The chemical resistance of pesticides in some agricultural production regions in Kien Giang province

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Abstract. The study provided the status of pesticide use in three ecological regions in Kien Giang province. The management and use of pesticides were still inadequate due to not being fully aware of their harmful effects, leading to environmental pollution, which affected rural community. The soil, surface water and groundwater analysis showed that environmental pollution was a significant concern. The soil acidity was low to moderate, soil organic matter was deficient and soil was contaminated with heavy metals such as Pb, Zn, Cu and As. In terms of surface water, salinity regulated the studied sites in the dry season, TSS of 5/9 sites was higher than the standard, Coliform of 4/9 sites was 46 times higher than the standard, DO was less than 5 and BOD was 2-3 times higher than the standard. Surface water nutrients $N\text{-}NO_3^-$ and $N\text{-}NH_3^-$ were below the allowable threshold, P_2O_5 of 2/9 sites exceeded the allowed standard, $N\text{-}NO_2^-$ of 5/9 sites exceeded the standard. Regarding the groundwater, the pH was neutral, the TSS at all sites was over the threshold, the water hardness of 2/9 sites exceeded the threshold, the Coliform at all sites was over the threshold and 3/9 of the areas were contaminated with *Escherichia coli*. This study showed that the perception of using pesticides in the study regions has to be changed.
Key Words: fertilizers, surface water, groundwater, environmental pollution.

Introduction. Clean agricultural production has become a main topic of Vietnam and the world. Farmers have become accustomed to using pesticides in agriculture, leading to residues of pesticides and chemical fertilizers in the field, polluting the environment, affecting the health of farmers and rural communities. In Vietnam, pesticides have been used since the 50s. Popular drugs of this era included DDT, parathion-methyl, and polyclorocamphen (Institute of Chemistry-Military Environment 2012). Currently, pesticides are very diverse and useful in increasing crop yield. However, many of them are causing adverse impacts on agricultural land (Nguyen 2005). Among them, many drugs containing toxic ingredients are still used, such as endosulfan (Meisner 2005; Sebesvari et al 2012). According to Pham (2013), people in the Mekong Delta often use pesticides with toxins type II and III (World Health Organization WHO). Among them, organochlorine and organophosphate pesticides are most commonly used (Nguyen et al 1999). Besides, these drugs are misused in frequency and dosage (Pham 2013). By 2010, 437 pesticides, 304 fungicides and 160 herbicides were allowed in agriculture (Ministry of Agriculture and Rural Development 2010). Each crop has 5.3 times pesticide spraying (Mekong River Commission 2007). When these drugs release into the environment, they cause harm to people, plants, animals and to the environment (Ohkawa et al 2007). According to Dasgupta et al (2005), up to 35% of surveyed farmers have pesticide residues in their blood. In addition, it also affects the growth and development of ecosystems (Margni et al 2002) and pollutes water sources (Dang & Gopalakrishnan 2003). Hence, it is required to survey and assess the situation of pesticides residues in the soil environment, field surface water and underground water.

This study was conducted to collect soil, surface water and underground samples in three ecological zones of Kien Giang province are Ca Mau Peninsula (CMP), Long Xuyen Quadrangle (LXQ) and West Hau River (WHR), in collaboration with the laboratory of Kien Giang University (KGU). Kien Giang Natural Resources and Environment Monitoring Center (KGREC) collected soil and water samples (from surface and underground water) in three ecological zones in Kien Giang provinces. The results analyzed at KGREC give a picture of the situation of the environmental pollution in the field on the use of pesticides and chemical fertilizers in Kien Giang province. From the results of this study, recommendations can be inferred to change agriculture farming methods in the direction of food safety, to implement clean agriculture, organic agriculture, to protect the health of fish farm, the farmers and of the consumers.

Material and Methods

Sample collection and analysis. Soil samples at nine sites in three zones (Figure 1) were drilled three times, in the period 1-30 June, 2021. Samples were taken in three depth ranges (0-20, 30-50 and 60-80 cm). The soil samples were placed in a plastic bag and labeled before transporting to the laboratory for analysis.

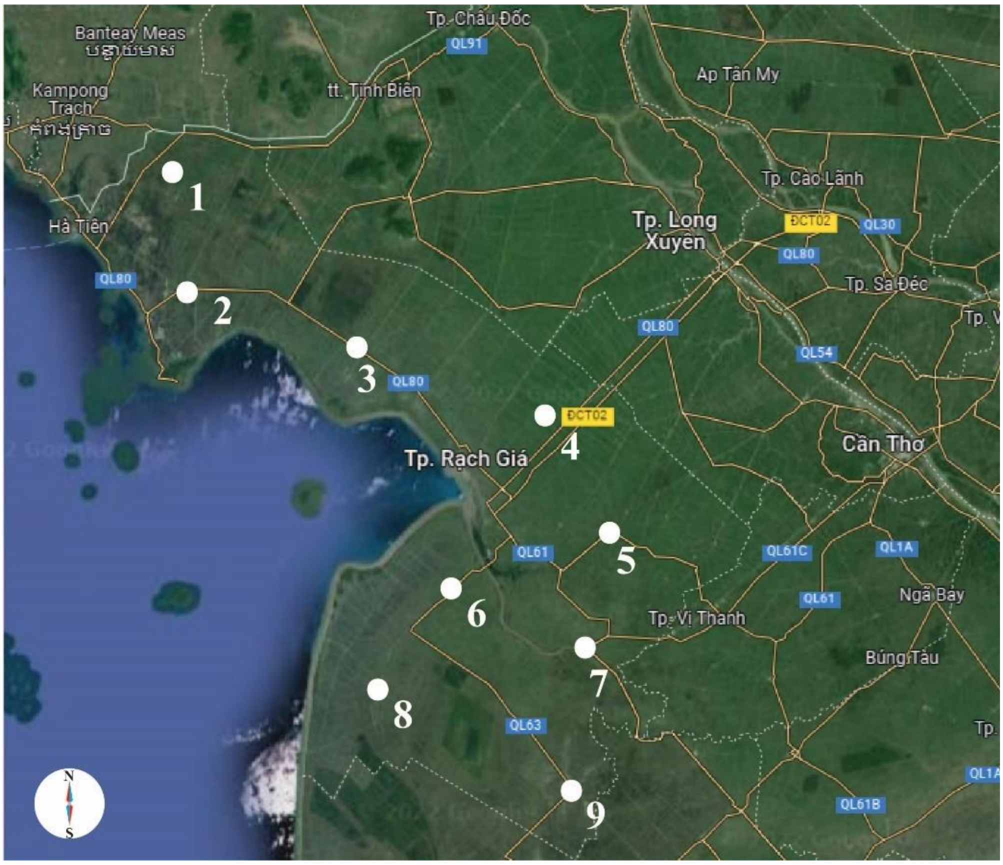

Figure 1. Map of soil samples (1: Giang Thanh; 2: Kien Luong; 3: Hon Dat; 4: Tan Hiep; Giong Rieng; 6: An Bien; 7: Go Quao; 8: An Minh; 9: Vinh Thuan; Source: Google Map).

The pH, As, Pb, Cu, Zn, Cd, organic matter (indicated by the organic matter intake - OMI), residues of chlorine-based pesticides, chlordane, DDD, DDE, DDT, dieldrin, endrin and heptachlor epoxide were analyzed according to the current standards of Vietnam (TCVN) (Ministry of Natural Resources and Environment 2015a) (Table 1).

In each sampling site, two liters of water were taken and stored in sealed bottles before labeling and transporting them to the laboratory for analysis. Surface water analysis parameters: pH, DO, TSS, coliform, nitrite, nitrate, ammonium, Fe, phosphate, Chloride, BOD_5, COD were analyzed using the TCVN (Ministry of Natural Resources and Environment 2015b) (Table 2).

Table 1

Soil analysis standard

Parameter	*Methods*
pH	TCVN 5979:2007
As	The US.EPA Method 200.7
Pb	The US.EPA Method 200.7
Cu	The US.EPA Method 200.7
Zn	The US.EPA Method 200.7
Cd	The US.EPA Method 200.7
Organic matter indicates	TCVN 6644:2000
Residues of chlorine-based pesticides	
Chlordane	
DDD	
DDE	US.EPA Method 3550C+
DDT	US.EPA Method 8270D
Dieldrin	
Endrin	
Heptachlor epoxide	

Table 2

Surface water analysis standard

Parameter	*Methods*
pH	TCVN 6492:2011
DO	TCVN 7325:2016
TSS	TCVN 6625:2000
Coliform	TCVN 6187-2:1996
Nitrite	TCVN 6178:1996
Nitrate	TCVN 6180:1996
Ammonium	SMEWW 4500 NH3-B&F:2017
Fe	TCVN 6177:1996
Phosphate	SMEWW 4500-P.E:2017
Chloride	TCVN 6194:1996
BOD_5	TCVN 6001-1:2008
COD	TCVN 6491:1999

Table 3

Groundwater analysis standard

Parameters	*Methods*
Climate	SMEWW 2550B:2017
pH	TCVN 6492:2011
Water hardness	SMEWW 2340C:2017
TSS	SMEWW 2540B:2017
Nitrite	TCVN 6178:1996
Nitrate	TCVN 6180:1996
Ammonium	SMEWW 4500 NH3-B&F:2017
Permanganate index (COD)	TCVN 6186:1996
Phosphate	SMEWW 4500-P.E:2017
Sulfate	SMEWW 4500-SO42-E:2017
Chloride	TCVN 6194:1996
Fe total	TCVN 6177:1996
Coliform total	TCVN 6187-2:1996

The hand pump collected water from wells in each sampling site. Samples were then stored in sealed bottles and labeled before transferring them to the laboratory for analysis. The pH, water hardness, TSS, nitrite, nitrate, ammonium, COD, phosphate, sulfate, chloride, Fe total, coliform were analyzed according to the TCVN (Ministry of Natural Resources and Environment 2015c) (Table 3).

Results and Discussion

Natural characteristics. A soil pH ranging from 4 to 5 in three zones, Ca Mau Peninsula (CMP), Long Xuyen Quadrangle (LXQ), West Hau River (WHR), shows a low acidity (acid sulfate) (Le and Ho 2010). In the zones of the CMP site, An Bien (AB) and An Minh (AM), the pH was at least 4.25–4.30; this indicator was not favorable for rice cropping. Only one site, Vinh Thuan (VT), showed a pH of 5.29, ecologically suitable for crops and aquatic products. Kien Luong (KL), situated in the LXQ) had a pH of at least 4.17, which is not favourable for agriculture. For rice planting, costly alum improvements are necessary. The Hon Dat (HD) site also had a high acidity, but lighter than KL. Giang Thanh (GT) had a high pH (low acidity), appropriate for agricultural investments. Giong Rieng (GR), located in WHR, had a low pH, at 4.99 but still usable for the agricultural production. Other zones, such as Tan Hiep (TH) and Go Quao (GQ) had a pH of 5.34 and 5.43, respectively, also appropriate for rice cultivation (Table 4).

Table 4

Results of analysis of natural indicators of metals and non-metals of soil

Parameter	*Ca Mau Peninsula*			*Long Xuyen Quadrangle*			*West Hau River*		
	AM	*VT*	*AB*	*HD*	*KL*	*GT*	*GR*	*GQ*	*TH*
pH	4.25	5.29	4.30	4.54	4.17	5.48	4.99	5.43	5.34
OMI	61.85	47.93	72.43	31.55	121.28	118.03	24.07	14.70	24.64
Pb	24.60	24.30	25.90	11.17	11.73	12.17	14.70	24.07	24.64
Zn	58.18	62.99	49.20	14.55	13.29	19.09	17.96	28.83	48.05
Cu	19.45	115.07	17.80	11.22	97.31	9.66	9.58	16.34	20.20
As	8.93	6.4	7.87	7.61	8.12	3.75	3.14	5.2	5.67
Cd	0	0	0	0	0	0	0	0	0
Maximum threshold*	pH neutral=7; OMI g kg^{-1} no threshold; Pb mg kg^{-1} (70 mg kg^{-1}); Zn mg kg^{-1} (200 mg kg^{-1}); Cu mg kg^{-1} (50 mg kg^{-1}); As mg kg^{-1} (12 mg kg^{-1}); Cd mg kg^{-1} (2 mg kg^{-1}).								

*Ministry of Natural Resources and Environment 2015a).

The OMI in the three zones was 14.70–121.28 g kg^{-1}, which varied with the sampling site, being used as an agricultural pollution indicator. The OMI reached the highest value at LXQ (31.55–121.28 g kg^{-1}) and the lowest at WHR (14.70–24.64 g kg^{-1}). In CMP zone, OMI increased from 47.93 g kg^{-1} (VT) to 61.85 g kg^{-1} (AM) and even to 72.43 g/kg (AB). In the LXQ zone, OMI was the lowest at HD (31.55 g kg^{-1}) and the highest at KL (121.0 g kg^{-1}). In the WHR zone, OMI was the lowest at GQ (14.70 g kg^{-1}). The difference of OMI in each region and each district is a consequence of the past farming practices. For instance, an intensive farming of 2-3 crop cycles per year do not allow the OMI cycling in the rice land (Le & Ho 2010).

Heavy metal pollution. The Pb in all three zones was still under the allowable threshold, of 70 mg kg^{-1}. Pb was 24.30–25.90 mg kg^{-1} in the CMP zone, 11.17–12.17 mg kg^{-1} in LXQ and 14.70–24.64 mg kg^{-1} in WHR. In terms of districts, CMP had the lowest Pb concentration, 24.30 mg kg^{-1}, followed by AM, with 24.60 mg kg^{-1}, and AB with the highest concentration, of 25.90 mg kg^{-1}. In the LXQ zone, the lowest Pb concentration was recorded in HD, 11.17 mg kg^{-1}, followed by KL, with 11.73 mg kg^{-1}, and by GT, with the highest value, of 12.17 mg kg^{-1}. In the WHR zone, the lowest Pb concentration was recorded in GR, 14.70 mg kg^{-1}, followed by GQ, with 24.07 mg kg^{-1}, and by TH, with the highest value, of 24.64 kg. Although under the threshold, lead was present in a non-biogradable form, so it was very toxic to human and animal health. Pb is accumulated in the soil due to pesticides in agriculture. Although the permitted threshold has not been exceeded, it is necessary to have measures to use pesticides in the field rationally. Pb was a heavy metal element with poor mobility that had a decomposition time in the soil of 880–6,000 years (Nguyen 2014). In nature, Pb was abundant in the form PbS. After that, it was converted to $PbSO_2$ by weathering process Pb^{2+}. It participated in various processes in the soil, by clay minerals, organic matter or metal acid immobilized in the form of compounds: $Pb(OH)_2$, $Pb_3(PO_4)_2$, PbO, PbS, $PbCO_3$. In soil, Pb was adsorbed, with ionic exchange rates of less than 5%. In the form of compounds, Pb persisted in the soil, was highly toxic and limited the microbial activity.

Zn reached the highest value at CMP (49.20–62.99 mg kg^{-1}), followed by WHR (17.96–48.05 mg kg^{-1}), and the lowest at LXQ (13.29–19.09 mg kg^{-1}). In the CMP zone's districts, was of: 49.20 mg kg^{-1} in AB, 58.18 mg kg^{-1} in AM and 62.99 mg kg^{-1} in VT. The values of Zn in the districts of the LXQ zone were 13.29 mg kg^{-1}in KL, 14.55 mg kg^{-1}in HD and 19.59 mg kg^{-1} in GT. At the WHR zone, the Zn concentration in GR was the lowest (17.96 mg kg^{-1}), followed by GQ (28.83 mg kg^{-1}) and by TH (48.05 mg kg^{-1}), the highest. The allowable threshold of Zn was 200.0 mg kg^{-1}. The Zn concentration in the whole Kien Giang province did not exceed the allowed threshold. The results indicate that the use rate of the pesticides containing Zn residues was compatible with the regulations. However, it was also necessary to manage drugs with residues to protect the environment. Zinc is an essential trace element for the cell's functions (Nguyen 2014). According to Nguyen (2014), excess zinc can be toxic to organisms. Some manifestations when taking 15 mg Zn day^{-1} were nausea, abdominal pain, diarrhoea, frequent bitter mouth, low cholesterol HDL, heart risk, atherosclerosis. At a dose of 40 mg dL^{-1}, there is a risk of cardiovascular disease, immune response disorder, impaired cellular function, risk of invasive diseases (Ngoc Thinh 2020; Pasteur School of Medicine 2021).

Cu in CMP zone ranged from 17.86–115.07 mg kg^{-1}, in LXQ zone it ranged from 9.66–97.31 mg kg^{-1} and in WHR zone from 9.58–20.20 mg/kg. In the CMP zone, Cu concentration was the lowest at AB (17.80 mg kg^{-1}) and the highest at VT (115.07 mg kg^{-1}); at AM it was 19.45 mg kg^{-1} (2.3 times the Vietnamese Standard value). In LXQ zone, Cu concentration was the lowest at GT (9.66 mg kg^{-1}), followed by HD (11.22 mg kg^{-1}) and the highest was recorded at KL (97.31 mg kg^{-1}) (1.95 times the Vietnamese Standard value). Unlike the other two areas, the Cu content in WHR has not exceeded the allowable threshold. In this zone, Cu increased from 9.58 mg kg^{-1} (GR) to 16.34 mg kg^{-1} (GQ) and even to 20.20 mg kg^{-1} (TH). The results showed that the Cu content in CMP and LXQ regions exceeded the allowable threshold for agricultural soil. This is very problematic, as it can be harmful to the human health. According to Cao (2012), Cu content in the soil samples of agricultural lands in Van Lam district, Hung Yen province, ranges from 21.91–91.06 ppm (mg kg^{-1}). The Cu content in the soil ranges between 2-100 mg kg^{-1} with an average of 20 mg kg^{-1}. In addition to the natural amount of Cu in the soil, it also comes from industrial waste. Cu has a role in the human body: it is involved in producing red blood cells, white blood cells and many enzyme components (Luu 2017), but in large amounts, Cu is accumulated in the liver, kidneys and brain, causing diseases such as schizophrenia and developmental abnormalities in children. Too much Cu (>30 g) can be fatal in humans.

Toxic non-metallic pollution. Arsenic (As) was one of the substances found in pesticides. The amount of As varied in three ecological regions. The As reached the highest value at CMP (6.40–8.93 mg kg^{-1}), followed by LXQ (3.75–8.12 mg kg^{-1}) and by the lowest, at WHR (3.14–5.67 mg kg^{-1}). In terms of districts, at the three sites in the CMP zone, the As content in the soil were: 6.4 mg kg^{-1}at VT, 7.87 mg kg^{-1} at AB and 8.93 mg kg^{-1} at AM. In the LXQ zone, lowest As concentration was 3.75 mg kg^{-1} (GT), followed by 7.61 mg kg^{-1} (HD) and the highest was 8.12 mg kg^{-1} (KL). In WHR zone, As increased from 3.14 mg kg^{-1} (GR) to 5.20 mg kg^{-1} (GQ) and even to 5.67 mg kg^{-1} (TH). This result shows that the As concentration at the sampling points did not exceed the allowable threshold. As exists in the soil as compounds, mainly as arsenat (AsO_4^{3-}), under oxidizing conditions, absorbed by clay minerals, iron, manganese oxides or hydroxides and organic substances. In acidic soils, arsenic is abundant in the form of arsenite, with iron and aluminium ($AlAsO_4$, $FeAsO_4$). In alkaline and carbonate soils, which have many Ca3(AsO4)2 and phosphorus forms, As is strongly absorbed by chemisorption. The mobility of As in soil increases in reductive conditions, forming arsenite, which is more toxic than the arsenate. Cadmium (Cd) in CMP, LXQ, WHR zones was not detected, although the allowable Cd is 2.0 mg kg^{-1}. Cadmium and its metabolites are highly toxic, even at very low concentrations, they accumulate and cause bone diseases, anemia, liver and kidney failure, and many other diseases (Le & Dan 2012,2013).

BHC groups*.* the active ingredient BHC (Benzin hexachloride), a banned insecticide based on organic chlorine, has a great durability and leaves an unpleasant odour in soil, water and agriculture products such as potatoes, vegetables and beans. The thresholds for its residues in the soil environment are: Alpha BHC (Al. BHC) <0.003; Beta BHC (Be. BHC) <0.003; Gama BHC (Ga. BHC) <0.006; Delta BHC (De. BHC) <0.008. Monitoring results at the sampling sites of the three ecological zones showed that substances belonging to the BHC group do not exist in the soil. This indicates that pesticides containing BHC are strictly regulated and banned from use in these three zones.

In addition to compounds belonging to the BHC group, pesticides may contain other toxic compounds such as DD groups (Diclodiphenyl triclosan), endosulfan groups, Aldrin groups. The permissible thresholds for these groups of compounds were shown in Table 5. The results showed that in CMP, LQX and WHR zones these banned substances are not detected.

Table 5

Pollution of group BHC, DD, endosulfan, aldrin (organic chlorine base mg kg^{-1})

Parameter	*CMP zone*			*LXQ zone*			*WHR zone*		
	AB	*AM*	*VT*	*RG*	*HD*	*KL*	*GR*	*GQ*	*TH*
Al. BHC	0	0	0	0	0	0	0	0	0
Be. BHC	0	0	0	0	0	0	0	0	0
Ga. BHC	0	0	0	0	0	0	0	0	0
De. BHC	0	0	0	0	0	0	0	0	0
P,P'-DDD	0	0	0	0	0	0	0	0	0
P,P'-DDE	0	0	0	0	0	0	0	0	0
P,P'-DDT	0	0	0	0	0	0	0	0	0
a-Endosul.	0	0	0	0	0	0	0	0	0
b-Endosul.	0	0	0	0	0	0	0	0	0
End. sul.	0	0	0	0	0	0	0	0	0
Aldrin	0	0	0	0	0	0	0	0	0
Dieldrin	0	0	0	0	0	0	0	0	0
Endrin	0	0	0	0	0	0	0	0	0
End. ald.	0	0	0	0	0	0	0	0	0
End. ke.	0	0	0	0	0	0	0	0	0
Maximum threshold*	Alpha BHC (Al. BHC: 0.003); Beta BHC (Be. BHC: 0.003); Gama BHC (Ga. BHC: 0.006); Delta BHC (De. BHC: 0.008). P,P'-DDD (0.004); P,P'-DDE (0.002); P,P'-DDT (0.005). a-Endosulfal (a-Endosul.:0.016); b-Endosulfal (b-Endosul.:0.024); Endosulfal sulfat (End. sul.: 0.016). Aldrin (Ald.:0.003); Dieldrin (Diel.:0.005); Endrin (End.0.005); Endrinaldehyde (End. Ald.:0.009); Endrin kelon (End. ke.:0.005).								

*Ministry of Natural Resources and Environment 2015a.

Surface water pollution caused by pesticides and fertilizers. The results of pH measurement (at a temperature of 28-30^{0}C) in three zones give the following results: 6.14–7.22 at CMP, 6.19–6.60 at LXQ and 4.89–6.04 at WHR. There were significant salinity differences among the three ecological zones: the highest value was observed at CMP (2.78–6.45‰), followed by WHR (0.20–2.72‰) and the lowest at LXQ (0.00–0.07‰) (Table 6). The difference in pH and salinity in the three zones showed that each area was suitable for different farming methods. CMP was ideal for aquaculture, with a neutral salinity and pH. Meanwhile, LXQ and WHR had a low salinity, ideal for rice.

The allowable threshold for TSS (total suspended solids), representing the turbidity of water, ranged from 30 to 50 mg L^{-1}. The results of surface water analysis showed that the TSS measured at CMP zone ranged from 30.75 to 66.25 mg L^{-1}, at LXQ zone it ranged from 29.00 to 50.50 and at WHR zone it ranged from 45.0 to 59.75 mg L^{-1} (Table 6). The whole province, across the three zones, had five districts with values over the allowable thresholds for these indicators. The zones over the permissible threshold can still be suitable for agriculture but not for the aquaculture production.

Table 6

Natural parameter, chemical properties and nutrient pollutions

Parameter	*CMP zone*			*LXQ zone*			*WHR zone*		
	AB	*AM*	*VT*	*RG*	*HD*	*KL*	*GR*	*GQ*	*TH*
T^0	29.50	29.17	29.4	28.35	28.57	29.22	29.07	29.85	29.62
pH	6.76	7.22	6.14	6.59	6.60	6.19	6.04	5.99	4.89
Salinity	2.78	6.42	6.45	0.05	0.00	0.07	2.72	0.20	0.37
TSS	63.75	66.25	30.75	49.75	50.50	29.00	56.00	45.00	59.75
Fe	1.37	1.61	2.31	2.21	1.86	2.39	2.02	1.87	2.12
Coliform	35,500	1,700	6,100	12,025	42,500	1,425	7,007	2,325	229,825
DO	4.66	4.28	4.09	4.47	4.26	4.49	4.45	4.72	4.44
COD	27.37	30.75	35.87	29.25	20.62	17.75	26.75	23.12	29.25
BOD	15.00	15.5	17.37	17.12	12.37	11.12	14.75	12.12	15.00
$N\text{-}NO_3^-$	0.16	0.21	0.11	0.16	0.21	0.11	0.30	0.22	0.23
$N\text{-}NH_3^-$	0.45	0.31	0.43	0.58	0.74	0.44	0.33	0.11	0.39
P_2O_5	0.14	0.07	0.04	0.17	0.26	0.05	0.15	0.10	0.29
$N\text{-}NO^{2-}$	0.07	0.37	0.22	0.04	0.07	0.00	0.02	0.00	0.06
Cl	1,080	2,327	2,274	18	31	31	955	54	138
Maximum threshold*	Climate (20-25^{0}C), pH (6-8.5) (5.5-9.0), Salinity (‰), TSS (mg L^{-1}) (30-50), Fe (mg kg^{-1}) (1-5), Coliform (NPN 100 mL^{-1}) (5,000-7,500); DO (mg L^{-1}) (≥5); COD (mg L^{-1}) (15); BOD (mg L^{-1}) (6); $N\text{-}NO_3^-$ (mg L^{-1}) (15 mg L^{-1}); N-NH_3 mg L^{-1}) (1 mg L^{-1}); P_2O_5 (mg L^{-1}) (0.2 mg L^{-1}); $N\text{-}NO_2^-$ (0.05 mg L^{-1}); P_2O_5 (0.2 mg L^{-1}); Cl (mg L^{-1}) (350 mg L^{-1}).								

* Ministry of Natural Resources and Environment 2015b.

Fe was toxic for plants and human health. Fe in water was measured at temperatures between 28-29^{0}C, its values ranged in the intervals: 1.37–2.31 mg kg^{-1} at CMP, 1.86–2.39 mg kg^{-1} at LXQ and 1.87–2.12 at WHR. Coliform in water ranged in the intervals: 1,700–35,500 NPN 100 mL^{-1} in CMP, 1,425–42,500 NPN 100 mL^{-1} in LXQ and 2,325–229,825 NPN 100 mL^{-1} in WHR. Salinity in the whole province Kien Giang had a large values dispersion, influencing the cropping structure and planning for the Kien Giang province. DO concentration in the waters ranged in the intervals: 4.09–4.66 mg L^{-1}in the CMP zone, 4.26–4.49 mg L^{-1} in theLXQ zone and 4.44–4.72 mg L^{-1} in the WHR zone; In the whole province ranged from 4.09 to 4.72 mg L^{-1}. Compared to the allowable threshold indicated by Vietnam standards, DO content has a higher value than the permissible threshold (4 mg L^{-1}), thus, appropriate solutions are required in aquaculture. COD concentration at CMP, LXQ and WHR were in the intervals 27.37–35.87 mg L^{-1}, 17.75–29.25 mg L^{-1} and 23.12–29.25 mg L^{-1}, respectively. Compared to the allowable threshold indicated by Vietnam standards, COD content has a higher value than the allowable threshold (15 mg L^{-1}). BOD in the three zones waters ranged from 11.12 to 17.12 mg L^{-1}. The BOD reached the highest value at CMP (15.0–17.37 mg L^{-1}), followed by LXQ (11.12–17.12 mg L^{-1}) and by WHR, with the lowest level (12.12–15.00 mg L^{-1}). Compared to the allowable threshold indicated over Vietnam standards, the BOD content has a lower value than the permissible threshold (6 mg L^{-1}). DO and COD represent the oxygen concentration level in the water. In contrast, BOD is the oxygen demand in aerobic organisms. High DO and COD content are suitable for aquatic organisms.

Conversely, when the BOD is too high, it leads to a lack of oxygen and inhibits aquatic species growth. The organic matter composition is not thorough due to the continuous cultivation of many crops per year, without field sanitation. The excess amount of chemical fertilizer and pesticides in the field has contaminated the aquifers.

A major nutrient was nitrate $N\text{-}NO_3^-$, a residue from rice crops. During the cultivation process, a lot of chemical fertilizers generated residues in the field. $N\text{-}NO_3^-$ in the three zones ranged from 0.11 to 0.30 mg L^{-1} and in each zone it ranged as following: in the CMP zone from 0.11 to 0.21 mg L^{-1}, in the LXQ zone from 0.16 to 0.21 mg L^{-1} and in the WHR zone from 0.22 to 0.30 mg L^{-1}. Considering the allowable threshold, of 15.0 mg L^{-1}, 7/9 sites exceed the standard limits, certain sites even two times (GR). Another major nutrient was the ammonium, $N\text{-}NH_3^-$, also a residual product of fertilizers used in the fields that were not yet consumed. $N\text{-}NH_3^-$ in the three zones ranged from 0.11 to 0.74 mg L^{-1} and in each zone it ranged as following: in the WHR zone from 0.11 to 0.39 mg L^{-1}), in the LQX zone from 0.44–0.74 mg L^{-1} and in the CMP zone from 0.31 to 0.45 mg L^{-1}, all under the allowable threshold. Phosphorus pentoxide (P_2O_5) nutrient content in the waters also results from chemicals and fertilizers. P_2O_5 at sites from the Kien Giang province ranged from 0.1 to 0.29 mg L^{-1}. This compound in the three zones ranged from 0.04 to0.14 mg L^{-1} and in each zone it ranged as following: from 0.05 to 0.26 mg L^{-1} at CMP, from 0.05 to 0.26 mg L^{-1} at LXQ and from 0.01 to 0.29 mg L^{-1} at WHR. Considering the allowable threshold, of 0.20 mg L^{-1}, 2/9 sites exceed the standard limits. Nitrite ($N\text{-}NO_2^-$) nutrient in the three zones ranged from 0.00 to 0.37 mg L^{-1}; in the CMP zone, it ranged from 0.07 to 0.37 mg L^{-1}; in the LXQ zone, it ranged from 0.00 to 0.07 mg L^{-1}; in the WHR zone, it ranged from 0.00 to 0.06 mg L^{-1}. The allowable threshold is 0.2; in the whole province, there were 2/9 sites exceeding the standard limits (AM and VT).

Groundwater pollution caused by effects of surface water. The quality of groundwater for drinking purposes required the monitoring of more indicators. Groundwater in the province ranged from neutral to alkaline (pH=6.1–7.63). The pH increased from 6.1–6.57 (CMP) to 6.41–6.90 (WHR) and even to 7.50-7.63 (LXQ) (Table 7). TSS of the groundwater in the three zones ranged from 323 to 1,158 mg L^{-1}; it ranged from 470 to 895 mg L^{-1} in CMP, from 724 to 966 mg L^{-1} in LXQ and from 323 to 1,158 mg L^{-1} in WHR. This result shows that groundwater is not usable for drinking because the turbidity is higher than the standard level (30 mg L^{-1}) from 6.46 to 23.0 times. To use this water source, it is necessary to have appropriate treatment measures.

The measurement results of Fe concentration in groundwater showed that the value had not exceeded the standard threshold. Fe concentrations ranged from 0.52 - 0.86 mg L^{-1} in WHR to 0.45-1.28 mg L^{-1} in CMP and 0.4-1.32 mg L^{-1} LXQ. The COD groundwater in three zones ranged from 0.0 to 3.7 mg L^{-1}. The COD at CMP was 0.0–2.7 mg L^{-1}, at LXQ it was 3.0–3.7 mg $L^{-1}$and at WHR it was 1.0–2.2 mg L^{-1}. The results show that the COD in the water was below the standard maximum threshold (4 mg L^{-1}). Water hardness in the CMP zone ranged from 104 to 152 mg L^{-1} and in the LXQ zone it ranged from 80 to 450 mg L^{-1}. Water hardness is the highest at WHR (84–540 mg L^{-1}). The allowable threshold was 500 mg L^{-1}; in the whole province, 1 site exceeded the permissible threshold, namely GR, with 540 mg L^{-1}. Coliform of groundwater in the three zones ranged from 7.0 to 240.0 MPN 100 mL^{-1}. This value varied: from 9 to 43 MPN 100 mL^{-1} in WHR, from 7 to 93 MPN 100 mL^{-1} in CMP and from 93.0 to 240.0 MPN 100 mL^{-1} in LXQ. The allowable threshold of the coliforms is 3.00 MPN 100 mL^{-1}; all sites of the province exceeded by factors from 2.25 to 60.0 times the standard limit.

E. coli is one of the clean water and environmental sanitation indicator, it ranged from 0 to 9 MPN 100 mL^{-1}. *E. coli* was 0–4 MPN 100 mL^{-1} at CMP zone, 0–9 MPN 100 mL^{-1} at LXQ zone and 0 at WHR zone. The allowable threshold for clean water is 0; in the whole province, 3/9 sites did not reach a clean water status: VT, GR, HD.

Table 7

Parameters of groundwater pollution by effects of surface water

Parameter	*CMP zone*			*LXQ zone*			*WHR zone*		
	AB	*AM*	*VT*	*RG*	*HD*	*KL*	*GR*	*GQ*	*TH*
pH	6.1	6.57	6.35	7.63	7.52	7.50	6.59	6.41	6.90
T	29.2	28.9	28.9	28.9	28.8	28.8	28.3	27.2	27.6
TSS	512	895	470	724	854	966	1158	323	624
Fe (ts)	0.96	1.28	0.45	1.32	1.21	0.4	0.67	0.52	0.86
COD	2.4	2.7	0.0	3.7	3.3	3.0	1.0	1.2	2.2
Hardness	152	104	110	450	156	80	540	84	172
Coliform	9	7	93	240	240	93	9	9	43
E. coli	0	0	4	7	9	0	0	0	0
NO_3^-	0	0	0	0	0	0	0.16	0.16	0
NH_4^+	0	0	0	0	0	0	0	0	0.23
SO_4^{2-}	67	40	29	72	188	68	86	79	88
NO_2^-	0	0	0	0.1	0	0	0.09	0.13	0.22
Cl^-	886	123	157	143	120	979	16	18	369
Pts	0	0.25	0.19	0	0	0	0	0.26	0
Maximum threshold*	T ºC (20), TSS mg L^{-1} (50 mg L^{-1}); Fe total mg L^{-1} (5 mg L^{-1}); COD mg L^{-1} (4 mg L^{-1}); Hardness mg L^{-1} (500 mg L^{-1}); Total coliform MPN 100 mL^{-1} (3 mg L^{-1}); *E. coli* MPN 100 mL^{-1}. NO_3^- mg L^{-1} (15 mg L^{-1}); NH_4^+ mg L^{-1} (1 mg L^{-1}); SO_4^{2-} mg L^{-1} (400 mg L^{-1}); NO_2^- mg L^{-1} (1 mg L^{-1}); Cl^- mg L^{-1} (250 mg L^{-1}); P total mg L^{-1} (0.2 mg L^{-1})								

* Ministry of Natural Resources and Environment 2015b.

Nitrate (NO_3^-) in the whole province ranged from 0.00 to 0.16 mg L^{-1}. NO_3^- varied from 0.0 (CMP and LXQ) to 0.0–0.16 mg L^{-1} (WHR). In WHR, 2/3 sites exceed the allowable threshold of nitrate (15 mg L^{-1}) and the whole province has 2/9 sites found to be contaminated with nitrate and still in the allowable threshold for nitrate. NH_4^+ in three zones was 0.00–0.23 mg L^{-1}. This value was 0.0 at CMP and LXQ zones, but it was 0.00–0.23 mg L^{-1} at WHR. The allowable threshold of NH_4^+ was 1 mg L^{-1}. The WHR zone has one site with a NH_4^+ contamination, but below allowable threshold. SO_4^{2-} in the whole province has ranged from 29.0 to 188.0 mg L^{-1}. This value in the three zones ranged from 29.0 to 67.0 mg L^{-1} at CMP, from 68.0 to 188.0 mg L^{-1} at LXQ and from 79.0 to 88.0 mg L^{-1} at WHR. The acceptable standard limit of 400.0 mg L^{-1} was not exceeded. However SO_4^- being an alum ion, the groundwater cannot be used for drinking. Nitrite (NO_2^-) in the whole province ranged between 0 and 0.22 mg L^{-1}. NO_2^- at CMP was 0 mg L^{-1}, but this value ranged from 0 to 0.1 mg L^{-1} (LXQ) and from 0 to 0.22 mg L^{-1} (WHR). Allowable threshold is 1 mg L^{-1}. Cl^- in the whole province ranged from 16.0 to 979.0 mg L^{-1}. The values recorded at LXQ ranged from 120.0 to 979.0 mg L^{-1}, at CMP they ranged from 123.0 to 886.0 mg L^{-1} and at WHR they ranged from 16.0 to 369.0 mg L^{-1}. in the whole province, there were 9/9 sites exceeding the allowable threshold, of which 3/9 sites exceeded it 1.45–3.9 times (TH 1.45 times, AB 3.45 times, KL 3.9 times).

Conclusions. The results of the soil composition investigation in Kien Giang show that the soil structure varied from low to medium acid soil. In the dry season, soil structure is also affected by saline intrusion. The content of some heavy metals in the soil like Pb, Zn, and As was within the allowable range. However, the content of Cu and Fe in the soil is relatively high and exceeds the permissible threshold in agricultural land. No residues of pesticides were detected at the 9 study sites. The amounts of DO and OM in the soil at these sites were relatively low, but TSS, BOD, and Coliform existed beyond the threshold at some points. In addition, the investigation results of groundwater pollution showed that TSS content exceeded the threshold from 6 to 23 times the allowable standard. Concentrations of COD, coliform, and *E. coli* in the water are all above the permissible threshold. This result shows that the soil in the study sites in Kien Giang province is being polluted by heavy metals (Cu and Fe). Meanwhile, groundwater standards are also polluted and do not meet acceptable standards. These data are instrumental in proposing solutions to soil and groundwater pollution in the study area. There is a need to set up suitable solutions to treat water before raising aquatic species, creating a clean food source, and protecting the health of farmers and consumers.

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