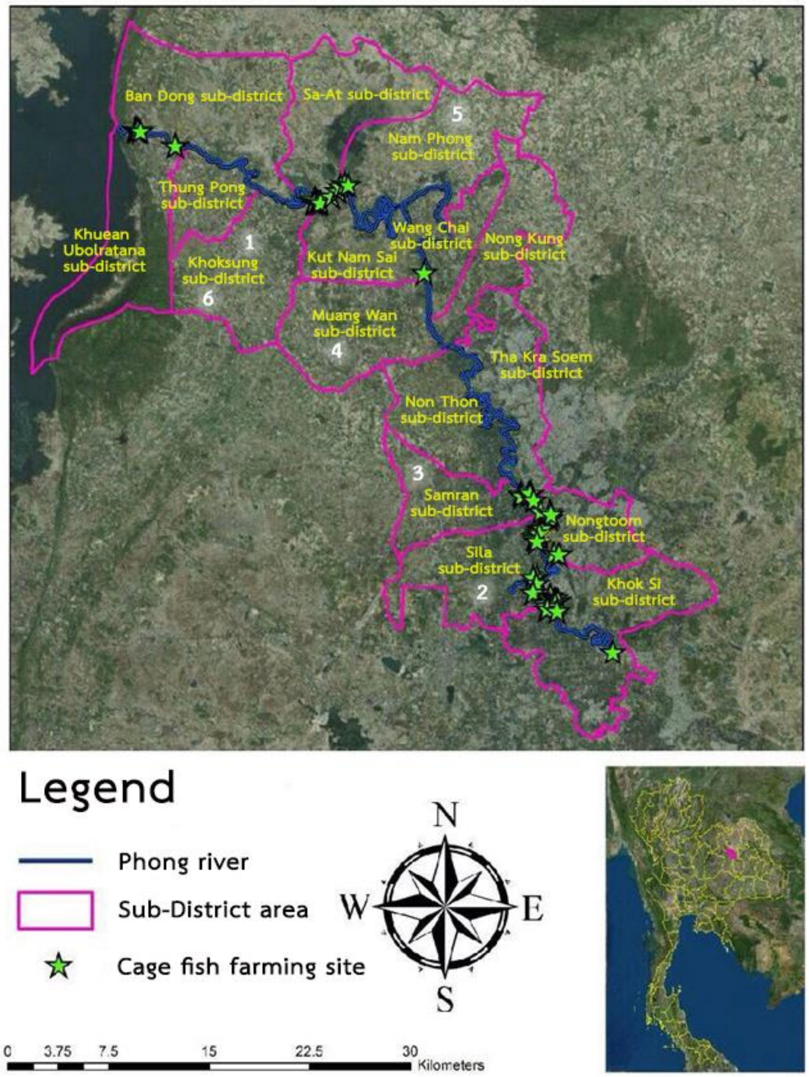

Figure 1 Sampling site and case fish farming location

2. Water analysis

Water samples were kept in the ice box and analyzed in Environmental Science laboratory, Faculty of Science and Technology, Rajabhat Mahasarakham University. Some of physicochemical parameters such as temperature, pH, electrical conductivity, dissolved oxygen (DO) were measured by WTW 350i/SET multi-parameter (Germany). Other water parameters including suspended solid (SS), Total dissolved solid (TDS), Biochemical oxygen demand (BOD), Nitrate (NO_3^-) and Phosphate (PO_4^{3-}) were analyzed following the standard manual. Total Cd, Cu, Zn, Pb and were measured after digestion using Atomic Absorption Spectroscopy (AAS), Model Pin AAcle 900F and Hg were measured by ICP MS 7500 C with the limited 0.1 ppb as shown in Table 2.

The research was an experiment work and the results were presented in the forms of values and correlation analysis was used to evaluate the strength of relationship between the water quality values.

Table 2 Parameter and methods for analysis

Characteristics	Parameters	Methods for analysis	Reference
1. Physical	- Temperature	- Thermometer	- WTW 350i/SET multi-parameter (Germany)
	- Conductivity	- Electrical Conductivity	- WTW 350i/SET multi-parameter (Germany)
	- Suspended Solid (SS)	- GF/C drying at 103 C^0	- Standard Methods for the Examination of Water and Wastewater, APHA, AWWA,WEF, 21^{st} Edition, 2005
	- Total Dissolved Solid (TDS)	- GF/C drying at 103 C^0	- Standard Methods for the Examination of Water and Wastewater, APHA, AWWA,WEF, 21st Edition, 2005
2. Chemical	- pH	- pH Meter	- WTW 350i/SET multi-parameter (Germany)
	- Dissolved Oxygen (DO)	- Dissolved Oxygen Meter	- WTW 350i/SET multi-parameter (Germany)
	- Biochemical Oxygen Demand (BOD)	Azide - Modification	- Standard Methods for the Examination of Water and Wastewater, APHA, AWWA,WEF, 21st Edition, 2005
	- Nitrate (NO_{3-})	- Nessler's Method	- Standard Methods for the Examination of Water and Wastewater, APHA, AWWA,WEF, 21st Edition, 2005
	- Phosphate (PO_4^{3-})	-Nessler's Method	- Standard Methods for the Examination of Water and Wastewater, APHA, AWWA,WEF, 21st Edition, 2005
	- Cd, Cu, Zn, and Pb	- Atomic Absorption - Spectroscopy; AAS	- Standard Methods for the Examination of Water and Wastewater, APHA, AWWA,WEF, 21^{st} Edition, 2005
	Hg	ICP MS/OES	Water and Wastewater, APHA, AWWA,WEF, 21^{st} Edition, 2005

Results

The water samples collected from Pong river flowing through Khon Kaen province near cage fish farming sites in March during summer of 2016, in August during monsoon season of 2016, and in January during winter of 2017 were investigated. The physical parameters of water quality included temperature, conductivity, Suspended Solids (SS), Total Dissolved Solids (TDS). The chemical parameters consist of Potential of Hydrogen (pH), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate (NO_3^-), Phosphate (PO_4^{3-}), heavy metals which were Cd, Cu, Zn, Pb and Hg. The results of water quality of each season are shown in Table 3, 5 and 7.

Table 3 Water quality from each site during summer in March 2016

Station	Temp (^{0}C)	Conductivity (µs/cm)	SS (mg/L)	TDS (mg/L)	pH	DO (mg/L)	BOD (mg/L)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)
1. Ban Nong Tao	28.5	367	23.33	16.66	8.0	3.50	5.70	0.810	0.2
2. Ban Dong Phong	29.4	370	10.00	13.33	6.7	2.82	4.15	0.400	0.1
3. Ban Na Pieng	29.4	358	6.66	6.66	6.7	2.65	4.95	0.390	0.2
4. Ban Kham Kaen Koon	28.0	316	3.33	6.66	6.8	3.70	4.00	0.760	0.2
5. Ban Huai Sua Ten	27.5	251	3.33	10.00	6.7	1.42	5.10	0.489	0.1
6. Ban Khambon	26.4	213	16.66	6.66	7.2	3.49	5.15	0.758	0.1
*** Standard criteria	ธ	-	-	-	**5-9**	**2-6**	**1.5-4**	**5.0**	-

Remark ; *** refers to the surface water quality standard criteria.

Table 3 shows the results of surface water quality for each site during summer in March 2016. The temperatures were the environmental temperatures which were between 26.4-29.4 °C. Conductivity valued ranged from 213 to 370 µS/cm. The Suspended Solids values were between 3.33-16.66 mg/L. The Total Dissolve Solids (TSD) values were between 6.66-16.66 mg/L. The Potential of Hydrogen (pH) levels were around 6.7-8.0. Dissolve Oxygen (DO) levels were between 1.42-4.49 mg/L for every station except Ban Huai Sua site. Since Ban Huai Sua Ten station is near the pulp paper factory and sugar factory, the DO level was lower than the standard at 2 mg/L. The Biochemical Oxygen Demand (BOD) values were between 4.00 – 5.70 mg/L. The Nitrate (NO_3^-) levels were between 0.390 - 0.810 mg/L. Finally, the Phosphate (PO_4^{3-}) levels were between 0.1 - 0.2 mg/L.

Table 4 Heavy metals from each site during summer in March 2016

Station	Zn (mg/L)	Cu (mg/L)	Pb (mg/L)	Cd (mg/L)	Hg (mg/L)
1. Ban Nong Tao	0.2390	0.0010	0.0100	0.0350	0.0061
2. Ban Dong Phong	0.3500	0.0070	0.2390	0.0440	0.0079
3. Ban Na Pieng	0.5760	0.0090	0.2070	0.0510	0.0017
4. Ban Kham Kaen Koon	0.4190	0.0090	0.0420	0.0460	0.0010
5. Ban Huai Sua Ten	0.3680	0.0080	0.1140	0.0450	0.0054
6. Ban Khambon	0.4630	0.0160	0.1530	0.0490	0.0012
*** Standard criteria	1.0	0.1	0.05	0.005	0.002

Remark ; *** refers to the surface water quality standard criteria.

Table 4. displays the values of heavy metals found in each site during summer in March 2016. The results revealed that Zn and Cu values met the standards. However, Pb, Cd, and Hg values were higher than standards. The maximum values of Pb, Cd, and Hg were 0.2390 mg/L, 0.0510 mg/L and 0.0079 mg/L, respectively.

Table 5 Water quality from each site during rainy in August 2016

Station	Temp (C^0)	Conductivity (µs/cm)	SS (mg/L)	TDS (mg/L)	pH	DO (mg/L)	BOD (mg/L)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)
1. Ban Nong Tao	27.0	202	40.00	73.66	8.6	2.46	6.73	1.80	0.545
2. Ban Dong Phong	26.7	201	50.00	18.33	7.5	2.80	6.76	1.80	0.436
3. Ban Na Pieng	26.3	190	83.33	33.00	7.5	3.58	6.50	1.80	0.436
4. Ban Kham Kaen Koon	26.6	185	17.66	16.66	7.5	3.60	7.20	1.30	0.325
5. Ban Huai Sua Ten	26.7	100	13.00	10.00	7.2	2.10	6.96	1.80	0.284
6. Ban Khambon	27.3	121	22.33	12.66	7.4	2.50	6.44	1.90	0.188
*** Standard criteria	ธ	-	-	-	5-9	2-6	1.5-4	5.0	-

Remark ; *** refers to the surface water quality standard criteria.

Table 5. shows the surface water quality for each site during rainy in August 2016. Temperatures (Temp.) were the environmental temperatures which were between 26.3-27.3 °C. Conductivity values were 100-202 μS/cm. The Suspended Solids values were rather high ranging from 13.00-83.33 mg/L because of the sediment interference in rainy season. The Total Dissolve Solids (TDS) values were between 10.00-73.66 mg/L. The Potential of Hydrogen (pH) levels were around 7.2-8.6. Dissolve Oxygen (DO) values were between 2.10-3.60 mg/L for all stations. The DO ranged from 2.10-3.60 mg/L. The Biochemical Oxygen Demand (BOD) values from every station were higher than the standard values due to the high volume of organic matter accumulation. The Nitrate (NO_3^-) values were between 1.30-1.90 mg/L. The Phosphate (PO_4^{3-}) values were between 0.188-0.545 mg/L.

Table 6. presents the values of heavy metals found from each site during rainy in August 2016. The results showed that Zn and Cu values met the standards. However, Pb, Cd, and Hg values were higher than standards. The maximum values of Pb, Cd, and Hg were 0.1450 mg/L, 0.0586 mg/L and 0.0071 mg/L, respectively.

Table 6 Heavy metals from each site during rainy in August 2016

Station	Zn (mg/L)	Cu (mg/L)	Pb (mg/L)	Cd (mg/L)	Hg (mg/L)
1. Ban Nong Tao	0.5420	0.0460	0.1450	0.0586	0.0025
2. Ban Dong Phong	0.1600	0.0080	0.1000	0.0549	0.0012
3. Ban Na Pieng	0.1280	0.0120	0.1400	0.0504	0.0071
4. Ban Kham Kaen Koon	0.1550	0.0150	0.0880	0.0548	0.0012
5. Ban Huai Sua Ten	0.2140	0.0200	0.1370	0.0560	0.0020
6. Ban Khambon	0.2120	0.0160	0.1090	0.0559	0.0011
*** Standard criteria	**1.0**	**0.1**	**0.05**	**0.005**	**0.002**

Remark ; *** refers to the surface water quality standard criteria.

Table 7 Water quality from each site during winter in January 2017

Station	Temp (C^0)	Conductivity (µs/cm)	SS (mg/L)	TDS (mg/L)	pH	DO (mg/L)	BOD (mg/L)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)
1. Ban Nong Tao	21.3	192	1.33	19.66	6.8	6.80	1.00	0.70	1.041
2. Ban Dong Phong	21.8	188	4.00	18.00	8.6	6.75	0.93	0.60	3.000
3. Ban Na Pieng	20.7	183	5.66	17.00	6.6	7.39	1.20	0.80	3.000
4. Ban Kham Kaen Koon	21.0	113	1.33	15.66	6.7	7.90	1.05	0.40	3.000
5. Ban Huai Sua Ten	20.1	187	0.66	16.00	6.6	3.62	1.35	0.30	0.347
6. Ban Khambon	20.0	170	0.66	14.66	6.7	4.27	1.50	0.20	0.388
*** Standard criteria	ธ	-	-	-	5-9	2-6	1.5-4	5.0	-

Remark ; *** refers to the surface water quality standard criteria.

Table 7. exhibits the results of surface water quality from each site during winter in January 2017. Temperatures (Temp.) were corresponding to the environment temperatures at 20.0-21.8 °C. Conductivity values were between 113-192 µS/cm. The Suspended Solids values were between 0.66-5.66 mg/L. The Total Dissolve Solids (TDS) values were between 14.66-19.66 mg/L. The Potential of Hydrogen (pH) levels were around 6.6-8.6. Dissolve Oxygen (DO) levels ranged from 3.62-7.90 mg/L for every station. The Biochemical Oxygen Demand (BOD) values were between 0.93-1.50 mg/L. The Nitrate (NO_3^-) values were between 0.20-0.80 mg/L. The Phosphate (PO_4^{3-}) values were between 0.347-3.000 mg/L.

Table 8 Heavy metals from each site during winter in January 2017

Station	Zn (mg/L)	Cu (mg/L)	Pb (mg/L)	Cd (mg/L)	Hg (mg/L)
1. Ban Nong Tao	0.0358	0.0085	0.0700	0.0078	0.0052
2. Ban Dong Phong	0.0464	0.0049	0.0084	0.0024	0.0051
3. Ban Na Pieng	0.0305	0.0065	0.0089	0.0024	0.0039
4. Ban Kham Kaen Koon	0.0118	0.0089	0.0609	0.0031	0.0035
5. Ban Huai Sua Ten	0.0134	0.0040	0.0110	0.0012	0.0039
6. Ban Khambon	0.0404	0.0072	0.0535	0.0065	0.0052
*** Standard criteria	1.0	0.1	0.05	0.005	0.002

Remark ; *** refers to the surface water quality standard criteria.

Table 8. shows the values of heavy metals found from each site during winter in January 2017. The values of Zn and Cu met the standards while Pb, Cd, and Hg values were higher than the standards. The maximum values of Pb, Cd, and Hg were 0.0700 mg/L, 0.0078 mg/L and 0.0052 mg/L, respectively.

Discussion

According to the results of surface water quality of Pong river in terms of both physical and chemical characteristics investigated in the six sites found the value of water quality parameter were in standard criteria such as conductivity and TDS that were not higher than the rang of surface water resource namely 150-300 (µs/cm) and 100-200 mg/L, respectively(Klomjek and Navanugraha, 2013). However, it was found that seasons can affect the change of surface water quality. In the rainy season, the water could be more turbid and had the higher suspended solids values as a consequence of the high rainfall of 1368.1 mm. (Thai Meteorological Department, 2016). Meanwhile, DO values in the summer season were reduced to 1.42 mg/L. which was lower than standard value as seen in the results in March. The DO values measured in this research were not similar to the reported values of Regional Environment Office 10 from the same season in 2017 due to the sampling points in this study were near cage fish farms that caused the decrease in the DO values and the increase in BOD values from fish farming (Chatvijitkul *et al.,* 2015).

In addition, the changes of surface water quality can be caused by other factors such as land use, cage fish farming along Pong river. The BOD levels in water can be escalated due to the leak of feed and feces from fish cage into the river (Chatvijitkul *et al.,* 2015). These results can be comparable to the previous studies discovering that seasons and land use influenced the water quality in both long and short terms including changes of dams and river ecosystems. Moreover, the land used and urbanization also had an impact on the water quality and the impact was stronger in winter than in summer (Guoce *et.al.* 2019 ; Zengliang *et.al*. 2020). The study of impact of land uses and seasons on water quality in Malaysia also disclosed the correlation between the agricultural activities and water quality while the values of parameters such as DO, salinity and turbidity were significantly different between dry and monsoon seasons (Camara *et al*., 2019; Abdullah *et al*., 2018).

Furthermore, considering the correlation between BOD and DO in Fig. 2, every value of DO and BOD from each sampling station were statistically showed in the form of the scatter plot. There was a significant correlation (R^2 =0.5639), indicating that the variations of DO might have not been influenced by the variations of BOD as the seasons changed. However, Fig. 3 shows the statistic scatter plot with the values of DO and BOD from each sampling sites in three seasons. Since the higher significant correlation (R^2 =0.6374 -0.9007) was found, it can be explained that the use of land as cage fish farming could probably cause the water pollution which would enable the variations of BOD to affect the variations of DO.

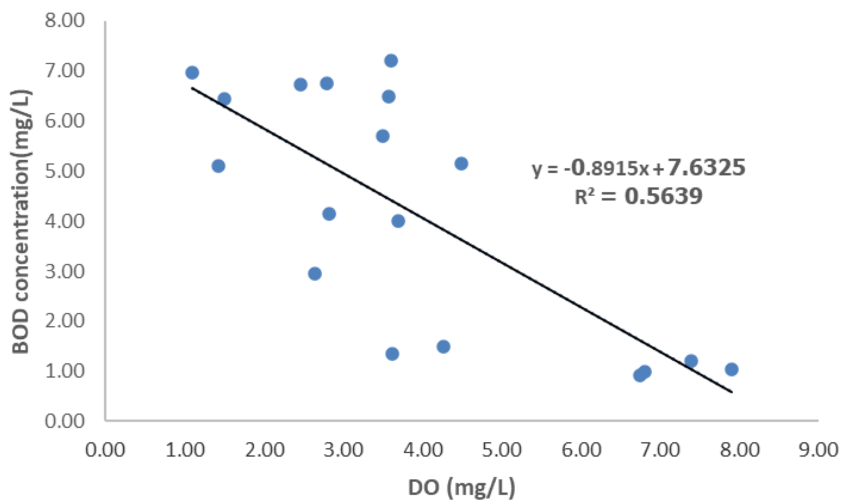

Figure 2 The correlation between the temperatures and dissolved oxygen levels of whole study period.

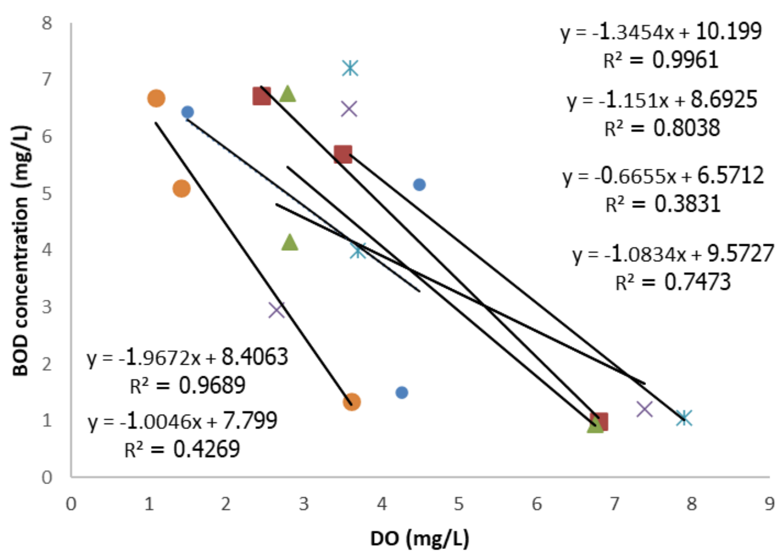

Figure 3 The correlation between the temperatures and dissolved oxygen levels of each site during 3 seasons

In terms of heavy metals, even though the values of Zn and Cu could meet the standards, the Pb, Cd, and Hg values were higher than the standard values and there could be several reasons for the mentioned results. Firstly, along Pong river, there was not only the agricultural but also residential, and industrial areas. In the industrial area, there were many factories, for example, pulp and pare factory, liquor factory, sugar factory, sand gravel washing factory. The factories could discharge the heavy metals in Pong River. According to the research by Tipawan (1989), in the areas where certain industrial plants, namely pulp mill and sugar factories, were established, there could be the increase in natural metals and other metals in the environment. Similarly, Mohamed *et.al.* 2014 said that the effluents from different industrial sites released to the canal water caused heavy metal pollution in river. Furthermore, the sediment from cage fish farming in Pong river is possibly the cause of heavy metal accumulated in water as reported in the previous work revealing the values of heavy metals measured in descending order as Zn> Cu> As> Cr> Pb> Cd (Natsima, 2012). Moreover, Uraiwan (2001) also reported that heavy metals were found in the sediment of Pong river; Zn had the highest value and Cd had the lowest value.

Conclusions

The research aimed to study the water quality and heavy metal monitoring in water by measuring the water quality in six different sites along Pong River in three different seasons including summer, rainy and winter seasons in Khon Kaen Province, Thailand. This study emphasized on physical and chemical properties of water quality in the areas where cage fish farming densely takes place in Pong river. The water samples were collected from the cage fish farms in March during summer of 2016, in August during monsoon season of 2016, and in January during winter of 2017 and then the water quality parameters were measured. The analysis of physical parameters of water quality included temperature, conductivity, Suspended Solids (SS), Total Dissolved Solids (TDS) while the analysis of chemical parameters consists of Potential of Hydrogen (pH), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate (NO_3^-) Phosphate (PO_4^{3-}), heavy metals which are Cd Cu Zn Pb and Hg. The results revealed that Biochemical Oxygen Demand (BOD) values ranged from 0.93-7.20 mg/L, and the BOD values measured in March and August from every station exceeded the surface water quality standard values which are 1.5-4.0 mg/L owning to the huge amount of accumulated organic matter in the water. The heavy metals measured in the water in each station were Zinc (Zn), Copper (Cu), Cadmium (Cd), and Mercury (Hg). It was found that the values of Zn in every site ranged from 0.0118-0.5420 mg/L, and the values of Cu were 0.0010-0.0460 mg/L; thus, the values did not violate the surface water quality standard values. The values of Pb, Cd, and Hg were 0.0084-0.1530 mg/L, 0.0012-0.0586 mg/L, and 0.0010-0.0079 mg/L respectively. Unlike Zn and Cu, the values of these three heavy metals in most stations exceed the surface water quality standard values standard. The highest values of Pb, Cd, and Hg found were 0.1530 mg/L, 0.0586 mg/L, and 0.0079 mg/L respectively while the defined surface water quality standard values for Pb, Cd and Hg must not be over 0.05 mg/L, 0.005 mg/L, and 0.002 mg/L respectively. Furthermore, it was also found that seasons and land uses could affect the water quality, especially cage fish farming which caused the release of pollutants such as BOD and heavy metals. From the results of this research, the future work on ecotoxicology study is suggested as it can necessarily help ensure that fish consumption will not provide a route for heavy metals transfer to human. Furthermore, the risk assessments of public health as well as human health should be performed to contribute to improving fish farming management in order to reduce the environmental loss in the future.

Acknowledgements

This work was supported by National Research Council of Thailand.

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