American Journal of Agriculture and Forestry
2023; 11(6): 233-246
http://www.sciencepublishinggroup.com/j/ajaf
doi: 10.11648/j.ajaf.20231106.14
ISSN: 2330-8583 (Print); ISSN: 2330-8591 (Online)

Beneficiation of Agricultural Waste from Piggeries Located Within Residential Areas in Promoting Green Production

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To cite this article:
Samuel Kodani. (2023). Beneficiation of Agricultural Waste from Piggeries Located Within Residential Areas in Promoting Green Production. *American Journal of Agriculture and Forestry*, *11*(6), 233-246. https://doi.org/10.11648/j.ajaf.20231106.14

Received: August 10, 2023; **Accepted**: September 13, 2023; **Published**: November 29, 2023

Abstract: Piggeries are a quick way of generating an income in agriculture. It also raises some policy challenges in economic, environmental, health and social dimensions for sustainable agriculture. An evaluation of implications of piggery projects sited within homesteads indicated that 70% of the population do not support having piggeries in their midst. This population understood the implications of pig waste and waste water on environment implications. Pig waste was noted to possess high levels of nutrients necessary for crop production and these may also pollute the environment. Splitting of the waste into solid and liquid was noted as a way of reducing foul smell peculiar to piggeries. Using the waste management hierarchy priorities, piggery waste nutrients and waste water recycling was recommended as a better option for environmental sustainability. The solid waste was composted or processed to solid fertilizers. Irrigation suitability tests was used to recommend the liquid for reuse in irrigation and also in liquid fertilizer manufacturing. This study demonstrated the need for proper piggery waste management in communities and adequate enforcement and updating of statutory instruments to suit current environmental demands.

Keywords: Piggery Waste, Beneficiation, Pollution, Waste Management, Environmental Sustainability

1. Introduction

1.1. The Concept of Agricultural Waste Management

Agricultural waste management is a big challenge especially in the developing world. It is defined as the collection, transportation, processing, treatment, recycling or disposal, and monitoring of agricultural waste materials. Waste management relates to materials produced by human activity and is generally undertaken to reduce their effect on health, the environment, or aesthetics according to Demirbas [4]. Waste can be in the form of solid, liquid, gas and particulates according to Prakriti Kashyap [12]. Solid waste is known as the third pollution after air and water pollution. Agricultural waste consists of highly heterogeneous matrix of organic and inorganic chemicals that vary from farm to farm and also animal to animal, hence cannot be generalized in its definition and handling. It can be categorized into four main groups, namely, animal waste, crop waste, food processing waste, and hazardous and toxic wastes.

Pig waste and faeces accrue very fast and often spread to the surrounding neighborhood, polluting the air and water with toxic waste particles. Pig waste was characterized as consisting of faeces, urine, wasted feed, and water spilled from the drinking nipples by Taiganides Paul. E [22]. He noted that total solids content of wastewater is normally less than 3%. There are limited options of disposing the ever accumulating piggery waste and Table 1 helps “would be farmers” in prioritizing decisions on waste management. Soils become saturated with organics hence stockpiling begins. Dumping into the sea or burning are not a good environmental options according to Table 1 priority recommendations.

Table 1. *The waste management hierarchy arranged in descending order of priority. Source: Fatimatul ZA et al [7].*

Goal	Attribute of ways	Outcomes
Avoid and reduce	Preventative	Most Desirable
Reuse, recycle, recover energy	Predominantly ameliorative, part preventative	⇕
Treatment	Predominantly assimilative, partially ameliorative.	
Disposal	Assimilative	Least Desirable

Waste management is very useful for recycling nutrients sustainably for food production. The world major easy access sources for macro elements like potassium and phosphorus are dwindling as noted by hence the need for recycling. Turning nutrients in agricultural wastes (liquids and solids) into agricultural resources by transforming the agricultural sanitation systems becomes the guiding principle for sustainability. “Life-cycle thinking” should be applied with consideration of environmental impact when utilizing mineral resources in agriculture. This process starts from extraction of the resource to – and including – its disposal phase either intentionally or unintentionally. According to van Dijk et al [24], action should begin where waste originates, rather than where it ends up unlike in the traditional “end-of-pipe” treatment which generates a lot of challenges in waste management. This is where the usefulness of Table 1 comes into play.

1.2. Legislation in Pig Production in Zimbabwe

Several policy documents has been adopted in Zimbabwe that recognize the importance of developing efficient waste management systems like the Environmental Impact Assessment policy launched in 1994. This spells out that an Environmental Impact Assessment (EIA) as a national instrument shall be undertaken for proposed activities that are likely to have adverse impact on the environment. Prior to the enactment of EIA Policy was the Environmental Management Act (Cap 20:17) [6], the EIA policy and the national EIA process carried no legal force. The Environmental laws, the Urban Councils Act, the public Health act and Municipal by-laws governs refuse collection in Zimbabwe as governed by [6]).

Checkups on enforcement are done by the Environmental Management Authority (EMA) and the Ministry responsible for the Environment. The Water Act Chapter 20:24 addresses the issue of waste management in Section (1) where it prohibits the discharge of any organic and inorganic matter into any surface or groundwater, either directly or indirectly so as to cause pollution of water. The Public Health Act (Chapter 15:09) under section 68 (1) (b) provides for the Minister of Health and Child Welfare to make regulations prohibiting the erection of dwellings, sanitary conveniences, stables, cattle kraals, pig sties, ostrich pens, dip tanks, factories or other works likely to entail risk of harmful pollution of water supply or prohibiting or regulating the deposit in the vicinity of, or draining into any such place, of manure, filth or noxious or offensive thing. This shows that the problem is one of inadequate enforcement rather than absence or ineffectiveness of the laws and policies within the country.

1.3. Nature of Pig Manure

Pig manure is rich in phosphate and nitrogen in the form of nitrate apart from the high organic content according to Olorf D (2018), Jongbloed WA (2008) and also shown in Table 3. Electrical conductivity which is a measure of a solution to conduct electricity is directly linked to Total Dissolved Solids (TDS). This has proved to be high in piggery wastewaters. Separation processes such as removal of suspended solids through sedimentation or filtration will give no changes ion conductivity proving that it is centred on dissolved solids. Kristen Philipkoski [14] noted that piggeries pollution of soil, water and air is an aspect more stressed in the Netherlands, where 90% of ammonia emissions come from animal husbandry. Kadurumba et al [10] alluded to River State, Nigeria, where most small scale communal farmers have established their ventures within residential areas.

Table 2. *nutritional composition and distribution in separating the solid and liquid fractions of pig waste. Source:*

Fertilizer element	% in solid waste	% in liquid waste
Nitrate (N)	50	50
Phosphorus (P)	95	5
Potassium (K)	15	85

They noted that piggeries are naturally polluting hence an assessment on the technical and social context of the impact on the environment should be carried out. Pollution can be from the whining noise of the pigs, smells from the waste, solid waste and wash water handling challenges and possibilities for eutrophication. According to Kiratikarnkul S [13], locating piggeries within residential areas poses human health challenges. Flies can be agents of diseases hence need proper handling. Many drugs fed to pigs are passed out in faeces and can contribute to antimicrobial resistance in humans and animals. Pungent smell of ammonia and other gases are common occurrences around piggeries. It is not possible to force closure many of the establishments that have been misplaced within residential areas and the environment but instead, environmental engineering and technology should take charge for acceptable options. There must be specific regulations on pig waste management.

1.4. Potential Uses of Piggery Waste

Accordint to Kwasyn J, Kowalski Z, Banach M [15] pig waste can be converted to useful products that have a positive impact on the social and economic wellbeing of society. Phosphates, nitrates and other trace elements can be harnessed in a way that excludes their deleterious merits. Composting can be done to come up with high value added organic material that can be used directly as manure or organic fertilizers. Biogas generation has been noted as another beneficial possibility from pig waste management by [15], though they noted that this could only be achieved with some process modification because pig waste is a low methane yielding substrate because of its high moisture content. Contrary to theis assertion Kiratikarnkul S (2010), in Thailand urges farmers to manufacture biogas as a lucrative business. The farmers meet the idea with repugnance though.

Irrigation ranks amongst the major uses of water especially with climate change at play.Rains are becoming unpredictable and erratic under this phenomenon, putting much strain on the already strained demand for domestic water consumption. Many countries have come to recycling water from various sources and also seeking other non-conventional water sources to cater for the scarce renewable resource. Agricultural waste water as a useful resource for irrigation. Physico-chemical composition of different waste waters can be used to evaluate their suitability for irrigation purposes according to Magessa Olumana Dinka) [17]. Piggery waste water when used for irrigation in its unedified form may contribute to some adverse effects like promoting an increase in salinity, excessive leaching of nutrients, heavy metals and human health risk.

1.5. Challenges in Utilizing Piggery Waste

Pigs are known to return more than half of consumed feed as waste hence a necessary requirement to manage it. Phosphate is a major challenge to eutrophication and underground water contamination if not controlled as indicated in Figure 1. Jongbloed W. Age [9] noted that amount of phosphate released is attributed to free phosphate, phytate phosphate content, phytase activity and processing. Kwasyn J. et al, [15], noted that phytotoxicity of soil and other adverse effects on the environment can arise from immature composted products. Nutrients excreted by animals get impartial utilization in the soil-plant-animal system and gets to accumulate in the environment. Enrichment of phosphates and nitrates result in the loss of biodiversity as noted by Jongbloed W. Age [9].

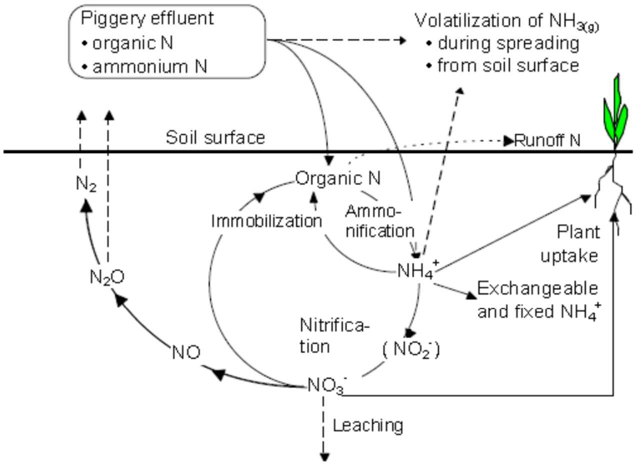

Figure 1. *Nitrogen cycle in piggery waste management. Source: Rate A.R (1997).*

Rate AW [21] noted that manure nitrogen can be lost through one or more of three ways like volatilization, denitrification and leaching during handling and in storage.as depicted in Figure 1. Slurries have the least nitrogen loss amongst the liquid manure systems and this tallies with research findings from Dejong Jodi Marne [3]. According to Chastain P. John et al [2], volatilization losses can occur from air exposed manure surfaces. Much of the organic and ammoniacal nitrogen will be converted to nitrate in the soil and will be lost through leaching or converted to nitrogen gas and be lost to the air. Dust and other particulate matter are contaminants known to affect both the farmer and his animals according to Machete and Ghabo [16]. Stabilization ponds are mostly used for waste handling in the smallholder sector and these are known to remove much of the organic load, but show insufficiencies in the removal of nutrients (N, P) and of pathogenic microorganisms from the technical point of view.

1.6. Area of Study

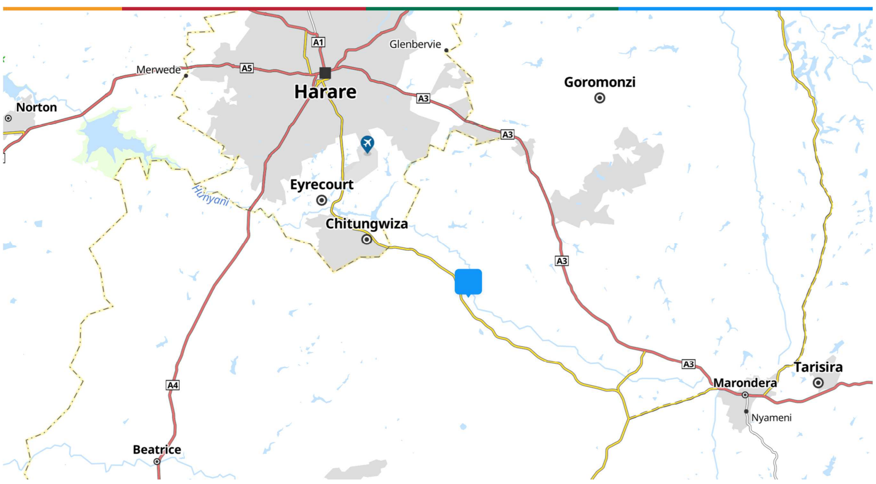

Figure 2. *Location of Dema Growth Point in relation to Harare and Chitungwiza cities. Source: © MICHELIN (2023).*

1.7. Location of a Piggery

The proper location of the pig farm according to Kadurumba et al [10] should be such that it is located downwind of the residential area and also about 300 to 500m away. According to the Pig Farming Magazine) [19], it should have enough space for further expansion because pigs breed very fast. High topography, broad terrain and good ventilation are good for hygiene and epidemic prevention: The site should be far away from the residential areas, medical institutions and slaughter houses. The farm should be away from drinking water sources and have space for sewage treatment. There is need for using an integrated approach to help eliminate emissions of odour and also act as to reduce soil and water contamination. It also enables isolation of valuable ingredients from the effluent which can be of economic benefit to the farmer.

This study intended to qualify and quantify the piggery waste disposal systems practiced in Seke Communal lands in Mashonaland East Province of Zimbabwe. This in turn was intended to effect an environmental evaluation whose results and recommendations could be adopted into regulations. This would then be used to promote greener production in the piggery sector. This study was conducted at the peak of the Corvid 19 pandemic that caused much disruptions to social and economic activities round the globe had a major influence in determining the extent to which this study was conducted. With lockdown and travel restrictions together with reduction in staff manning workplaces, access to the sampling sites, lab facilities and other resources required for the study which has been put under curfew, hindered freedom to scientific exploration as required. Delimitation was attained through working with locally available farmers within whose vicinity the farmer had flexibility for interactions. Improvisations for equipment have to be accommodated as well as substitution for some consumables that are were not available during the time of study. The researcher had to make do with carrying out some experiments from home during the lockdown like the aerobic digestion for the organic liquid base manufacturing.

2. Methodology

A questionnaire as in Appendix 1 was drafted and used for consulting the neighborhood for opinions on their appreciation of having piggeries within their area of residents and also associated environmental challenges. The questionnaire helped bring an understanding of academic levels and environmental pollution literacy among the residents. It also helped assess levels of understanding on anticipated environmental, health and economic implications of piggeries.

On the technical context, samples were taken and various tests conducted to have a quantitative and qualitative environmental assessment. This was conducted after sampling and subsequent laboratory analysis of collected samples. After making the material homogeneous by mixing using a bucket, the sample was scooped into another bucket and placed in collecting sample bottles. These sample bottles were then taken to the laboratory for characterization and further studies. Solid samples were collected using a shovel and a clean sheet of polythene paper for mixing the material prior to taking the representative sample.

Total nitrogen determined by the Kjeldhal process and nitrate nitrogen determined using Devarda's Alloy. The pH and temperature were measured using a Mettler Toledo pH meter whilst phosphates were measured using the Cintra 3030 spectrophotometer. Electrical conductivity was measured using the Dionic Water Tester Conductivity meter. Sodium and potassium were measured using Flame Emission Spectrophotometry whilst calcium, magnesium and heavy metals were determined using Atomic Absorption Spectrophotometry on the Varian AA-1275 series Spectrophotometer. Carbonates and bicarbonates were determined by titration. Sulphur was determined using gravimetric analysis. Characterization enabled fertilizer manufacturing from the available piggery waste materials.

Liquid organic fertilizers were made by an initial aerobic digestion of the pig waste in the shade, sheltered from direct heat and rain according to a method by Kansie Sie Bernard [11]. This process produced the organic liquid base later to be used for liquid fertilizer formulations and blending. The biotransformation technique consisted of a 200L drum portioned such that a third of it was filled with piggery waste, the next third with green matter as source of sugars and minerals then 2 shovels each of living earth and ash. The drum was then topped up with water leaving space for stirring. Mixing was done for at least 10 minutes per day for up to 14 days. After 14 days, aerobic biological decomposition completed, the organic liquid fertilizer base was decanted and the remaining solid waste added to a compost as illustrated in Appendix 2.

The liquid fertilizer was characterized through nutritional composition to make recommendations for beneficiation processes to upgrade it to various commercial grades of organic fertilizers. Some formulations of organic liquid fertilizers and organic blended liquid fertilizers were made. Solid fertilizers were made by first characterizing nutrition and anti-nutritional components of the solid waste from the piggeries. Blending was done in accordance to formulations for specific fertilizer grades. Odour was minimized by the separation of the solid from the liquid. The separated liquid was acidified using dilute sulphuric acid as recommended by van Kampen Theo [25] to minimize odour and also capture the ammoniacal nitrogen as ammonium sulphate which is a useful fertilizer on its own. This acidified liquid could also be used to flush manure out of the pig sty. Concentrated solids were taken to the compost heap or digester.

Irrigation suitability was determined by first getting the carbonates and bicarbonates content of the liquid waste and organic liquid fertilizer base made through titrations. The calcium and magnesium content were determined by using the flame atomic absorption spectrophotometer. These four parameters were used in calculation for the Residual Sodium Carbonate (RSC) as in (1). Sodium derived from Flame Emission spectrophotometry was used in a formula together with calcium and magnesium to give the Sodium Adsorption Ratio (SAR) (2). The SAR together with the Electrical conductivity reading of the water give the C-S class code where "C" represent total concentration of soluble salts and "S" represent relative proportion of sodium to other cations. The excess of the carbonate and bicarbonate concentration to that of calcium and magnesium was represented by the letter "R" in the code. In irrigation, the calcium: magnesium (Ca: Mg) ratio means a lot to the class code and is represented by symbol X, where X is the ratio of calcium to Magnesium hence the quality assessment of the irrigation water will be expressed in a code composed of the four symbols C_w - S_x - R_y - X_z where w, x, y and z are variables in the code.

Calculations for Sodium Hazard parameters

Residual Sodium Carbonate (RSC)

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad (1)$$

Sodium adsorption Ratio (SAR)

$$SAR = Na^+$$

$$\sqrt{[(Ca^{2+} + Mg^{2+}) / 2]} \quad (2)$$

In interpreting the code of any irrigation water, salinity and sodium hazard are first considered prior to the independent characteristics of calcium magnesium ratio and the residual sodium carbonate. The final recommendations on the use of any irrigation water will take into account other factors like soil characteristics and also the crop intended to be irrigated using the water.

Names used in study

Syrene – Farmer Syrene

Gift – Farmer Gift

Gadaga – Farmer Gadaga

3. Results and Discussion

Taking a glimpse of the production systems within Rubatika Village in Dema Communal Lands, Figure 3, one can clearly see piggery locations area with mounted green Jojo tanks. Further scrutiny of Figure 3 reveals that the other homesteads are located within a distance of less than 500km to a piggery in all directions. Some of these homesteads are also located on the windward side in relation to the piggeries.

Figure 3. Proximity of some households in relation to the piggeries in Rubatika Village, Demas. Source: Authors data.

Most small holder farmers have been using one of three ways to manage piggery waste. The first and mostly used method has been the use of small ponds that are just dug into the ground with no liner involved to promote slow permeation of the water percolating into the ground. Figure 4 shows a pond that has an attribute of a three in one function. The first is the dumping area for the piggery waste. When it gets into the pond, there is mixing of the solid waste and the water which now produces a slurry. Further down the pond there is waste water which decreases in viscosity as we move away from the middle slurry region. The pond is made such that if there happen to be flash floods, water can easily fill up the pond and the waste overflows to the surrounding environment. There are no liners neither is there any precaution put in place to prevent pollution and contamination of the environment. Despite all these drawbacks, the piggery is located amongst other homesteads.

Figure 4. One farmer's way of channelizing and managing waste water from a piggery. Source: Authors data.

There is no standard for ponds used for piggery waste handling in the area and no particular regulations to this regard. Lateral and vertical permeation of waste water has been promoted by the non-engineered ponds resulting in the walls curving in and collapsing as depicted in Figure 4. This pond naturally works on the waste by carrying out a change in the viscosity of the waste from semi solid near the pigsty where there is straw and other crude material to trap the organic material that is semi solid, then comes the slurry that exudes from the straw entrapment and later turns to liquid rich in organics and other nutrients further down the pond.

Another typical non engineered pond found within the area shows a shallow sinkhole used as the collection pond for washings from the pigsty as depicted in Figure 5. It is very deep but narrow hence is not well aerated since there is no stirring of the substrate. It smells pretty bad and this may be due to it being uncovered and also poor separation of solid and liquid. There is a combination of both aerobic and anaerobic activities within the same pond. The pond is structured in such a way that it cannot prevent overflowing in the case of flash floods and even during the cleaning process of the pigsty. Comparing the vegetation surrounding the pond to that just a few meters from this periphery shows that the waste water has a lateral influence on the environment to a certain distance as depicted in Figure 5. It is contributing surplus nutrients to the soil around it hence the grass looks greener. This is a sign of negative interaction with the surrounding environment. It also calls for a need to assess its influence on the underground water source by sinking boreholes and sampling out the quality of it. There is no lining on the pond and the nature of the soil is sandy making the pond a risk to the quality of underground water. There is also no mechanism to prevent overflowing of the pond in the event of a flashflood.

Figure 5. *Another farmer's way of handling washings from a piggery located within residential stands. Source: Authors data.*

There is another kind of setup which is a two way system for pig waste management. These run concurrently at the same locality as depicted in Figure 6. The first method is stockpiling of the solid waste into a heap. The pile is not covered and stinks strongly with the odour infiltrating the neighborhood. Maggots can be seen if you slice through the pile with a shovel on just a little distance from the surface as depicted in Figure 6.

Figure 6. *Two systems of piggery waste management running concurrently within the same locality. Source: Authors data.*

When it rains, a lot of nutrients from the pile solubilize and flow with the rain contaminating the neighborhood. After putting the bulky of the waste on the pile, water is used to wash the remaining waste into a pond with twigs and other debris as depicted in Figure 6. Still the same, the pond is not free from overflowing during flashfloods. This is not a sustainable way of handling piggery waste material in terms of environmental protection. Under normal circumstances, stock piling should be done in large holding tanks or lagoons from where bacteria breakdown the manure into solids and liquids as directed in the Pig Manure Management Magazine [20].

Sixty four percent (64%) of candidates interviewed through the questionnaire had never taken any charge or complaint to any authorities with regard to piggeries environmental fouling. Those that have been vocal, were misdirecting their complaints hence no action nor address has been accorded them as a remedy to the challenge. Figure 7 shows the major causes of annoyance among neighbors on the location of piggeries within their place of residents.

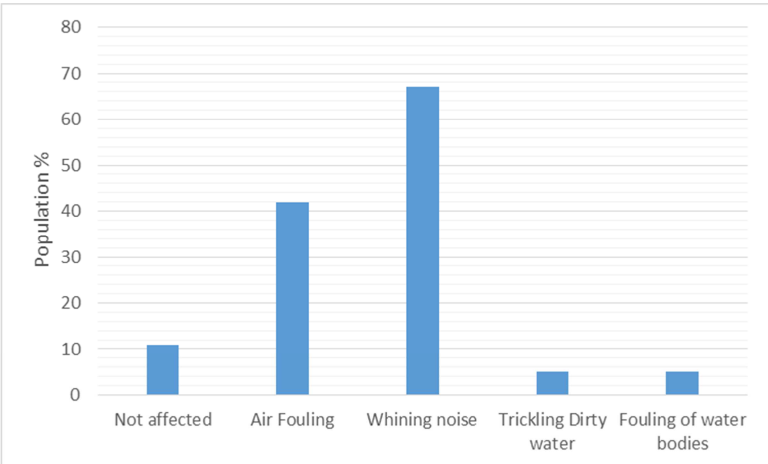

Figure 7. *Percentage of population giving justification to decisions on acceptance or rejection of piggeries within homesteads. Source: Authors data.*

The questionnaire revealed that about 67% of the population was grumbling about the whining noise of the pigs whereas 42% was worried about the air fouling. These are the major, easily notable signs of the bad impact of piggeries located within homesteads. The other not so obvious signs which have long term impaction to the environment are not an urgent concern to the general populace which is either through ignorance or otherwise.

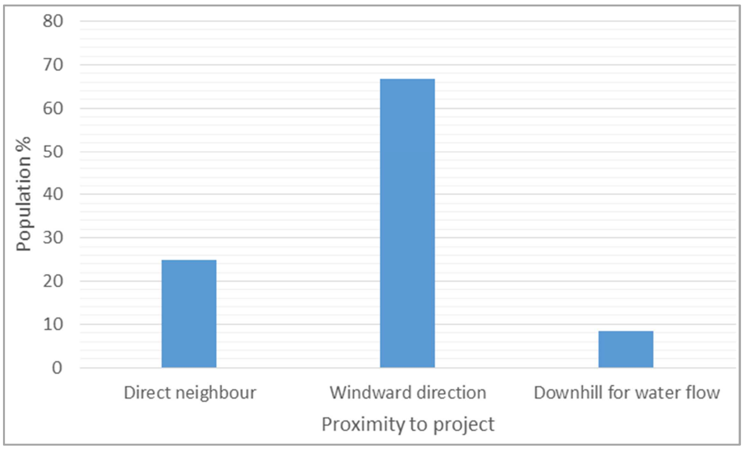

Figure 8. *Proximity of population to project. Source: Authors data.*

About 67% of the population is located on the windward side of the piggeries under study as depicted in Figure 8. This is one reason why the neighbors remain disgruntled and grumbling about the location of piggeries within their locality. It looks like it becomes a norm to live with the foul air from the piggeries especially after having stayed under such circumstances for a long period.

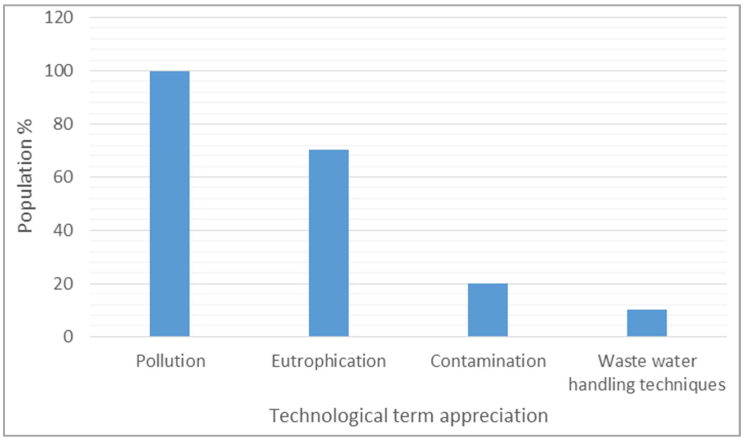

Figure 9. *Appreciation of technological terms used in waste management for sustainable development. Source: Authors data.*

All 100% people interviewed through the questionnaire are familiar with the pollution term and what it means. As the terminology become more technical and specific, the number of the population versed with these terms dwindle significantly as depicted in Figure 9. This generally proves the level of education of the general population and also dictates the degree of awareness required to conscientize the population on waste management.

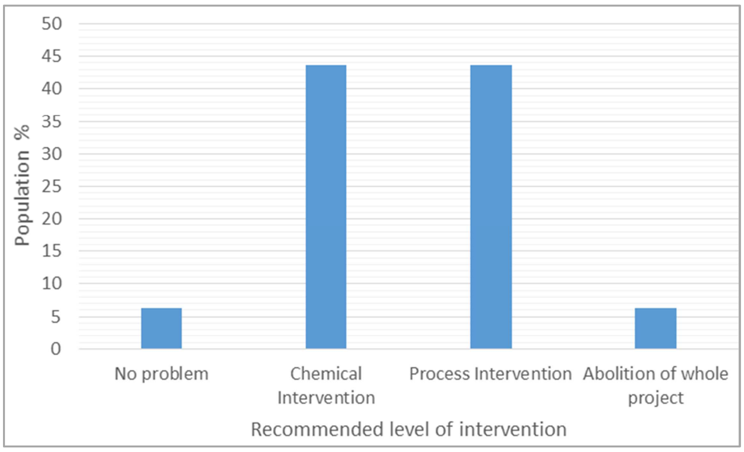

Figure 10. *Recommended level of intervention from within the population. Source: Authors data.*

There is a normal distribution pattern within the population with regard to people's attitude towards possible actions that may be effected to bring peace and harmony within the neighborhood as depicted in Figure 10. About 7% of the population does not show concern for any probable remedial action necessity. The other extreme end of 7% favor the abolition of the whole process of establishing piggeries amongst homesteads whilst the remaining percentage showed the need for an intervention in one way or another for as long as it brings solace to their challenge as depicted in Figure 10. They agreed they should be an intervention especially with process control to curb pollution and contamination of the environment.

Nitrate (NO_3^-) is the major form of nitrogen in the study samples as depicted in Figure 11. The nitrogen composition also varied with state of the waste that is from solid, semi-solid, slurry and liquid. Handling of sample also determined nutrient levels in the final product. The solids had the highest nitrogen levels followed by slurries then liquids. Nitrate accounts for over half the percentage of total nitrogen in the study samples meaning special care should be given to nitrate management. There is need to boost total nitrogen percentage by optimizing nitrogen loss through conversion to ammonia gas and lost by volatilization as depicted in Figure 1.

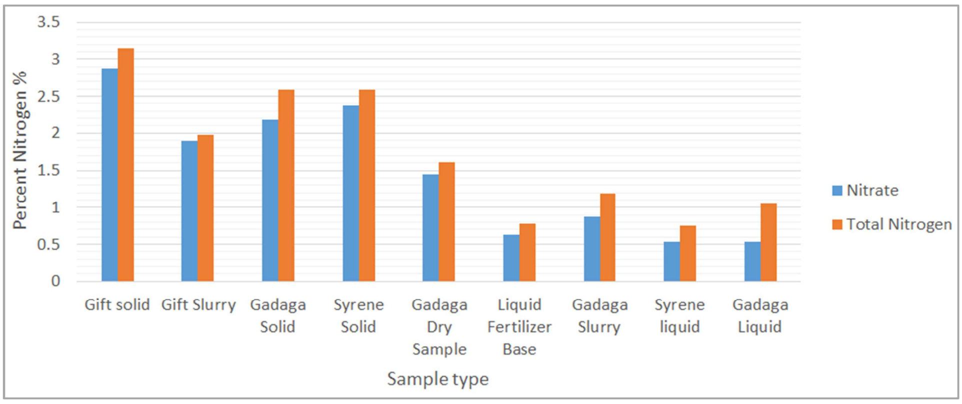

Figure 11. *Characterization of the nitrogen source and percentage in waste from piggeries under study. Source: Authors data.*

Nitrogen and phosphorus are the major macro elements present in waste from piggeries as depicted in Figure 12. Potash trails somewhere not as high as the former two and this trend is dominant in the solid samples. The situation is different with the slurries and liquids. The slurries have moderate levels of nitrogen, phosphate and potash concentration and the liquids have the least. The pattern is a bit reversed with the liquids. Nitrogen and Sulphur take dominance with the liquids as depicted in Figure 12. Phosphate and potash remain very low and phosphate is missing in some liquids. This is due to the partitioning of the nutrients which is in agreement with observations noted by Chastain P. John et al [2] that phosphate remains with the solid and nitrate become dominant in the liquid. They noted that phosphate partitions between the solid and liquid waste water component in the ratio of 95:5. Nitrate is the only nutrient that was noted to partition equally between the solid and liquid pig waste after separation. Sulphur and potash does not show any dominance in the liquid samples.

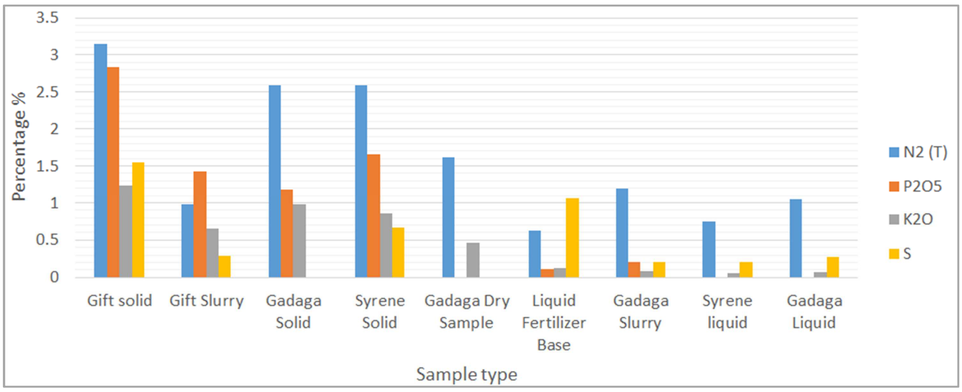

Figure 12. *Comparison of the macro elemental composition (NPKS) of the waste from piggeries under study at Rubatika Village. Source: Authors data.*

Nutrient composition has proved to vary with depth in storage facilities and also with treatment given the waste and washings. There is a gradient in nutrient composition as we move through the different phases of the waste within the facility as we transition from sample solid, slurry to liquid as depicted in Figure 12. Generally since the solids settle to the bottom, they carry the highest proportions of the macro elements. It is lower at the top that is in the liquid and increase through the slurry region then down to the solid sludge at the bottom. Organic Nitrogen and phosphates are concentrated in the settling solids in abundance. Phosphate is missing in some liquid samples meaning if we can separate the liquid from the solid, we can confine the phosphate to one source and be better able to manage it within that source. This observation was noted by van Kampen Theo [25], that if you separate the liquid from the solid, you are better able to handle the pollutant nitrates and phosphates from pig waste and waste waters.

With micro elements, solid waste has the highest composition per unit mass than slurries and liquids. It would be unfair to make a direct comparison of the solids, slurries and liquids at the same time. These samples better be categorized and compared accordingly. The liquid organic base fertilizer has proven to be superior above the liquid fertilizers especially when it comes to elements like calcium, magnesium, sodium, iron, zinc, copper and manganese as depicted in Figure 13. The pattern shown in Figure 13 proves the justification for need to make the organic liquid base as the basal material for the synthesis of other liquid fertilizers. It guarantees the presence of all the necessary elements within the formulation and blending.

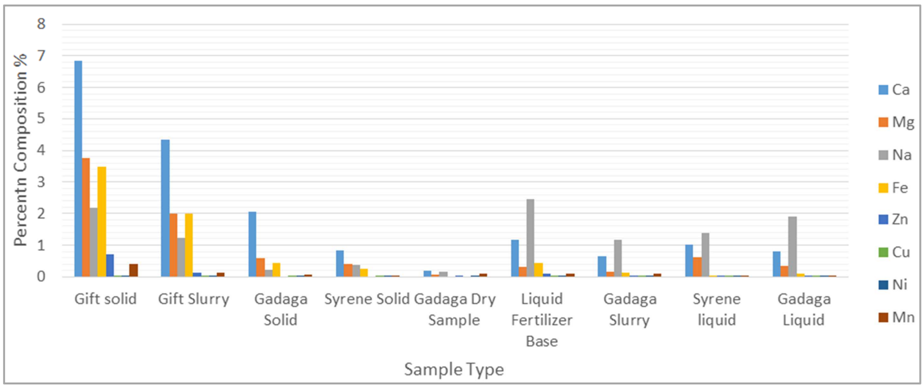

Figure 13. *Micro elements and some heavy metals in products and waste from piggeries. Source: Authors data.*

Trends in comparing the solids on their own and the liquids on their own is visible in Figure 13 hence it can be deduced that amount of nutrient abundance depends on the waste collection system. Chastain P. John et al [2] noted that these nutrients also depend on the feeds, supplements and medications availed to the animals and then modified by the amount of water consumed by the animals. In support, Rate AW [21] also noted that the nutrient and volatile solids content of swine manure will vary with the digestibility of the ration, animal age, amount of feed wasted, the amount of water wasted, and the amount of water used to remove manure from the building. This trend is very visible in Figure 13 and supports the argument on the necessity to separate solids from liquids. Copper (Cu) and zinc (Zn) are commonly added to pig feeds as growth promoters and these elements are known to be present in piggery waste in notable quantities. According to Alloway [1], while both these elements are essential micronutrients for plants, both Cu and Zn can be toxic to organisms when present at higher concentrations.

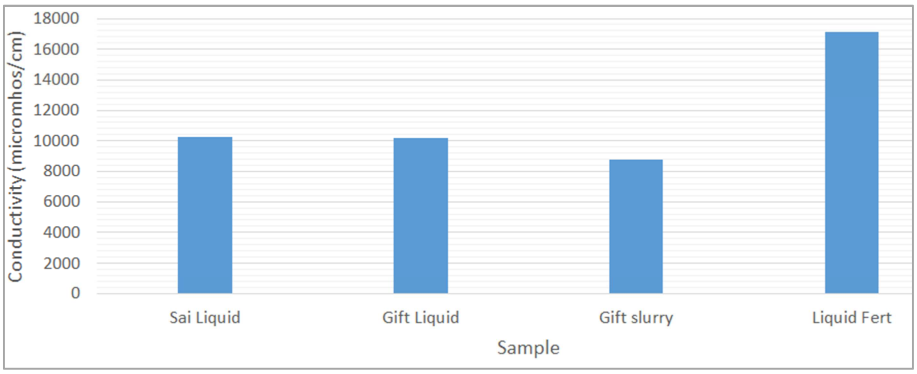

Figure 14. *Electrical conductivity of liquids and organic fertilizer base from piggery waste. Source: Authors data.*

The organic liquid fertilizer base shows the highest level of electrical conductivity as compared to the other liquids as depicted in Figure 14. This is due to the addition of solutes through the ash and leaf extracts during the manufacturing process. Its level of dissolved substances has been enhance through the added materials. The rest of the liquids fall short of qualifying to the definition of organic fertilizers without supplementary material added to boost nutritional levels according to the Fertilizer (Control) Order [8] of India. Degree of solubility of solutes play a major role in determining level of electrical conductivity and is also reflective of concentration of ions within the liquid that act as electrical conductors.

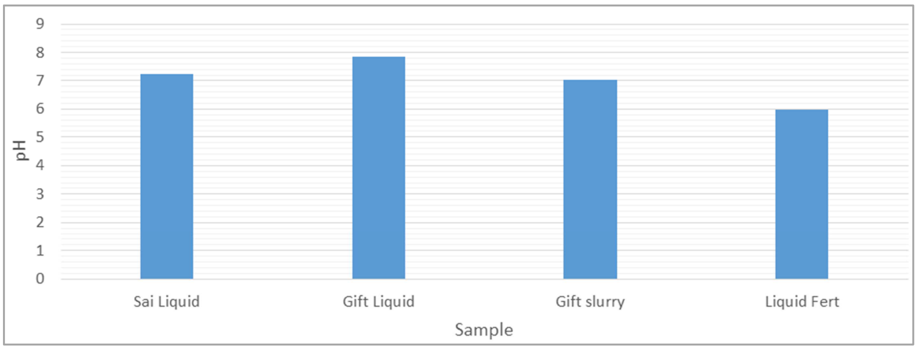

Figure 15. *Comparison of pH from the various components of liquid waste from the study farmers. Source: Authors data.*

One important aspect of a piggery wastewater that determines its merit for irrigation use in agricultural systems is pH, which is a chemical component characteristic of the wastewater. It has a direct influence on water treatment regardless one is using a chemical, physical or biological process. It also gives a hint on the treatment procedure necessary and the appropriate chemicals to use in the treatment. Adjustment of pH is usually all one needs to treat and dispose of wastewater for example in colour, phosphate, heavy metal removal and lime softening systems. Figure 15 shows that most manures have a slightly alkaline pH except for the organic liquid fertilizer base which is a bit acidic with a pH of 6. Recommendations for pH of organic manures according to the Fertilizer Control Order of India [8] publication stipulates that it should lie between 6.5-7.5.

Characterization of water for irrigation suitability showed that all waste water from the study piggeries cannot be recommended for irrigation without some modifications. Amount of salts in the water, slurry and liquid fertilizer base fall in the same classification category on irrigation suitability as shown in Table 3.

Table 3. *Irrigation suitability characterization of piggeries waste water from the study areas.*

Property Measured	Syrene Waters	Gift Waters	Liquid Fertilizer Base	Gift Slurry
pH	7.22	7.85	5.98	7.03
R. S. C	-1.51	-1.075		
S. A. R	1.51	2.51	2.83	1.85
EC (mmhoscm^{-1})	10250	10195	17100	8750
Ca/Mg Ratio	1.63	2.4	3.6	3.988
Code	C_3-S_1-X_1-R_1	C_3-S_1-X_1-R_1	C_3-S_1-X_1-R_1	C_3-S_1-X_1-R_1

Source: Authors data.

Typical water with characteristics as in Table 3 cannot be used on soils with restricted drainages. Even with adequate drainages, special management for salinity control is required. The waters in Table 3 are suitable for plants with good salt tolerance. High Residual sodium carbonate or high Sodium Adsorption Ratio values discourage recommendations for use of the waters for all crops. Where there are limitations in availability of good quality water, it is discouraged to use this saline water at early stages of plant growth. Dilution may be necessary as well as alternating irrigation with good quality water.

The liquid fertilizer was necessitated by the fact that swine manure resulted in a piggery wastewater rich in solids, nutrients, heavy metals, and pathogens as noted by some researches. There was need to split the nutrients between the liquid and the solid so that formulations of fertilizers from both sources could be effected. The main objective of this process was in reducing organic matter, nutrients, and pathogens in the treatment of the effluents with low or high organic load rate then modify them to suit certain fertilizer formulations.

The solid waste from piggeries was used in making organic fertilizers which are high in nutrition that is evenly distributed within the bulky material. It is quite comprehensive in nutrition in addition to the three macro-nutrients of nitrogen, phosphorus and potassium. There are also rich in calcium, magnesium and silicon, which change the soil composition and facilitate crop growth. Dried, ground pig waste can be blended with inorganic fertilizers to come out with what are termed “Organic enriched fertilizers”. Some formulations to this regard are shown in Table 4.

Table 4. *Organic Blended Compound D (7:14:7:6) fertilizer for maize, wheat, sugar beans and other crops as basal fertilizer. Source: Authors data.*

Raw material	% inclusion	Total N	P_2O_5	K_2O	S
Pig solid waste	60	1.88	1.7	0.74	0.93
Compound DD (14:28:14:6)	40	5.6	11.2	5.6	2.4
Total nutrients %	100	7.48	12.9	6.34	3.33

The formulations in Table 4 depicts the potential beneficiation of pig waste and waste products to substitute for pure inorganic fertilizers which have their own drawbacks. The current state of our soils in Zimbabwe demand input of the organic matrix as a fertilizer. The inadequacy of pure compound D fertilizers in addressing Zimbabwean kind of soil challenges in most provinces can be addressed by the organic matrix. This acts to adsorb the nutrients, retain moisture and make them be released rather slowly in addition to other positive traits imparted. The organic matrix does not only save on fertilizer costs but also on soil properties like water holding capacity, pH and buffering effect as well as improving soil structure, increasing biodiversity in soil and help prevent soil erosion. A 50Kg bag of compound D fertilizer costs about US$35.00 on average in Zimbabwe. At 40% inclusion of pig waste in Table 5 means one would have bought one 50Kg bag at US$14.00 meaning a 40% saving in costs.

Table 5. *Formulation of a basal organic blend fertilizer. Source: Authors data.*

Raw material	% inclusion	Total N	P_2O_5	K_2O	S
Pig solid waste	55	1.73	1.56	0.68	0.85
Compound DD	20	2.8	5.6	2.8	1.2
Potassium Sulphate	10	0	0	5	1.75
Ammonium sulphate	15	3.09	0	0	3.45
Total nutrients	100	7.62	7.16	8.48	7.25

It is feasible to use the organic waste from piggeries to formulate organic enriched fertilizers as depicted in Tables 4-5. Many other formulations can be made and still serve in increasing value of the piggery waste. It is also feasible to make pure organic fertilizers by blending various organic materials to come up with the desired fertilizer grades.

4. Conclusion

The study revealed that majority of the population does not support the location of piggeries within residential areas. It also proved that there should be a system modification either chemically or physically to prevent pollution if there happen to be such a scenario. Separation of the solid from the liquid reduce nutrient load and hence foul odour of pig waste. Nitrates and phosphates split between the solid and liquid components of the waste with the latter dominant in the liquid. Nutrient composition varied with handling techniques used and state of the waste from solid, slurry and liquid. Beneficial re-use of piggery waste is a viable option for environmental protection and progression of agricultural productivity. The solid and liquid waste can be used in either organic or inorganic fertilizer manufacturing. Piggery waste water can be edified through irrigation suitability tests to suite irrigation purposes in horticulture. It is not recommended for irrigation in its crude state.

5. Recommendations

One should select a site downwind to establish a piggery and should consider a distance of at least 500m from the nearest residence. The location of the waste collection system should be such that there are no sinkholes or abandoned wells and the structure of the underlying rock should be such that it is not fractured limestone. Consideration should be given to channelizing rain water so that it flows directly into watercourses or it can be contained in some reservoir where it will be treated first before release to the environment. Lagoons must be made such that there is no overflow in flush floods. Effluent ponds must be constructed that can meet the permissible maximum permeability of 0.1mm per day other than leave unsupported ponds without built walls that end up collapsing from within. If you stockpile manure, put a roof over it to contain foul smell polluting the environment. Local authorities should consider piggery waste water treatment criteria while granting a pig farm permit license. This study concur with Tesfaye Burju Roba [23] that the integrated nutrient management system is an alternative of choice and is characterized by combined use of inorganic fertilizers with organic materials such as animal manures, crop residues, green manure and composts.

Acknowledgments

Special thanks to my family especially Samantha and Hannah, my two daughters who endured maximum separation during study for this manuscript. I also want to acknowledge the late Professor Nkosikhona Hlabangana from NUST for all the encouragement, may his soul rest in peace. Lastly to the Research Services Department and FFRI family, this manuscript wouldn't be possible without your support. God bless you all.

Conflict of Interests

The author want to acknowledge that there is no conflict of interest with anyone or organization with regard to this study. The results here displayed are sourced from the author's study data.

Appendix

Appendix 1. Questionnaire on Neighborhood's Attitude Towards Piggery Among Homesteads

Would you accept siting of piggeries within homesteads?
1) YES
2) No

What is the reason for your response to question 1 above?
1) Not affected
2) Foul air
3) Whining noise
4) Dirty water trickling to neighbours
5) Contamination of domestic water sources
6) All of the above.

How are you located in relation to the pigsties in your neighborhood?
1) Direct neighbour
2) Windward location
3) Downhill for water flow
4) Share the same water bodies for domestic consumption
5) No direct proximity

How are you handling the situation responded to in question 3?
1) Complaining to the owner.
2) Complaining to authorities,
3) Building barricades,
4) No action taken as yet,
5) Am not worried.

Given an opportunity, would you accept raising pigs at your homestead?
1) Yes
2) No
3) Yes but with conditions

According to your opinion, what is so lucrative about Hog raising?
1) An interesting hobby,
2) A means of livelihood,
3) No choice but just this venture.

Do you know the meaning of the following terms:

Pollution
1) Yes
2) No
3) Partially

Eutrophication
1) Yes
2) No
3) Partially

Contamination
1) Yes
2) No
3) Partially

Wastewater handling
1) Yes
2) No
3) Partially

In your opinion, what should be done about pigsties to make them acceptable within the neighborhood?
1) Good as they are
2) Need an intervention

What kind of intervention is necessary about pigsties within your neighborhood?
1) No problem at all,
2) Chemical intervention
3) Process intervention
4) Abolition of the whole project

What message do you want to share with the piggery owners in connection with issues raised in discussion above?
1) No comment
2) No to piggeries within homesteads
3) Consider process control to curb pollution in any way.

Appendix 2. The Making of the Liquid Fertilizer Base from Pig Waste Source: Authors Data

Figure 16. *Steps involved in the making of the liquid fertilizer base for the synthesis of various liquid fertilizer grades. Source: Authors data.*

A: Pig waste added as the organic core of the Organic liquid fertilizer base formulation.
B: Green matter added to formulation in equal volume to the pig waste.
C: Addition of water, living earth and ash to start the aerobic digestion process.
D: Daily ten (10) minutes mixing of the aerobic digestion process during the early days.
E: State of the substrate after seven (7) days of aerobic digestion.
F: End of decomposition process and status of mixture after fourteen (14) days.

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