INDUSTRY PRIMER

MEAT PROCESSING

CORRECT MANAGEMENT OF WASTEWATER IN THE AGRIBUSINESS SECTOR FOR IDB INVEST

Futuris SUSTAINABILITY ADVISORS

IDB Invest

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Acronyms

BOD	Biochemical Oxygen Demand
BWMP	Best Wastewater Management Practices
CIP	Clean-In-Place
COD	Chemical Oxygen Demand
DAF	Dissolved Air Flotation
DO	Dissolved Oxygen
EC	Electrocoagulation
EHS	Environmental, Health and Safety
FOG	Fats, Oils, and Greases
GPN	Good Practice Note
IDB	Inter-American Development Bank
ISO	International Organization for Standardization
LAC	Latin America and the Caribbean
LWK	Live Weight Equivalent
MPN	Most Probable Number
SBR	Sequencing Batch Reactors
TSS	Total suspended solid
UASB	Up flow Anaerobic Sludge Blanket
UV	Ultraviolet
WBG	World Bank Group
WHO	World Health Organization
WWTP	Wastewater Treatment Plant

1 Introduction

1.1 THIS INDUSTRY PRIMER AND THE GOOD PRACTICE NOTE

This industry primer has been prepared to complement the Good Practice Note (GPN) for Wastewater Management for the Agribusiness Sector[1]. A reference to the GPN has been made in the following sections to reduce duplication whenever the information in the GPN complements what is presented in this industry primer.

It provides a comprehensive overview of the best wastewater management practices (BWMP) for managing the environmental impacts of meats – beef, pork, and poultry - processing wastewater, helping companies ensure compliance with relevant regulations and promoting sustainable practices that protect public health and the environment. Section 2 describes the sector's characteristics, and Section 3, the BWMP, including pollution prevention BWMPs (Section 3.1) and wastewater treatment BWMPs (Section 3.2).

Information regarding key performance indicators is linked to the specific regulatory (KPIs) frameworks of each country, and this information can be located in Section 2 and Annex I of the GPN. For further exploration of pollution prevention examples and BWMP in wastewater treatment, please refer to Section 4 and Section 5 of the GPN, respectively. More detailed monitoring information can be found in Section 6 of the GPN.

1.2 SOURCES OF INFORMATION

This industry primer on meat processing wastewater has been developed using various sources of information. Primarily, it is built upon the foundation of the World Bank Pollution Prevention and Abatement Handbook (1998), which provides the underlying framework for the more specialized industry guidelines known as the Environmental, Health, and Safety Guidelines for Meat Processing, published by the World Bank Group in 2007. A comprehensive compilation of references is available in Section 4. Moreover, insights from client-based interviews of IDB Invest, have been incorporated.

2 *Sector Characteristics and* ***Wastewater Production***

2.1 GENERAL OVERVIEW OF THE SECTOR

Meat and poultry slaughtering and processing activities involve a comprehensive range of tasks, from the reception of the animals to the preparation of carcasses for sale or subsequent processing. These facilities and slaughterhouses are significant consumers of clean water, utilizing it extensively in various processing steps such as lairage, slaughtering, scalding, de-feathering, evisceration, deboning, and cleaning activities associated with meat and facility sanitation. Consequently, these operations generate substantial volumes of wastewater that pose significant environmental challenges. The wastewater contains a considerable concentration of suspended solids and organic matter, creating unpleasant odors. The composition of the wastewater is further complicated by the presence of detergents and disinfectants used for sanitization and cleaning. Given the high-strength characteristics of these effluents, comprehensive treatment processes are necessary to ensure safe discharge into the environment.

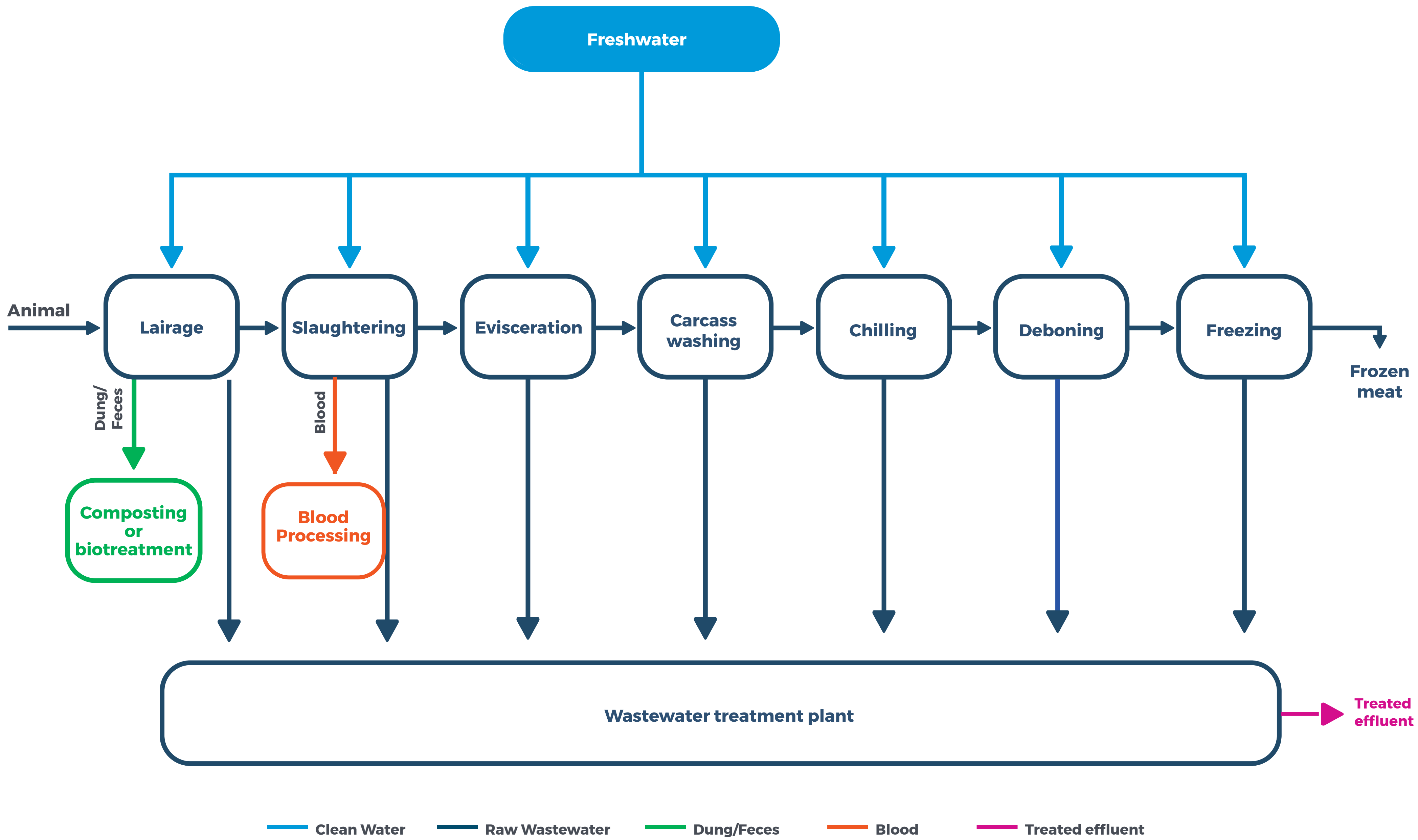
Latin America and the Caribbean (LAC), despite representing merely 13.5% of the global population, contribute to a significant portion of the world's meat production. A review of the meat production breakdown shows that poultry meat holds the largest share in the LAC region, with nearly half of the total production. Beef production follows with a 35% share, and pork production lags with 16%. Collectively, these three categories contribute to more than 99% of the region's meat production. Brazil emerges as the leading meat producer in the region, responsible for over half of the total LAC production. It holds the top position in beef production, generating 19 million tons, as well as pork production, with 4.5 million tons, and poultry production, with nearly 13.8 million tons. Mexico secures the second spot, accounting for 13% of the region's pork and poultry meat production. On the other hand, Argentina claims the second-largest beef producer title in the region, accounting for 11% of the total production [2].

2.2 WATER USE WITHIN THE INDUSTRIAL PROCESS

The meat processing industry consumes, directly and indirectly, at least 29% of the total freshwater used by the agricultural sector. The water consumption in slaughterhouses and meat processing plants is closely related to the number and type of animals slaughtered. To produce one ton of beef, pork, and poultry meat, 15,500m^3, 4,800m^3, and 4,000m^3 of freshwater are required, respectively[3,4].

The meat processing industry uses water for various purposes, including sanitation, processing of meat, and ancillaries and equipment usage (such as washing equipment, steam production, hot water generation, cooling compressors, and ice water production). The main use of water in meat processing plants is washing carcasses after skinning cattle and calves, de-feathering birds, or removing hair from pigs after evisceration. There is also water use in cleaning, sanitizing equipment and facilities, cooling mechanical equipment like compressors and pumps, equipment sterilization, and work area clearing [5]. A schematic review of water use in a general meat processing industry is presented in ***Figure 1***.

FIGURE 1 Flowchart of water consumption within a general meat processing plant



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2.3 GENERAL REVIEW OF WASTEWATER GENERATION

2.3.1 PRIMARY POLLUTANTS AND THEIR SOURCES

The volume of wastewater generated during the slaughtering process varies based on the type of animal processed. **The wastewater volume generated[1] varies depending on the livestock type. For cattle, the range is approximately 1.6-9 m^3 per ton of meat produced. Poultry processing yields a wastewater volume of 5-15 m^3 per ton of poultry carcass, while pig processing results in 1.6-6 m^3 per ton of pig carcass [6]**.

In general, the wastewater from meat processing facilities contains a variety of pollutants. Still, it is important to note that the composition of raw wastewater in meat processing facilities is heavily influenced by the type of animal being slaughtered. Common pollutants include blood, pouch contents (such as stomach and intestine contents), dung, urine, meat trimmings, hairs, feathers, fat, disinfectants, undigested food, microbial pathogens, pharmaceuticals, loose meat, and residues from facility cleaning [5]. These result in a complex raw water composition, including fats, proteins, fibers, fecal bacteria and possibly pathogenic bacteria.

Wastewater quality is significantly influenced by rendering in the meat processing facility. The rendering process contributes about 60% of a plant's total organic load. The efficacy of blood collection is a significant factor in determining biological oxygen demand (BOD) concentration in wastewater. The degree to which manure (urine and feces) is handled separately as solid waste is a significant factor determining the BOD of meat processing wastewater[7], especially when it comes from receiving areas.

As a result of slaughtering and processing meat, wastewater has an elevated amount of organic matter represented as high concentrations of BOD and COD, FOGs, TSS, nutrients such as total nitrogen (TN) and total phosphorous (TP), pathogens (especially *E. coli and Salmonella*), and sometimes antibiotics and heavy metals such as copper, chromium, molybdenum, nickel, titanium, zinc, and vanadium [5]. The detergents and disinfectants used for sanitization and cleaning also add to the complexity of the raw wastewater composition.

2.3.2 MAIN ENVIRONMENTAL IMPACTS

The untreated effluent from meat processing greatly impacts the environment. When untreated slaughterhouse wastewater is discharged into water bodies, it can severely affect the water quality by reducing DO levels. It may also turn water sources into bacteria-laden public health hazards. Additionally, the disposal of macronutrients, such as nitrogen (N) and phosphorus (P), can cause eutrophication by promoting excessive algae growth and decay, which leads to a decline in aquatic life as the mineralization of algae can cause a depletion of DO levels. Furthermore, compounds like chromium and unionized ammonia in slaughterhouse wastewater can harm aquatic life [3].

The meat processing industry is also a source of contamination due to the addition of surfactants during the cleaning process. These surfactants are the main components in detergents. They may enter the aquatic environment if wastewater treatment is inadequate, resulting in short-term and long-term changes in the ecosystem that can impact humans, fish, and vegetation[3].

Aside from the pollution caused by surfactants, nitrate, and chloric anions, meat processing wastewater can also harbor pathogens that endure in the soil and continue to propagate. These pathogens pose a potential risk to human health if transmitted through exposure to a via contact with a water body. Consequently, areas contaminated with meat processing untreated wastewater are unsuitable for drinking, swimming, or irrigation [3].

2.4 DESCRIPTION OF INFLUENT WASTEWATER QUALITY

The composition of slaughterhouse wastewater varies considerably depending on the different industrial processes and specific water requirements, which implies that meat processing wastewater has a significant variation in pH, COD, BOD, TSS, FOGs, high N content (from blood), P[9], and other parameters. **In pig slaughterhouses, an estimated 2.4 kg of BOD is produced per ton of carcass weight. On the other hand, for cattle and poultry slaughterhouses, the corresponding values are approximately 4.4 kg of BOD per ton of carcass weight and 6.8 kg of BOD per ton of LWK**[10].

Several factors influence the concentration and composition of pollutants in raw wastewater. These factors include the product type, the production schedule, operating procedures, the design of the processing plant, the level of water management being employed, and, consequently, the amount of water being saved. Ranges of quality parameters reported for raw wastewater in the meat processing industry are summarized in Table 1.

TABLE 1 Average quality parameters values for aquaculture raw wastewater from various sources

Parameters	Tilapia ponds with recirculation [13]	Clam cultivation [14]	Shrimp farms [15]
COD (mg/L)	253	140.02	564
TSS (mg/L)	NR	NR	9510.67
Total N as NO_3-N (mg/L)	18.1	5.81	3.29
Total P as PO_4(mg/L)	2.5	4.5	-
pH	6.97	-	8.23

3 Best Wastewater **Management Practices**

3.1 POLLUTION PREVENTION BWMP

It is essential to increase the application of technologies such as water recirculation and pollution prevention management techniques to achieve sustainability. Staying updated on technological advancements and scientific research is important to attain this goal. To effectively manage wastewater, the meat processing industry must implement pollution prevention BWMP to prevent pollutants from entering a treatment plant; further pollution prevention information is described in Section 4 of the GPN. Examples in **Table 2** should encourage pollution prevention at the source in a meat processing facility.

TABLE 2 Management techniques for wastewater pollution prevention in meat processing

Management Techniques for Pollution Prevention	Description of controls
General	
Maximize the segregation of blood and water and recover blood for use in other industries as a by-product (at least 90%) [8,15]	• Design suitable blood collection facilities. Extend the time of bleeding to at least 7 min. • Implement proper collection methods, equipment, and staff training to ensure that blood is collected separately from other waste streams.
Separate and recirculate cooling water or reuse relatively clean wastewater from cooling systems for washing livestock if possible. [10]	• Install filters to remove debris and particles from cooling water before reuse. • Implement regular testing and monitoring of water quality, at least quarterly, to ensure it meets the required standards for livestock washing and other uses. • Consider Clean in Place (CIP) cleaning procedures to improve water, energy, and chemical consumption. • Install a separate recirculation system for cooling water to prevent it from mixing with other wastewater streams.
Remove fats from wastewater at the start of the treatment process and handle them as solid waste or by-products.	• Implement a system for separating and collecting fats at the source, such as grease tramps or grids. • Implement daily cleaning and maintenance procedures for the collection and storage equipment to prevent odors, spills, and contamination. • Properly dispose of the collected fats and grease as solid waste or recycle them as by-products, depending on their quality and quantity.
Poultry	
Minimize water consumption as much as possible in production [16]	• Install nozzles in hygienic hoses and increase mechanical cleaning of solids. • Install a water recirculation network for the drag of feathers. • Increase the frequency of dry cleaning, using meat and blood aspirators in the slaughterhouse premises. • Decrease the size of the scalding tank or change the conventional process. • Replace pre-cooling by immersion in water by pre-cooling with cooled air. • Use of the effluent generated in the stunning tank, after preliminary, in the pre-wash of the cages. • Reuse the final washing effluent from the abattoir cleaning process in the pre-wash of the by-product factory.
Swine and Cattle	
Minimize water consumption as much as possible in production [16]	• Implement dry pre-cleaning of pens. • Implement dry stomach emptying. • Use auto matically operated scalding chambers rather than scalding tanks for the de-hairing of pigs. • Replace the scald by immersion in water with a spray system.

3.2 WASTEWATER TREATMENT BWMP

Several biological, chemical and physical processes are commonly employed to treat slaughterhouse wastewater. Depending on the internal operations of slaughterhouses and meat processing plants, the wastewater characteristics, availability of treatment facilities, and effluent discharge standards, facilities may have a pre-treatment process before being released to treatment plants. Regularly, a wastewater treatment plant (WWTP) is based on primary and secondary treatment. Tertiary treatments are installed for disinfection depending on the final discharge method. Sludge management methods are also used and in most cases necsesary. There are emerging technologies for treating meat processing wastewater, such as electrocoagulation (EC), electrochemical advanced oxidation process (EAOP), and membrane technologies. However, these require specialized maintenance and high capital investment. Different examples of technologies are listed in Table 3.

PRELIMINARY TREATMENT

Prioritizing certain pretreatment stages is crucial for optimal operation. The screening and sedimentation stages significantly reduce organic loads and remove gross solids from the influent. Equalization tanks are essential components that aid in homogenizing the influent wastewater before it reaches the WWTP. By equalizing the flow and characteristics of the wastewater, these tanks contribute to more consistent and efficient treatment processes. Grease traps are vital in eliminating FOGs, which can cause mechanical issues in pipes and equipment and inhibit the activity of microbes involved in the treatment process.

PRIMARY TREATMENT OR PHYSICAL AND CHEMICAL TREATMENTS

Physical treatments include sedimentation, aeration, and filtration. Chemical treatments include coagulation, which effectively removes colloids and fine particles and reduces the time required to settle out suspended solids; however, it requires frequent use of chemical reagents and thus generates secondary pollutants. Also, physicochemical treatments like the DAF could be implemented as they allow high COD, color, and turbidity removal rates. However, it is important to consider their high energy costs, occasional malfunctioning, moderate nutrient removal, and possible limited disposal of sludge because of its toxicity[3].

SECONDARY TREATMENT

Considering the high concentration of organic matter in meat processing plant wastewater, as indicated in **Table 1**, with up to 8,500 mg/L of BOD, the use of secondary treatment (bioreactors) is more common compared to more costly alternatives like electrocoagulation, membrane separation, and advanced oxidation. Integrating aerobic and anaerobic digestion methods improves the removal of pollutants from slaughterhouse wastewater. This approach makes sense because relying solely on aerobic methods becomes challenging due to their high energy requirements.

When incorporating bioreactors, it is crucial to carefully manage the wastewater input to prevent the accumulation of inhibitory substances like heavy metals and antibiotics. Predominantly, methods such as anaerobic digesters, up-flow anaerobic sludge blanket reactors (UASB), sequencing batch reactors (SBR), and lagoons are employed for anaerobic treatment. Anaerobic digestion is highly advantageous for effectively treating wastewater with elevated levels of organic matter, concurrently generating valuable biogas for energy production or heating purposes. However, this requires the implementation of desulfurization and moisture removal steps.

Additional treatment of the digested material (digestate) is required when using anaerobic reactors, due to organic matter, pathogens, odor, and nutrients like N and P. If this effluent is directly discharged into water bodies or used in irrigation, it could lead to water or soil pollution. To effectively handle the digestate, additional measures such as implementing aerobic reactors or a filtration system should be considered; commonly employed technologies include trickling bed filters, lagoons, and activated sludge reactors.

TERTIARY TREATMENT

Most treatment facilities will also need to implement a tertiary treatment, consisting of a disinfection stage to kill or inactivate harmful pathogens present in the wastewater before discharging it into the environment[5].

SLUDGE TREATMENT

Significant sludge volumes may be produced during both primary and secondary treatment stages in meat processing WWTPs. Managing this sludge often involves employing technologies like drying beds, centrifuges, or decanters for dewatering. These processes not only help decrease the moisture content of the sludge but also yield biosolids, which are used in activities like composting or fertilizer production. Ongoing research is dedicated to understanding the potential effects of other contaminants in the sludge, including heavy metals, pathogens, antimicrobial drugs, hormones, pesticides, and disinfectants. Even though these constituents might be introduced in minimal quantities during product processing or treatment, there's a particular concern regarding their potential accumulation in the soil and crops. This apprehension is accompanied by potential inadvertent losses through surface runoff or near-surface runoff, which could find their way into aquatic environments[17].

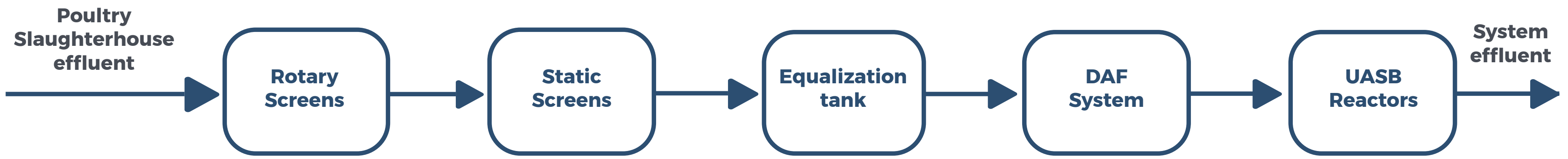
TABLE 3 Common treatment technologies used for treating meat processing wastewater.

Industry	Preliminary treatment	Primary treatment	Secondary Treatment	Tertiary Treatment	Sludge treatment	Emerging technologies
Meat processing	Flow equalization, screens, and mechanical filters.	Sedimentation basin, DAF, and pH regulation (if needed)	Anaerobic treatment, such as anaerobic filters and UASB, is followed by aerobic reactors or ponds.	Chlorine, ozone, UV (if pathogens are present, especially if wastewater is irrigated)	Sludge produced in primary and secondary treatment should be dewatered before disposal using sludge drying beds, centrifuges, or decanters. It is encouraged to dry the sludge further to produce biosolids that can be repurposed.	Ultrasound, Electrocoagulation, advanced oxidation process, electrochemical oxidation, and membrane technologies such as microfiltration, nanofiltration, ultrafiltration, reverse osmosis, and electrodialysis[18,19]

3.3 EXAMPLE OF WASTEWATER TREATMENT BWMP

In Figure 2, the case study of a poultry slaughterhouse is presented[20]. In this plant located in Sorocaba, Brazil, a study was conducted on the wastewater treatment system of a poultry slaughterhouse. The system consists of rotary and static screens, a DAF system, and two UASB reactors. The screens remove solid waste larger than 1,000 um and 750 um, and the effluent from the static screen and liquid blood fraction is collected in a 142 m^3 equalization tank before entering the DAF system and UASB reactors. The reactors were inoculated with sludge from a municipal sewage treatment plant, and the start-up period lasted 163 days. A base was added to the reactors' influent flow to maintain pH buffering conditions. Applying surface-loading rates of 1.6 ± 0.4 m^3/m^2/h to the DAF system yielded average removal efficiencies of 51% for FOGs and 37% for TSS. The UASB reactors demonstrated similar and satisfactory performance with BOD and COD removal efficiencies of 67% and 85%, respectively, despite varying organic loading rates ranging from 0.9 to 2.7 kg COD/m^3 day and up flow velocities from 0.2 to 0.5 m/h. The findings suggest that UASB reactors are suitable for maintaining acceptable operational efficiency despite the projected expansion in chicken meat production within the industry. Nevertheless, there is a need to address the remaining organic substances and nutrients to ensure that the effluent quality meets discharge parameters for safeguarding the receiving water bodies (such as complying with maximum allowable discharge limits like those set by the WBG). Thus, a supplementary secondary treatment unit, such as an anaerobic lagoon, must complete the wastewater treatment system.

FIGURE 2 Flow diagram of the final process in a poultry slaughterhouse facility in Brazil[20]



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3.4 KEY PERFORMANCE INDICATORS AND MONITORING

Each country has specific rules for managing and reusing wastewater, with regulations setting allowable water quality thresholds for different situations, such as the discharge into water bodies, coastal zones, and sanitary sewer systems, as well as the reuse of treated wastewater. The GPN in Section 2.2. includes a comparison of the quality parameters established in different countries. Table A-1 in Annex I provides a comprehensive overview of the legislative framework for wastewater management in the LAC region.

General EHS Guidelines of the WBG for meat processing establish the maximum allowable discharge limits in water bodies for the parameters listed in **Table 4**[21]. These must be achievable under normal operating conditions in appropriately designed and operated facilities and can be used as KIPs of wastewater treatment. New projects must comply with WBG's EHS Guidelines or national regulations (Annex I of the GPN), whichever is more stringent.

TABLE 4 Permissible limits for discharges into water bodies[22].

Pollutant	Guideline Value
pH	6-9
BOD_5	50 mg/L
COD	250 mg/L
N_{Total}	10 mg/L
P_{Total}	2 mg/L
Oil and Grease	10 mg/L
TSS	50 mg/L
Temperature increase	< 3 °C
Total coliform bacteria	400 MPN/100 mL

It is crucial to monitor the quality of effluents regularly and provide appropriate feedback mechanisms to prevent environmental and social impacts; more information is provided in Section 6 of the GPN for the correct management of wastewater in the agribusiness sector. It is essential to develop and implement a program with sufficient resources and management oversight to achieve a monitoring program's objective(s) for wastewater and water quality. Table 9 of the GPN describes the sampling points and analytical requirements for process water and wastewater samples, and recommends a sampling frequency. Prioritizing adherence to local regulations and other mandates established by financial institutions or internal policies for monitoring wastewater and water quality should always take precedence. This priority should override any general guidelines or recommendations. While the suggested sampling frequency may be a good starting point, it is essential to understand and comply with the local regulations and requirements set forth by regulatory agencies.

In the case of meat processing wastewater, monitoring parameters such as pH, DO concentration, turbidity, temperature, TN, TP, COD, settleable solids, and water flow of the treated effluent should be conducted at a frequency that can provide representative data (for more information check Section 6.5. of the GPN). Due to the nature of the wastewater, it may be necessary to frequently monitor pathogenic microorganisms introduced into the wastewater as these Present potential hazards for the treatment plant and workers' health and safety. The recorded information should include the date, time, measurement results, adjustments made, and other relevant data. It is necessary to use calibrated equipment and ensure trained operators conduct the measurements. A laboratory space at the treatment plant is also required for this task. Record-keeping procedures should be in place to document the monitoring results. External certified laboratories (preferably ISO 17025) shall provide monitoring records for microbial and physicochemical analysis, and frequency will depend on the regulatory frameworks of each region. It is recommended to have at least a quarterly monitoring frequency.

4 References

(1) Futuris Consulting. Good Practice Note: Wastewater Management for the Agribusiness Sector, 2023.

(2) FONTAGRO. Meat production in Latin America and the Caribbean. https://www.fontagro.org/en/publications/press/meat-production-in-latin-america-and-the-caribbean/.

(3) Bustillo-Lecompte, C.; Mehrvar, M.; Quiñones-Bolaños, E. Slaughterhouse Wastewater Characterization, and Treatment: An Economic and Public Health Necessity of the Meat Processing Industry in Ontario, Canada. J. Geosci. Environ. Prot. 2016, 04 (04), 175–186. https://doi.org/10.4236/gep.2016.44021.

(4) Maré, F. A.; Jordaan, H. The Water Footprint of Primary and Secondary Processing of Beef from Different Cattle Breeds: A Value Fraction Allocation Model. Sustainability 2021, 13 (12), 6914. https://doi.org/10.3390/su13126914.

(5) Kharat, D. S. Pollution Control in Meat Industry. Curr. Environ. Eng. 2019, 6 (2), 97–110. https://doi.org/10.2174/2212717806666190204102731.

(6) European Commission. Integrated Pollution Prevention and Control: Best Available Techniques in the Slaughterhouses and Animal By-Products Industries, 2005.

(7) US EPA. Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Meat and Poultry Products Industry Point Source Category, 2002.

(8) World Bank Group. Environmental, Health and Safety Guidelines for Meat Processing, 2007.

(9) Aleksić, N.; Nešović, A.; Šušteršič, V.; Gordić, D.; Milovanović, D. Slaughterhouse Water Consumption and Wastewater Characteristics in the Meat Processing Industry in Serbia. DESALINATION WATER Treat. 2020, 190, 98–112. https://doi.org/10.5004/dwt.2020.25745.

(10) Food and Agriculture Organization of the United Nations. Management of Waste from Animal Product Processing; 1996. https://www.fao.org/3/x6114e/x6114e00.htm.

(11) Ngobeni, P. V.; Basitere, M.; Thole, A. Treatment of Poultry Slaughterhouse Wastewater Using Electrocoagulation: A Review. Water Pract. Technol. 2022, 17 (1), 38–59. https://doi.org/10.2166/wpt.2021.108.

(12) Suceveanu, M.; Suceveanu, I.; Grosu, L.; Alexa, I.-C. Treatment of Wastewater from Swine and Poultry Slaughterhouses. 2018, 24 (2).

(13) Villarroel Hipp, M. P.; Silva Rodríguez, D. Bioremediation of Piggery Slaughterhouse Wastewater Using the Marine Protist, Thraustochytrium Kinney VAL-B1. J. Adv. Res. 2018, 12, 21–26. https://doi.org/10.1016/j.jare.2018.01.010.

(14) Yetilmezsoy, K.; Ilhan, F.; Kiyan, E.; Bahramian, M. A Comprehensive Techno-Economic Analysis of Income-Generating Sources on the Conversion of Real Sheep Slaughterhouse Waste Stream into Valorized by-Products. J. Environ. Manage. 2022, 306, 114464. https://doi.org/10.1016/j.jenvman.2022.114464.

(15) Philipp, M.; Masmoudi Jabri, K.; Wellmann, J.; Akrout, H.; Bousselmi, L.; Geißen, S.-U. Slaughterhouse Wastewater Treatment: A Review on Recycling and Reuse Possibilities. Water 2021, 13 (22), 3175. https://doi.org/10.3390/w13223175.

(16) Bailone, R.; Roça, R.; Fukushima, H.; De Aguiar, L. K. Sustainable Water Management in Slaughterhouses by Cleaner Production Methods—a Review. Renew. Agric. Food Syst. 2021, 36 (2), 215–224. https://doi.org/10.1017/S1742170520000083.

(17) Shi, W.; Healy, M. G.; Ashekuzzaman, S. M.; Daly, K.; Leahy, J. J.; Fenton, O. Dairy Processing Sludge and Co-Products: A Review of Present and Future Re-Use Pathways in Agriculture. J. Clean. Prod. 2021, 314, 128035.

(18) Fatima, F.; Du, H.; Kommalapati, R. R. Treatment of Poultry Slaughterhouse Wastewater with Membrane Technologies: A Review. Water 2021, 13 (14), 1905. https://doi.org/10.3390/w13141905.

(19) Ng, M.; Dalhatou, S.; Wilson, J.; Kamdem, B. P.; Temitope, M. B.; Paumo, H. K.; Djelal, H.; Assadi, A. A.; Nguyen-Tri, P.; Kane, A. Characterization of Slaughterhouse Wastewater and Development of Treatment Techniques: A Review. Processes 2022, 10 (7), 1300. https://doi.org/10.3390/pr10071300.

(20) Del Nery, V.; de Nardi, I. R.; Damianovic, M. H. R. Z.; Pozzi, E.; Amorim, A. K. B.; Zaiat, M. Long-Term Operating Performance of a Poultry Slaughterhouse Wastewater Treatment Plant. Resour. Conserv. Recycl. 2007, 50 (1), 102–114. https://doi.org/10.1016/j.resconrec.2006.06.001.

(21) World Bank Group. Environmental, Health, and Safety Guidelines for Dairy Processing, 2007.

(22) World Bank Group. Environmental, Health, and Safety Guidelines for Aquaculture, 2007.

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