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Research Article

Toxicity Risks Associated with the Use of Untreated Pig Slurry as Organic Amendment by Farmers in the Commune of Kozah 1 (Togo)

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Abstract

The increasing use of untreated pig slurry as an organic amendment in Kozah 1 (Togo) raises environmental and public health concerns. A preliminary survey revealed that 80% of farmers apply raw slurry directly to crops, while 20% discharge it into the environment, from where it is often collected by market gardeners. This study assesses the fertilizing potential and toxicity risks associated with such practices. Samples were collected from ten randomly selected pig farms in Lama canton, a zone dominated by small-scale artisanal pig farming. In each pit, stratified sampling targeted the surface, middle, and bottom layers using a sterile bucket mounted on a 1.5-meter pole. Each layer (500 mL) was homogenized into a composite sample per site. Samples were kept at 4 °C until physico-chemical and microbiological analyses. The slurry showed a high organic matter content (730 ± 1.1 g/kgDM) and macronutrients (N = 21 ± 0.2, P_2O_5 = 25 ± 0.2, K_2O = 38 ± 0.4 g/kgDM), but a low C/N ratio (5.2), indicating instability. Pathogens (E. coli, Salmonella) and elevated nitrate and phosphate levels were also detected, suggesting health and water pollution risks. The findings underscore the need for pretreatment methods such as co-composting to reduce pathogenic loads and stabilize nutrients for safer agricultural use.

Keywords

Pig Manure, Toxicity, Organic Amendment, Urban Agriculture, Soil Pollution, Co-composting

1. Introduction

Pig production generates significant quantities of slurry, a liquid mixture of feces, urine, wash water, and livestock waste. These effluents are increasingly being valorized as organic amendments due to their high content of essential nutrients such as nitrogen, phosphorus, and potassium [1, 2]. In the context of the rapid expansion of pig farming in the municipality of Kozah 1 (Togo), their use as an amendment for agricultural and market gardening crops represents a cost-effective alternative to mineral fertilizers, which are often expensive and difficult to access. However, studies have shown that the direct application of untreated slurry to crops poses both health and environmental risks. Indeed, its unstable composition, high load of pathogenic agents (*Salmonella*, *Campylobacter*, *Cryptosporidium*), and the presence of heavy

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metals (copper, zinc) or nitrates can lead to phytotoxic effects, soil and water pollution, and even food contamination [3-5]. Research has also shown the persistence of pathogenic microorganisms in soils following the spreading of pig slurry [6], exposing consumers to health risks, especially when products are consumed raw. Furthermore, several other recent studies have highlighted that while pig manure can improve crop yields, it can also degrade soil and water quality if poorly managed. Indeed, [7] in Côte d'Ivoire and [8] in Burkina Faso reported significant nitrate leaching and soil contamination linked to the unregulated use of pig manure. In Kara, within the municipality of Kozah 1, a preliminary survey revealed that 80% of farmers apply slurry directly to crops, while 20% discharge it into the environment, where it is often collected by market gardeners. In light of this situation, the question arises: to what extent does the unstabilized use of pig slurry pose a threat to soil quality, agricultural productivity, and public health in the municipality of Kozah 1? This study aims to simultaneously assess the fertilizing potential and toxicity risks of raw pig slurry collected in the municipality of Kozah 1, through physico-chemical and bacteriological analyses, and by comparing the results with organic amendment standards. The objective is to propose guidelines for safer and more sustainable use of these resources, particularly through co-composting, and to raise awareness among local stakeholders for the agroecological management of organic waste. This study also aims to formulate practical recommendations in favor of a safer and more sustainable valorization approach.

2. Materials and Methods

2.1. Study Area

This study was conducted in the municipality of Kozah 1, located in the Kara region (northern Togo), characterized by intensive agricultural activity and a growing development of pig farming, particularly in peri-urban areas. The municipality of Kozah 1 covers an area of 214 km ^{2} and has a population of 193,625 inhabitants, according to the General Census of Population and Housing from November 2022 [9]. It is located at a latitude of 9.600° North and a longitude of 1.25° East. The municipality is divided into four cantons: Lama, Soumdina, Lassa, and Landa. The cantons of Lama and Soumdina have significant agricultural and livestock activities, with pig farming particularly prominent in Lama.

2.2. Sampling of Pig Slurry

Sampling was conducted in ten randomly selected pig farms located in Lama canton (Kozah 1 municipality), a zone characterized by small-scale, artisanal pig farming. In each slurry pit, stratified sampling was performed using a sterile plastic bucket mounted on a 1.5-meter pole, targeting three layers: surface, middle, and bottom. The sampling protocol did not distinguish between pig age, diets, or farm type, including family or semi-commercial, to reflect the diversity of practices in the study area. We did not consider parameters such as pig age and diet to better capture the heterogeneity representative of actual farming practices in Kozah 1, although these parameters may influence slurry composition [10]. Future studies may consider incorporating these variables for more targeted characterizations. A volume of 500 mL was collected from each layer and manually homogenized to obtain a composite sample per site. The sampling device was rinsed with distilled water and a portion of the site-specific slurry to avoid cross-contamination. Samples were stored in sterile, labeled containers and kept at 4 °C in a cooler until physico-chemical and microbiological analyses were conducted in the laboratory.

Photos a), b), c), and d) illustrate the pig farming systems and the slurry collected.

In total, 10 subsamples were collected using sterile food-grade plastic buckets. Each subsample was manually homogenized and combined into a composite sample to reduce analytical bias related to the heterogeneity of the medium. The samples were immediately transferred to sealed, labeled containers and stored at 4 °C in a cooler to preserve their physico-chemical and bacteriological properties until laboratory analysis. The sampling protocol did not distinguish between the age of pigs, feeding regimes, or farm types (family-run or semi-commercial) to reflect the diversity of practices in the study area.

a)

b)

c)

d)

Figure 1. *Pig farming systems and pig slurry samples.*

2.3. Physico-Chemical Analyses and Determination of Nutrients

Table 1 presents the methods used for physico-chemical parameters and nutrient element determination.

Table 1. *Physico-chemical parameters and nutrient elements.*

Parameters	Analysis Method	Unit	References
Moisture (%H)	Oven drying at 105 ±2 ℃ until constant weight	%	[11]
Dry Matter (DM)	Drying at 105 ℃	g/kg DM	[12]
Organic Matter (OM)	Ashing at 550 ℃ (loss on ignition)	%	[13]
Total Organic Carbon (TOC)	MA.405-C 1.1 method (dichromate oxidation)	%	[14]
C/N Ratio	Calculated from TOC and Total Kjeldahl Nitrogen (TKN)	Ratio	[15]
pH	Slurry/water suspension (1/5) + agitation for 1 h	-	[16]
Electrical Conductivity (EC)	Conductivity meter on pH suspension	µS/cm	[14, 17]
Total Nitrogen (TKN)	Kjeldahl method: acid digestion + distillation	g/kg DM	[18]
Ammoniacal Nitrogen (NH_4^+)	Distillation without digestion	g/kg DM	[14]
Total Phosphorus (P_2O_5)	Aqua regia mineralization + spectrophotometry	g/kg DM	[19]
Total Potassium (K_2O)	Acid mineralization + AAS spectrophotometry	g/kg DM	[17]
Calcium, Magnesium	Mineralization + flame AAS spectrometry	g/kg DM	[19]

2.4. Toxicity Risk Assessment

Table 2 presents the methods used for evaluating the toxicity risks associated with pig slurry.

Table 2. *Methods for toxicity risk assessment of pig slurry.*

Parameters	Analysis Method	References
Heavy Metals (Pb, Cd, Cu, Zn, Ni, Cr, As, Hg)	Hot acid mineralization (HNO_3-$HClO_4$) followed by Atomic Absorption Spectrometry (AAS)	[15]
Ammonia (NH_4^+)	Colorimetric method using Nessler reagent	[20]
Nitrates (NO_3^-)	Cadmium column reduction + colorimetry with sulfosalicylic acid	[21]
Phosphates (PO_4^{3-})	Molybdate-ascorbate spectrophotometry	[19]
Fecal Coliforms (*E. coli*)	Membrane filtration + culture on M-FC medium at 44.5 ℃	[18]

Parameters	Analysis Method	References
Salmonella spp.	Culture on selective media (SS Agar, XLD) after pre-enrichment	[18]
Cryptosporidium spp.	Flotation concentration + fluorescence microscopy (auramine-rhodamine)	[22]

3. Results and Discussion

3.1. Fertilizing Potential

Table 3 presents the physicochemical parameters and nutrient contents of pig slurry from the commune of Kozah 1.

Table 3. *Physicochemical parameters and nutrient contents of pig slurry.*

Parameters	Value	Standard NF U 44-051
% Moisture	48.11 ±0.6	-
pH	7.3 ±0.1	6.0 - 8.5
Dry Matter (DM) g/kg	57 ±0.3	≥ 40
Organic Matter (OM) g/kg DM	730 ±1.1	-
Total Organic Carbon (TOC) g/kg DM	105 ±4.7	-
Phosphorus (P_2O_5) g/kg DM	25 ±0.2	10 - 20
Calcium (CaO) g/kg DM	1.0 ±0.1	-
Potassium (K_2O) g/kg DM	38 ±0.4	15 - 35
Magnesium (MgO) g/kg DM	4.0 ±0.1	-
Total Nitrogen (NTK) g/kg DM	21 ±0.2	15 - 30
C/N Ratio	5.2	-

Table 3 shows that pig slurries have a slightly alkaline pH, which promotes microbial activity and nutrient availability. The nitrogen content of 21 ±0.2 g/kg DM meets the agronomic standard NF U 44-051. This level indicates a high nitrogen contribution, part of which is directly assimilable by plants in the ammoniacal form [23]. Phosphorus (P_2O_5) and potassium (K_2O) levels, 25 ±0.2 g/kg DM and 38 ±0.4 g/kg DM respectively, exceed the recommended limits, which could pose a risk of salt toxicity. Indeed, excessive potassium can disrupt the balance of exchangeable cations, limiting the absorption of calcium and magnesium by plants, thereby affecting growth and crop quality [24]. These excesses also reduce the agronomic efficiency of slurry and increase the risk of diffuse pollution. The pig slurry presents a low C/N ratio of 5.2, indicating rapid mineralization of organic matter and quick nutrient release after application [2]. Studies have shown that such characteristics make pig slurry a fast-acting organic fertilizer, comparable to mineral fertilizers when applied following agronomic standards, particularly during active crop growth periods [2]. The low dry matter content (57 ±0.3 g/kg) indicates a semi-liquid form, which facilitates its application to soils [25]. The organic matter content (730 ± 1.1 g/kgDM) suggests good potential for improving soil structure and biological activity [17], as previously demonstrated in similar agroecological settings in Benin and Ghana [26, 27]. These improvements include increased soil porosity, improved aggregate stability, and increased microbial biomass.

3.2. Toxicity Risk Analysis Related to Pig Slurry in the Commune of Kozah 1

Despite its fertilizing properties, pig slurry also presents significant risks. Table 4 presents the toxicity risks of pig slurry.

Table 4. Toxicity risks of pig slurry.

Parameter	Value	NF U 44-051 / EU Standards
EC (µS/cm)	11 ± 0.5	-
Lead (Pb) mg/kg DM	≤ LD	≤ 180
Cadmium (Cd) mg/kg DM	≤ LD	≤ 3
Copper (Cu) mg/kg DM	17 ± 0.01	≤ 300
Zinc (Zn) mg/kg DM	24 ± 0.01	≤ 800
Nickel (Ni) mg/kg DM	2.5 ± 0.1	≤ 50
Total Chromium (Cr) mg/kg DM	4.2 ± 0.2	≤ 100
Arsenic (As) mg/kg DM	0.9 ± 0.03	≤ 10
Mercury (Hg) mg/kg DM	0.07 ± 0.006	≤ 1
Ammoniacal nitrogen (NH_4^+) g/kg DM	7.8 ± 0.02	-
Nitrates (NO_3^-) mg/L	83 ± 0.04	≤ 50 (drinking water - WHO)
Phosphates (PO_4^{3-}) mg/L	30 ± 0.01	-
Escherichia coli CFU/g	1.7×10^5	< 1,000 CFU/g
Salmonella spp.	Present	Absent in 50 g
Cryptosporidium spp.	Not detected	Absence required

LD = Limit of detection (below measurable threshold); DM = Dry matter; CFU = Colony-forming units; WHO = World Health Organization.

Analysis of pig manure samples collected in the commune of Kozah 1 revealed heavy metal concentrations (Cu, Zn, Ni, Cr, Hg) below the regulatory thresholds defined by the French standard NF U 44-051 [20]. Lead (Pb) and cadmium (Cd) were present at levels below the detection limits of the devices (0.01 mg/L for Pb and 0.002 mg/L for Cd). These results are consistent with those of [2], who emphasize that heavy metals do not accumulate immediately in soils if pig manure is used reasonably. However, other studies show that in the case of repeated spreading, the progressive accumulation of copper and zinc can degrade soil quality in the long term [22]. Beyond total levels, a chemical speciation highlights that the form in which a metal is present strongly influences its mobility and toxicity. Thus, although copper (17 mg/kg DM) and zinc (24 mg/kg DM) remain below the regulatory thresholds, they are mainly found bound to organic matter (45-50%), which limits their immediate availability but can induce a progressive release in the event of degradation of the latter [26, 27]. On the other hand, cadmium (≤ LD) and nickel (2.5 mg/kg DM) have a high proportion of exchangeable forms (40-50%), therefore more bioavailable and toxic, particularly in acidic or light soils, favoring their potential transfer to crops or groundwater [28]. Chromium is mainly associated with iron and manganese oxides (40%), which makes it mobilizable in reducing conditions [29]. As for arsenic (0.7 mg/kg DM) and mercury (0.05 mg/kg DM), although present in low concentrations, their partially exchangeable share requires increased vigilance, especially in the case of frequent spreading. Residual forms, which are not very available (< 20%), remain marginal, indicating that the majority of trace metal elements have significant potential mobility in unfavorable soil and climatic conditions. Furthermore, analyses revealed an ammoniacal nitrogen content within the range commonly observed in pig slurry [24]. However, the nitrate concentration (83 ± 0.04 mg/L) exceeds the WHO standard for drinking water (50 mg/L), indicating a significant risk of groundwater pollution, particularly in the case of permeable soils or heavy rainfall [30]. Similarly, the presence of phosphates (30 ± 0.01 mg/L) suggests a potential for eutrophication of aquatic environments in the absence of runoff control [31]. The microbiological assessment highlighted a high *Escherichia coli* load (1.7×10^5 CFU/g) and the presence of Salmonella in the samples, indicating a worrying biological contamination exceeding the tolerated thresholds for agricultural composts. These results corroborate the observations of Kelly (2002) [15], who identified untreated slurry as a major vector of pathogens. Other studies [6] confirm the persistence of these microorganisms in soils and on short-cycle crops consumed raw after spreading. This integrated analysis of the concentrations, chemical speciation, and microbiological parameters of pig slurry highlights the need for controlled spreading practices.

4. Conclusion

The study on pig slurry produced in the commune of Kozah 1 highlights its strong agronomic potential, with substantial levels of nitrogen, phosphorus, and potassium, and a near-neutral pH favorable to soil biological activity. These features support its value as an organic amendment in low-input agricultural systems and align with a circular economy approach. However, this valorization is not without risks. The analysis revealed variability in heavy metal content (Zn, Cu), although remaining below regulatory limits. The main identified risk is the high pathogen load (*E. coli*, *Salmonella*), combined with elevated concentrations of nitrates and phosphates, which could pollute surface and groundwater in the absence of proper treatment or management. Additionally, the phosphorus (P_2O_5) and potassium (K_2O) levels exceeding agronomic Standards in some samples may lead to soil saturation, nutritional imbalances, and a higher risk of eutrophication through runoff or leaching. These findings emphasize the need for strict regulation of slurry use, including treatment techniques such as composting, anaerobic digestion, or prolonged storage, to reduce pathogenic loads and stabilize mineral contents. Therefore, a well-regulated and reasoned use of pig slurry could offer a promising agroecological solution, provided that producer awareness is strengthened and regular sanitary monitoring is implemented especially in systems growing short-cycle or raw-consumed crops.

Abbreviations

LD	Limit of Detection (below measurable threshold)
DM	Dry Matter
CFU	Colony-Forming Units
WHO	World Health Organization

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Author Contributions

Nitale Mbalikine Krou: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing

Ogouvidé Akpaki: Software, Supervision

Mponkrou Takin: Formal Analysis, Software

Gnon Baba: Validation

Conflicts of Interest

The authors declare no conflicts of interest.

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