Research article

Ecological Risk Assessment of Using Swine Wastewater for Agriculture

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Abstract The environmental consequences of swine farming are of increasing public concern particularly from waste and waste water. Environmental risk assessment is a key tool to deal with concerns from wastewater reuse by land application.The aims of this study were to evaluate: (i) the diffuse pollution from swine farm, in terms of water quality parameters in effluent and copper contamination due to the application of swine waste water in different Thai soil series; and (ii) the impact of copper in swine wastewater on soil biota activity (soil respiration and earthworm avoidance behavior). The results found that wastewater effluent had average BOD, COD,TDS, Total N, pH and EC at 467, 320, 3950, 0.048 mg/L, 7.8 and 4.5 dS/m, respectively, and average copper concentration of 0.05-0.28 mg/L. Copper contamination was analyzed in two Thai soil series (Roi et (Re) and Namphong (Ng) soil series) after application of the swine wastewater. The results showed that copper level in the Roi et soil series was higher than for Namphong soil series but the copper concentration in leachate from two soil series was the opposite. Soil microbial activity in soil receiving application of swine wastewater was greater than found for the control plot (without applying swine wastewater). The 50% avoidance behavior of earthworm on copper (EC_{50}) in the Namphong (Ng) and Roi et (Re) soil series were 153and 61 mg/kg soil at 7 days. In conclusion, the land application of swine waste water effluence should consider the ecological risks and impact on soil ecosystem from different soil ecosystems as a basis for land management.

Keywords diffuse pollution, swine wastewater, copper, soil series

INTRODUCTION

Swine production has been increasing in many countries including Thailand as pork is a major source of food. However, the environmental consequences of swine farming are of increasing public concern particularly offensive odors emitted from pig manure, urine and waste water. Moreover, an accumulation of copper (Cu) from swine feed in surface soils may have impact on the biological health of soil. Using waste from swine farm on land application has many limitations including risks of ground and surface water contamination by leachate and runoff. Moreover, it is known that the bioavailability and toxicity of Cu in soil varies across different soil types. The concentration and bioavailability of heavy metals in composted organic wastes have negative environmental impacts following land application (Bolan et al., 2003)

Copper is one of the metals found in waste and wastewater from swine production at high concentrations. Copper is an essential element for all organisms at low concentrations but toxic above threshold concentrations. Since heavy metals are not degradable, the accumulation of copper in the soil may have long effects on the plants growing in the soil. It has been reported that excess amounts of copper may inhibit photosynthesis of plants and cause chlorosis of leaves (Liu et al., 2006). The effluent of swine generated in the agricultural properties is known for its high pollutant potential. Usually, the effluents are treated and later applied to the soil as a manure form and in reuse of water

(Miaomiao et al., 2008). However, these applications may occur without a defined rate that considers the soil conditions in the area. As a consequence, it causes problems from diffuse pollution due to the runoff and movement of ions in the profile of the soil. Therefore, ecological risk assessment of swine wastewater uses in Thai soil ecosystem needs to be investigated.

The aims of this study were to evaluate (i) the ecological risk assessment of using swine wastewater from swine farm, in terms of water quality parameters in effluent such as BOD, COD, total nitrogen, nitrate, nitrite, phosphorus, and copper contamination due to the application of swine wastewater in different Thai soil series; and (ii) the impact of copper in swine wastewater on soil biota activity (soil respiration and earthworm avoidance behavior) and plant growth.

MATERIALS AND METHODS

The experiments of this study were divided into 3 parts: (i) swine wastewater characterization; (ii) laboratory based copper contamination due to the application of swine wastewater in different Thai soil series; and (iii) field assessment of the effects of using swine wastewater for land application in sugarcane plot using a ecotoxicological monitoring approach based on soil functionality, chemical soil property and plant growth, and laboratory based on ecotoxicity of copper in swine wastewater on earthworm avoidance.

Chemical analysis

Waste water was collected from the swine farms and analysed for water quality parameters following the standard methods for the examination of water and wastewater (American Public Heath Association, 1980). The experiment for the investigation of copper contamination in two Thai soil series was carried out in a laboratory. The experiments were conducted in polyethylene culture pots, each of capacity 500 ml. The soils series used for this study were from Roi et and Namphong (Sandy) soil series. The physical and chemical properties of soil are shown in Table 1.

The soil samples from the study site between the sugarcane plot using swine wastewater and without using swine wastewater were air-dried and ground well before chemical analysis, such as pH, organic carbon, organic matter, total N, available P, extractable K, Na, and Mg. To determine total copper concentrations, the soil samples were digested by tri-acid mixture (HCl-HNO_3-$HClO_4$). Copper was measured by AAS and data were tabulated as mean ± standard deviation (S.D.) or mean ± standard error (S.E.). Sugarcane’s growth and sweetness were measured.

Total heavy metals (Cu) concentrations were analyzed by digesting with HF-HNO_3-$HClO_4$ procedures (Carter, 1993) and then measured by AAS.

Soil biological activity was analyzed by basal respiration with placing 30 g of field moist soil in a 50 ml beaker and incubating the sample for 1 day in the dark at 25^{o} C in an air tight sealed jar along with 10 ml of 1 M NaOH. The CO_2-C evolved was determined after 1 day by titration (Anderson and Domsch, 1990). Basal respiration rate was calculated based on CO_2 evolution over the 1 day period.

The avoidance tests with earthworms were based on the ISO (2005).Each test chamber (replicate) consisted of a plastic box (20 cm in length, 12 cm in width and 5 cm in height) divided in two sides by a card divider inserted transversally in middle position. The control side was filled with 150 g dry weight of two Thai soil series (Roi et (Re) and Namphong (Ng) soil series) without contaminant, also in the other side, the same amount of contaminated soil was placed. The divider was then removed and 10 adult earthworms, previously washed and dried with absorbent paper, were placed onto the middle line. To prevent worms from escaping, the test containers were covered with a lid with a few pierced holes to allow for aeration. The tests were run for a maximum period of 1 week at 27ºC with a photoperiod of 16:8 h light dark.

Statistical analysis

Statistical analysis including calculation of average values, standard deviation (S.D.) and regression was performed on the data obtained in the tests with Microsoft Excel and SPSS 12.0. Test of significance was performed by one-way analysis of variance (ANOVA) by Statistic V8.

RESULTS

The water quality parameters of swine effluent are shown in Table 2. It was found that the swine wastewater effluent had an average BOD, COD ,TDS, total N, total Cu, pH and EC value at 467 mg/L, 320 mg/L, 3950 mg/L, 0.048 mg/L, 0.06 mg/L, 7.8 and 4.5 dS/m, respectively. The results showed that copper were found in Roi et (Re) soil series higher than Namphong (Ng) soil series, but in opposite with the copper concentration in leachate from two soil series (Table 3). The data for Cu accumulation in two Thai soil series (Roi et (Re) and Nampong (Ng) soil series) resulting from swine wastewater application indicated that higher level of Cu was found in Roi et (Re) soil series than Namphong (Ng) soil series (Table 3).

The difference in Cu accumulation between the soil series may be attributed to the difference in soil properties including organic matter content and CEC. The impact of using swine wastewater on sugar cane production was showed in Tables 4, 5 and 6. The results indicated that sugar cane growth with swine wastewater was better than that in the control. Moreover, there was no significant effect in sweetness of sugar cane in both sites ($P>0.05$) and in addition Cu concentration was slightly higher in effluent treated soil (Table 5). Fig. 1 shows the effects of avoidance percent of earthworm exposure on copper contaminated soil in two Thai soil series (Roi et (Re)). 50% avoidance of earthworm on copper contaminated Roi et (Re) soil serie was lower than that of Namphong (Ng) soil series. This result indicates that the impact of copper on the avoidance of earthworm in the Roi et soil series was higher in the Namphong soil series.

Table 1 The chemical characteristic of two Thai soil series

Parameter	Soil series	
	Roi et (Re)	Namphong (Ng)
pH	5.13	4.29
N (%)	0.03	0.01
P (mg/kg)	4.71	5.63
K (mg/kg)	42.63	0.04
CEC (cmol/100g soil)	9.95	3.96
OM (%)	1.13	0.44
Na (mg/kg)	12.11	1.23
Electrical Conductivity (dS/m)	0.06	0.19

Table 2 Selected water quality of swine wastewater effluent

Parameter	Value
pH	7.8 ± 0.07
BOD (mg/L)	467 ± 50
COD(mg/L)	320 ± 25
Electrical Conductivity(EC,ds/m)	4.5 ± 0.10
TN (%)	0.048 ± 0.004
TDS (mg/L)	3950 ± 120

[a] *values are means ± standard deviations (n = 3).*

Table 3 Copper concentration (mg/kg) in soil and leachate in different soil series after applied swine wastewater

	Cu concentration		% Distribution of Cu in soil and leachate	
	Roi et (Re)	Namphong (Ng)	Roi et (Re)	Namphong (Ng)
Soil (mg/kg)	5.758	4.030	52.6 %	30.6 %
Leachate (mg/L)	5.183	9.154	47.3 %	69.4 %

Cu concentration in swine wastewater was 0.05-0.28 mg/L, Cu concentration in swine manure was 284 mg/kg.

Table 4 The impact of wastewater from swine wastewater on sugar cane production

Plots	Height (metre)	Sweetness (Brix)
Sugar cane Plot (without swine wastewater)	2.786 ± 0.23a	9.311 ± 3.69
Sugar cane Plot (swine wastewater)	3.582 ± 0.089b	9.022 ± 2.11

Value are mean ± standard deviation. Mean with the same letter in the column is not significantly different (P>0.05).

Table 5 Copper concentrations in soil at study sites

Plots	Cu (mg/kg)
Sugar cane Plot (without swine wastewater)	1.19
Sugar cane Plot (with swine wastewater)	2.37

Table 6 Impact of wastewater from swine wastewater on soil respiration at study sites

Plots	Soil respiration (mg CO_2/day)
Sugar cane Plot (without swine wastewater)	20.23 ± 0.93^b
Sugar cane Plot (swine wastewater)	30.67 ± 1.53^a

Value are mean ± standard deviation. Mean with the same letter in the column are not significantly different (P>0.05).

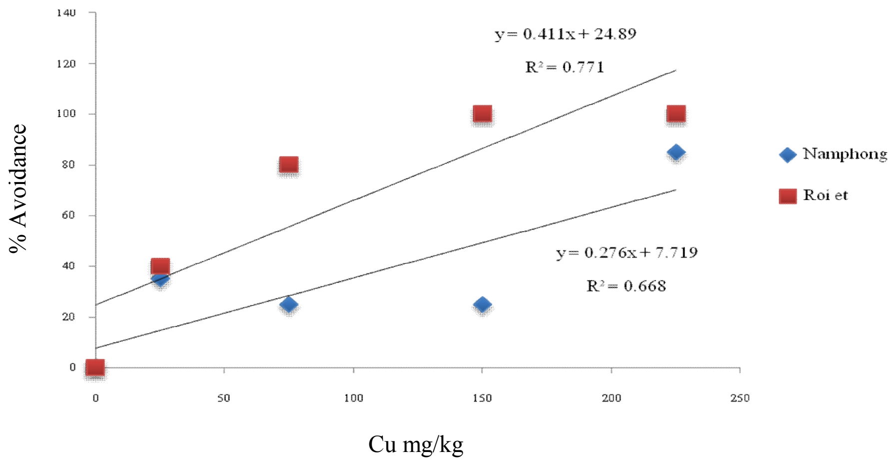

Fig. 1 Avoidance behavior of earthworm exposure to copper contaminated soils applying swine wastewater

CONCLUSION

It was clear that the land application of swine wastewater effluent should be considered from viewpoint of the ecological risk and the impact on soil ecosystem.

Based on the results from short term observation, the benefit of the reusing swine wastewater was more than the impact, as it can provide nutrients that was good for the plants growth and soil quality. The use of wastewater from swine farming did not cause any detrimental effect on soil biota in this short term study. The results from this study also showed that the effect of land application of swine wastewater effluents on soil ecosystem varies with soil types; hence appropriate application levels being suitable for various soil types should be investigated. However, long term effects of reuse swine wastewater for agriculture on soil ecology need to be investigated.

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