

GOOD PRACTICE NOTE

WASTEWATER

MANAGEMENT FOR THE

AGRIBUSINESS SECTOR

FOR IDB INVEST

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Acronyms

AOX	Adsorbable Organic Halogens	GHG	Greenhouse Gas	SDS	Safety Data Sheets
BOD	Biochemical Oxygen Demand	GPN	Good Practice Note	SM	Standard Methods
BMPs	Best Management Practices	H/O	Housekeeping and Operational	SS	Settleable Solids
BWMPs	Best Wastewater Management Practices	IDB	Inter-American Development Bank	TDS	Total Dissolved Solids
CIP	Clean-In-Place	K	Potassium	TSS	Total Suspended Solids
COD	Chemical Oxygen Demand	LAC	Latin America and the Caribbean	UASB	Up flow Anaerobic Sludge Blanket
DAF	Dissolved Air Flotation	MPN	Most Probable Number	UN	United Nations
DMZ	Discharge Mixing Zone	N	Nitrogen	UV	Ultraviolet
DO	Dissolved Oxygen	N.R.	Non-Regulated	VFA	Volatile Fatty Acids
EHS	Environmental, Health and Safety	NTU	Nephelometric Turbidity Units	WBG	World Bank Group
EPA	Environmental Protection Agency	P	Phosphorus	WHO	World Health Organization
EP	Emerging Pollutants	P&E	Processes and Equipment	WUE	Water Use Efficiency
EPI	Environmental Performance Indicator	R.B.	Risk Based	WWTP	Wastewater Treatment Plant
FOG	Fats, Oils and Greases	SAR	Sodium Adsorption Ratio	WQI	Water Quality Index
GIIP	Good International Industry Practices	SDG	Sustainable Development Goals		

7 Introduction



1.1 BACKGROUND AND OBJECTIVES

The agribusiness industry plays a vital role in the global economy as it supplies food, beverages, and essential products to the world's population. Ensuring food security and meeting the needs of a growing global population amplifies the importance of its function. As the worldwide demand for agricultural products rises, addressing the sector's environmental impact becomes increasingly urgent.

Additionally, the United Nations (UN) Sustainable Development Goals (SDGs) emphasize the importance of sustainability across all sectors, including agribusiness. Properly managing the environmental aspects of this sector aligns with several SDGs, such as promoting clean water and sanitation, responsible consumption and production, and taking clear actions to address climate change.

One of the primary environmental challenges linked to agribusiness is improper management of wastewater from its operations. This wastewater is known to have various pollutants, including high concentrations of organic pollutants, biochemical oxygen demand (BOD), chemical oxygen demand (COD), fat, oils, and greases (FOGs), total suspended solids (TSS), as well as nutrients like nitrogen (N) and phosphorus (P). Depending on the specific processing operations, other pollutants, such as disinfection agents, pesticides, veterinary drugs, or components of commercial chemical products, may also be present. These pollutants can adversely affect the environment and public health if not treated properly.

This Good Practice Note (GPN) aims to provide

practical guidance on properly managing wastewater in the agribusiness sector. Additionally, it has three other objectives:

- 1) Compile examples of best wastewater management practices in agro-industrial projects.
- 2) Guide on managing the risks of effluent discharge to water bodies or reuse in landscape irrigation, fertigation, or irrigation.
- 3) Assist environmental practitioners in evaluating the correct implementation of wastewater management.

By achieving these objectives, the note aims to contribute to environmental protection, ensure long-term sustainability, and support the attainment of the SDG No.6 for the Latin America and the Caribbean (LAC) region.

Overall, it is essential to note that wastewater management and implementation can vary greatly depending on the context and site-specific factors. The management of wastewater involves a wide range of factors, including varying water resource availability, levels of economic development, processing operations, and diverse climatic conditions, which can pose significant challenges for wastewater management. It is important to note that this GPN is complemented by industry-specific primers for aquaculture, dairy processing, food and beverage, and meat processing. These primers provide a more detailed approach to wastewater management, considering each industry's specific characteristics and challenges.

1.2 STRUCTURE AND GENERAL OVERVIEW OF THE GPN

This GPN guides businesses in achieving environmental protection and ensuring long-term sustainability through the adoption of good in the agribusiness industry. The note is organized into six sections:

THE FIRST SECTION

“Review of the LAC Regulatory Context,” provides an overview of regional regulatory frameworks and includes information from eight countries to show the different advances in regulatory matters. It also compares the values of the quality that effluents must achieve. It is worth noting that some countries in the LAC region use a risk assessment methodology based on the capacity of the receiving body to establish maximum discharge parameters. In contrast, other countries still have less developed legislation, and parameters depend on maximum permissible limits established.

THE SECOND SECTION

“Review of Best Wastewater Management Practices for Agribusiness and Food Processors,” discusses the Best Wastewater Management Practices (BWMP) for agribusiness. BWMPs are industrial practices that prevent toxic or hazardous substances from entering the environment. The management and accountability of BWMPs are crucial for effective and sustainable wastewater management. Accountability measures, such as public reporting and stakeholder engagement, can improve public perception and support for wastewater management practices. The responsibility of implementing BWMP falls on various stakeholders involved in wastewater management, including Environmental Health and Safety (EHS) officers, EHS coordinators, site managers, and WWTP operators. The section also discusses the barriers to adopting BWMPs, such as more awareness and vision, time and human resources, technical knowledge, and expertise.

THE THIRD SECTION

Focuses on implementing a Pollution Prevention Plan and stresses the significance of management commitment by applying BWMP. The section begins with a concise overview of pollution prevention BWMP and their associated benefits. Subsequently, it explores the implementation procedure of the plan and emphasizes the necessity of creating a tailored plan adapted to the industry’s requirements. The section also includes examples of pollution prevention BWMPs for agribusiness to illustrate the practical application of the plan.

THE FOURTH SECTION

Discusses the importance of implementing BWMP and provides a comprehensive review of wastewater characteristics from different agribusinesses and appropriate treatment approaches. The implementation process for wastewater treatment BWMPs is broken down into three essential steps. The first step involves classifying the wastewater treatment stages based on the wastewater characteristics and level of contaminants; the second step requires determining the appropriate treatment level based on the wastewater classification, local regulation, and final discharge; the final step is to select the specific treatment technology that will be used to achieve the required level of treatment.

THE FIFTH SECTION

Focuses on effluent management and the associated risks. This section outlines the general considerations that businesses need to consider when discharging wastewater, such as the quality and quantity of the discharge and the potential impact on the environment. This section also covers effluent reuse, which is becoming an increasingly popular option for businesses looking to reduce their water footprint. The risk-based assessment of wastewater discharge is another critical aspect of this section, guiding how to assess the risk associated with different types of wastewater discharge. The final part of this section covers effluent monitoring, which is essential to ensure compliance with relevant regulations and identify potential wastewater discharge issues.

THE SIXTH SECTION

Provides a background and rationale for a business case, including three case studies illustrating good practices for managing wastewater in agribusiness. The case studies are a lemon juice processing plant, a poultry processing company, and a swine breeding and production facility. The section concludes with a summary of the case studies’ key learnings.

1.3 APPLICABILITY AND INTENDED AUDIENCE

This GPN is designed to provide guidance and recommendations for IDB Invest clients and decision-makers responsible for planning, designing, and delivering wastewater management strategies, particularly those in the aquaculture, dairy processing, food and beverage, and meat processing sectors.

The intended audience includes professionals in the agri-business industry who are involved in developing and implementing wastewater management strategies to reduce environmental impacts and comply with regulatory requirements.

2

Review of the LAC Regulatory Context



2.1 OVERVIEW

This section provides an overview of the current regulations related to wastewater in LAC. It begins by describing the region's availability and management of water resources. It then discusses the key drivers that have led to the development of regulations, such as international agreements (Section 2.2.2). The section also emphasizes the importance of aligning wastewater treatment with the circular economy concept, thus reducing water footprint. Finally, the section provides a comparative analysis of wastewater regulations in eight LAC countries (Argentina, Brazil, Chile, Dominican Republic, Ecuador, Honduras, Mexico, and Peru) by examining the water quality parameters associated with effluent disposal.

The comparative analysis focuses on four disposal methods: direct discharge into surface water bodies, coastal zones, sanitary sewers, and reuse for landscape irrigation, fertigation, or infiltration. It is important to note that all countries under review have established regulations for wastewater discharge parameters. Still, there are significant differences in the quality values set forth. A comparative analysis of wastewater regulations of eight LAC countries is discussed in Section 2.3. It is important to note that this comparative analysis is not exhaustive and has limitations. For example, it includes only eight countries and does not represent the whole region. Moreover, the study does not consider the enforcement of wastewater regulations, which can vary significantly between countries and impact the quality of wastewater discharge. It is important to note that IDB Invest also adheres to the World Bank Group's Environmental, Health and Safety (WBG's) EHS Guidelines reference values. In cases where the host country's regulations differ from the levels and measures outlined in the EHS Guidelines, projects are

required to meet the more stringent of the two standards. In addition to the comparative analysis of wastewater regulations, the report includes two annexes that provide additional context for reference; in Annex 1, a wastewater regulatory reference table (Table A-1) for LAC is presented, which outlines the legislative framework on wastewater matters in LAC, as well as the main authorities related to the institutional administrative framework of wastewater management; Annex 2 provides a deeper background analysis of the regulatory context of three different countries: Mexico, Brazil, and Honduras.

2.2 LAC REGULATORY CONTEXT

2.2.2 KEY DRIVERS FOR REGULATORY SHIFTS

Each country has a unique story, which includes a particular combination of historical background, legal framework, and policy guidance, implementing highly context-specific regulations (Allaoui et al., 2015). Nevertheless, the LAC region has experienced a rapid and recent increase in institutional momentum surrounding wastewater treatment and disposal, resulting in a trend toward stricter regulations and enforcement. This shift has been driven by environmental degradation, population growth, urbanization, pressure from international organizations, international trade agreements, international finance requirements, and civil society awareness.

Additionally, fiscal penalties for environmental infractions are growing, and the enforcement of environmental laws is increasing Inter-American Development Bank (IDB), 2016.

A series of international initiatives and conferences, such as the International Conference on Water and the Environment of 1992, the Paris Agreement, U.N. Climate Change Conferences of the Parties, U.N. Frameworks Convention on Climate Change, and World Water Forum 2018 in Brasilia, have played a pivotal role in promoting pollution control and contributed to fostering agreement on international programs and policies, as well as the strengthening of the global legal framework that addresses the issues of wastewater management and the provision of safe drinking water and sanitation (Allaoui et al., 2015).

Similarly, SDG No. 6 highlights the need for clean water and sanitation, aiming to improve water quality by reducing pollution, eliminating uncontrolled dumping, minimizing the release of hazardous chemicals and materials, and substantially increasing recycling and safe reuse globally by 2030. As many LAC countries have adopted these goals as part of their national development strategies, they face the challenge of improving their regulations and policies to achieve them. Additionally, the 2030 Agenda for Sustainable Development aims to promote a transition towards a circular economy (General Assembly United Nations, 2015).

KEY DRIVERS FOR REGULATORY SHIFTS IN LAC

- Pressure from international organizations.
- Environmental degradation.
- Population growth and urbanization.
- International trade agreements.
- International finance requirements.

2.2.3 PARADIGM SHIFT AND CIRCULAR ECONOMY

A paradigm shift is currently occurring in the way wastewater is viewed in the LAC region. Rather than being seen as waste, it is increasingly being recognized as a resource that has the potential to improve sustainable water use. This shift aligns with the circular economy concept, which emphasizes reusing resources rather than disposing of them after use. Each country's internal policies and regulations largely determine the effectiveness of this approach. Currently, regulations regarding the reuse of wastewater vary greatly throughout the region. Some countries, like Argentina and the Dominican Republic, lack regulation, as shown in section 2.3.5, while others permit reuse for specific activities such as agricultural irrigation.

For instance, Colombia has updated its regulation to allow the reuse of treated wastewater for agricultural irrigation. At the same time, Guatemala and Mexico have regulations that authorize reuse for various agricultural and recreational purposes. Section 2.3.5 summarizes the limits encompassed in legal frameworks for water re-usage. Despite progress in some areas, the region needs help in transitioning to a circular economy of water. To achieve this, institutions and legislation must be strengthened to incentivize investment and development of wastewater treatment systems to revalue this resource and reduce pressure on water resources.

2.3 COMPARISON OF WASTEWATER REGULATIONS IN LATIN AMERICAN AND CARIBBEAN COUNTRIES

2.3.1 REFERENCES TO LAC WASTEWATER REGULATIONS

The political constitutions of most LAC countries include provisions for water resources, and most of these countries have enacted a comprehensive general water law to regulate water resource management and sanitation. While the regulations related to wastewater management vary among these countries, they are all intended to safeguard public health and the environment. Each country has specific rules for managing and reusing wastewater, with regulations setting allowable water quality thresholds for different scenarios, such as the discharge into water bodies, coastal zones, and sanitary sewer systems, as well as the reuse of treated wastewater. This section compares the quality parameters established by eight countries: Argentina, Chile, Brazil, Ecuador, the Dominican Republic, Mexico, Peru, and Honduras. Section 2.3.2. compares and discusses different regulations for discharge parameters.

2.3.2 DIRECT DISCHARGE TO SURFACE WATER BODIES

Table 1 illustrates that regulations for wastewater discharge parameters exist in all countries, but there are variations in how these values are established. For Argentina, the permissible discharge values are specified in [Table 1](#), but temporary values are also authorized when a parameter exceeds the allowable concentration. These temporary values are calculated using determined guide values of the watercourses established in Decree 674/89. Chile allows the emitting entities to increase the threshold concentrations established in the table by taking advantage of the receiving body's dilution capacity, following a standardized methodology. In Brazil, exceptions to the parameters defined in the table are allowed if they conform to what is obtained in a risk assessment of the receiving body and if they meet progressive improvement goals. Honduras recently passed a law in 2021 that introduced a phased discharge process, which considers the quality of the receiving water, available technology, and removal capacities as a risk-based approach.

Regarding the Dominican Republic, the values presented in Table 1 apply to industries in general. However, specific values also regulate activities, such as sugar production, soda manufacturing, coffee processing, breweries, distilleries, dairy farming, and animal slaughterhouses. In Ecuador, a mass balance methodology is used to calculate the discharge limits, incorporating the quality of the water body and pollutant load. The parameters presented in Table 1 are used when information about the receiving body is unavailable. Peru established the "Guide for the Determination of the Mixing Zone and the Evaluation of the Impact of the Discharge of Treated Wastewater into a Natural Receiving

Body” in 2017, which serves as the basis for calculating the parameters for the discharge of treated wastewater into the receiving body.

Overall, one evident trend is the move towards a mixing zone and impact evaluation of the discharge, as seen in the recent legislation

introduced by Honduras and the guidelines established by Peru.

Moreover, most countries in the region enforce regulations as strict as those recommended in the General EHS Guidelines of the WBC for parameters such as BOD, COD, and pH values.

However, there is still room for improvement in some areas, particularly in regulating the maximum concentration of total coliforms and other parameters such as FOGs, TSS, N, and P concentrations, which have less strict regulations in some countries like Brazil, Chile, Ecuador, Honduras, and Mexico compared to others in the region.

2.3.3 DISCHARGE TO COASTAL ZONES OR SEA

Table 2 provides a comparative summary of maximum parameter discharge values for effluent discharged in coastal areas or the sea. Chile, Mexico, the Dominican Republic, and Ecuador are among the countries that have established parameters governing this type of disposal. It is noteworthy that both Chile and the Dominican Republic have varying parameter values depending on the intended use of the coastal area where the effluent is discharged. Conversely, Brazil, Honduras, and Peru have implemented a risk assessment methodology to determine quality parameters based on the characteristics of the coastal zone. Adopting a risk assessment approach is recommended for countries lacking regulations, as further explained in Section 6.

TABLE 1 Comparison of effluent discharge limits in water bodies for quality parameters in LAC countries

Country	Type of establishment	Norms include risk assessments, or other special conditions for determining parameters	Parameters							
			BOD (mg/L)	COD (mg/L)	TSS (mg/L)	pH	FOGs (mg/L)	N (mg/L)	P (mg/L)	Total coliforms (MPN/100 mL)
Argentina	Industrial and special waters ¹	Watercourse quality guide values	50	N.R.	N.R.	5,5-10	N.R.	N.R.	N.R.	5000
Brazil	General	Risk assessment	60% ²	N.R.	N.R.	5-9	50	20	³	N.R.
Chile	General	Watercourse dilution capacity	35	N.R.	80	6-8.5	20	50	10	1000
Ecuador	General ⁴	Watercourse quality guide values	100	200	130	6-9	30	50	10	2000
Honduras	General	Risk assessments	100	200	100	6-9	10	30	5	5000
Mexico	General	Risk assessment just for BOD	Risk assessment	150	60	6-9	15	25	15	250 ⁵
Peru ⁶	Breweries ⁷	Risk assessments	30	50	30	6-9	3	N.R.	N.R.	N.R.
Dominican Republic	General	Watercourse quality	50	250	50	6-9	10	10 (N-NH4)	2	1000
General EHS Guidelines of the WBC	Agribusiness	Standard values	50	250	50	6-9	10	10	2	400

Table A - 1 in Annex 1 provides a comprehensive overview of the legislative framework for wastewater management in the LAC region. It lists

the primary institutions governing wastewater, each country’s key legislation and norms, and corresponding online links.

¹ The norm regulates discharges on rivers: Luján, Tigre, Matanza, Riachuelo, Río de la Plata, Reconquista, and tributaries.

² The DBO must be reduced to 60% of the concentration of the DBO of the inlet water of the WWTP.

³ Defined based on the historical concentration data of cyanobacteria.

⁴ The parameters shown are those used when no information about the water body is available.

⁵ This refers to E. Coli concentration.

⁶ There are no parameters for general industrial effluents; Decree No. 003-2010-MINAM regulates only municipal or domestic discharges.

⁷ General reference values were used for wastewater discharges from any source. The regulation also has values for some specific industries.

TABLE 2 Comparison of effluent discharge limits in coastal zones for quality parameters in LAC countries

Country	Norms include risk assessments or other special conditions to determine parameters	Parameters								
		BOD (mg/L)	COD (mg/L)	SS (mg/L)	TSS (mg/L)	pH	FOGs (mg/L)	N (mg/L)	P (mg/L)	Total coliforms (MPN/100 mL)
Argentina	Not regulated	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
Brazil	Risk assessment	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.
Chile	Depends on the usage of the coastal zone ⁸	60	N.R.	5	100	6-9	20	50	5	1000 - 70 ⁹
	Depends on the usage of the coastal zone ¹⁰	N.R.	N.R.	20	300	5,5-9	150	N.R.	N.R.	N.R.
Ecuador	Depends on the usage of the coastal zone ¹¹	200	400	N.R.	250	6-9	30	40	N.R.	2000
	Depends on the usage of the coastal zone ¹²	400	600	N.R.	250	6-9	30	40	N.R.	2000
Honduras ³	Risk assessment	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.
Mexico ¹⁴	Risk assessment just for the BOD value	R.B.	85	N.R.	20	6-9	15	25	15	250
Peru	Risk assessment	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.
Dominican Republic	Depends on the usage of the coastal zone ¹⁵	60	350	1	75	6-9	15	40	8	N.R.
	Depends on the usage of the coastal zone ¹⁶	200	350	2	200	6-9	25	N.R.	10	N.R.

2.3.4 DISCHARGE TO SANITARY SEWERS

In the case of discharge to sanitary sewers, most countries have regulations that specify the discharge parameters. However, specific parameters such as COD and total coliforms remain unregulated in countries like Argentina, Chile, and Mexico, as described in Table 3. The regulations in Brazil mandate that, in the

absence of specific legislation or guidelines from the collection system and sewage treatment operator, the indirect discharge of effluents into the receiving body must comply with the direct discharge limits. On the other hand, Peru implemented a regulation in 2019 that establishes maximum concentration key parameters for non-domestic wastewater discharges into sanitary sewer systems. In Honduras, the administrator of the wastewater treatment plant is responsible for determining the parameter values.

TABLE 3 Comparison of effluent discharge limits in sanitary sewer systems in LAC countries

Country	Sector	Parameters								
		BOD (mg/L)	COD (mg/L)	SS (mg/L)	TSS (mg/L)	pH	FOGs (mg/L)	N (mg/L)	P (mg/L)	Total coliforms (MPN/100 mL)
Argentina	Industrial	200	N.R.	0	N.R.	5,5-10	N.R.	N.R.	N.R.	5000
Brazil ¹⁷	General	60%	N.R.	N.R.	5-9	50	20	N.R.	N.R.	60%
Chile	Industrial	300	N.R.	20	300	5,5-9	150	80	10-15	N.R.
Ecuador	General	250	500	20	220	6-9	70	60	15	N.R.
Honduras	General	18	18	18	18	5-9	18	18	18	18
Mexico ¹⁸	General	N.R.	N.R.	5	N.R.	5,5-10	50	N.R.	N.R.	N.R.
Peru	Industrial	500	1000	8.5	500	6-9	100	80	N.R.	N.R.
Dominican Republic	Industrial sector	250	600	N.R.	400	6-9	N.R.	40	10	N.R.

⁸ Discharges through submarine outfalls.

⁹ In areas suitable for aquaculture and areas of management and exploitation of benthic resources, a value of 70 NMP/100 mL should not be exceeded.

¹⁰ Discharges through submarine outfalls.

¹¹ Discharges in the area of marine breakers.

¹² Discharges through submarine outfalls.

¹³ They are contemplated within the risk assessment guide using the criteria based on water quality and the best available technology.

¹⁴ The values shown are monthly averages. The daily average and instantaneous values are also regulated and vary depending on the parameter.

¹⁵ Discharges in coastal waters intended for the conservation of natural resources such as mangroves and reproduction and nutrition areas for marine organisms and areas for marine aquaculture, including mollusks, crustaceans, fishes, and commercial fishing.

¹⁶ Discharges in coastal waters used for industrial activities, shipping activities, and ports.

2.3.5 REUSE OF TREATED WASTEWATER IN LANDSCAPE IRRIGATION, FERTIGATION, AND INFILTRATION.

Because of its comparatively abundant water resources in comparison to other global regions, the LAC area has given lower priority to the promotion of water reuse (Wellestein & Makino, 2022). This region has a insufficient regulation or ambiguous directives regarding wastewater usage for fertigation and other wider water reuse purposes.

Table 4 presents an overview of various national stances on treated wastewater reuse. For instance, countries such as Argentina, Chile, and the Dominican Republic lack specific regulations on this topic. In contrast, Brazil allows untreated industrial effluents for fertigation upon approval from a competent environmental agency. On the contrary, in Ecuador, certain water quality parameters for irrigation and agricultural use, including dissolved oxygen (DO), metals, and salts, are subject to specific regulations, although most of the parameters in the table fall outside the norm. Honduras' regulation is solely relevant to sugarcane irrigation, while Mexico's regulation outlines reuse possibilities for infiltration and crop irrigation. In Peru, the evaluation of treated wastewater reuse is contingent upon authorities

considering sector-specific values or the health guidelines established by the World Health Organization (WHO) in 1989.

While there is widespread agreement on the rationale behind using wastewater in agriculture from agronomic, economic and sustainability perspectives, it is crucial to acknowledge that wastewater possesses unique qualities that may give rise to environmental and health concerns. The viability of substituting conventional or other non-conventional water sources for fertigation with wastewater is largely contingent upon whether the associated health risks and environmental consequences remain within acceptable limits (FAO, 1992). It is recommended that all activities involving fertigation or water reuse be overseen through a site-specific risk assessment, which should consider a range of factors, including wastewater composition, potential contaminants, local ecosystem, and hydrogeological interactions, and potential pathways of exposure. The main points to consider when deciding whether to conduct a site-specific risk assessment for landscape irrigation, fertigation, or infiltration and how to undertake it are detailed in sections 6.

When contemplating the use of wastewater for either landscape irrigation, fertigation, or infiltration, it is essential to consider certain criteria. These criteria encompass wastewater parameters such as electrical conductivity, concentrations of sodium, calcium, and magnesium ions, pH levels, total suspended solids (TSS), Biochemical Oxygen Demand (BOD₅), pathogenic bacteria, as well as levels of nitrogen (N), phosphorus (P), and heavy metals. A more detailed explanation of the reasoning behind these considerations can be found in **Section 6.2.4**. Additionally, it is advised to refer to the prescribed thresholds outlined in Table A-3.1, Table A-3.2, and Table A-3.3 for further guidance.

TABLE 4 Comparison of effluent discharge limits for the reuse of treated wastewater through landscape irrigation, fertigation, or infiltration in LAC countries

Country	Parameters								
	BOD (mg/L)	COD (mg/L)	SS (mg/L)	TSS (mg/L)	pH	FOGs (mg/L)	N (mg/L)	P (mg/L)	Total coliforms (MPN/100 mL)
Brazil ²⁰	N.R.	N.R.	N.R.	N.R.	5-9	20 or 50 ²¹	N.R.	N.R.	1000/10000 ²²
Ecuador	N.R.	N.R.	N.R.	N.R.	6-9	absent	N.R.	N.R.	1000
Honduras ²³	500	1000	20	300	6-9	10	30	N.R.	N.R.
Mexico ²⁴	R.B.	150	N.R.	100	6-9	15	N.R.	N.R.	250 ²⁵

²⁰ The resolution does not apply to effluents from tanneries and industries producing ethanol, sugar and liquor. It allows the reuse of industrial effluents that have not passed through stabilization processes for fertigation, as long as the competent environmental agency authorizes it.

²¹ FOGs are 20 mg/l for vegetable oils and 50 mg/l for animal fats.

²² E. Coli. 1000 UFC for irrigation in human consumption crops and 10000 UFC for other pastures or cultures.

²³ For irrigation of sugar mill wastewater in areas cultivated with sugarcane. The value corresponds to the concentration of E. Coli.

²⁴ Data for irrigation that is not for green areas. The values presented correspond to the monthly average values. Daily average values and instantaneous values are also regulated.

²⁵ The value corresponds to the concentration of E. Coli.

3 *Best wastewater Management Practices (BWMPs)*



BEST' related to techniques

The most effective available to achieve a high level of protection of the environment.

'MANAGEMENT' related to tasks

Effective and practicable (including technological, economic, and institutional considerations) means to prevent or reduce pollution.

'PRACTICES' - related to working methods or innovations

Economically and technically viable conditions considering the costs and advantages of implementation.

3.1 BEST WASTEWATER MANAGEMENT PRACTICES

The Best Management Practices (BMPs) approach, developed and established by the United States Environmental Protection Agency (EPA), consists of a series of industrial practices or measures to prevent toxic or hazardous substances from entering the environment (US EPA, 1993). The concept is described as follows:

The BWMPs are BMPs specifically formulated for wastewater management and directed at reducing the discharged pollutants of an effluent entering a water body. Common BWMPs include housekeeping practices, maintenance plans, water consumption reduction and quality improvements, wastewater monitoring, and treatment improvements (OCETA, 2005). The BWMPs can be grouped into two large groups:

Pollution prevention BWMPs (Section 4 of this GPN).

Wastewater treatment BWMPs (Section 5 of this GPN).

Both BWMPs are intended to be site-specific, and are formulated according to the site, process, and specific wastewater pollutants.

The agribusiness and the food processor sectors benefit from implementing the BWMPs approach due to the difficulty of consistently achieving wastewater discharge parameters and their highly variable and water-demanding processes.

3.2 MANAGEMENT AND ACCOUNTABILITY OF THE BWMPs

3.2.1 COMMITMENT AND MANAGEMENT STRUCTURE FOR IMPROVING BWMPs

Commitment and accountability

Implementing pollution prevention and BWMPs relies on an express commitment from upper management to improve water consumption practices and effluent quality to meet regulatory or any other applicable standards.

Management and accountability for BWMPs are essential for effective and sustainable wastewater management. Accountability measures -such as reporting to key stakeholders- can help promote transparency and build trust, improving public perception and supporting wastewater management practices.

The responsibility of implementing BWMPs falls on various stakeholders involved in wastewater management. Some crucial internal stakeholders that need to be considered while setting a BWMP plan are described below:

EHS OFFICERS OR MANAGERS

Environmental Health and Safety (EHS) officers/managers oversee regulatory compliance and promote safe working practices. EHS officers ensure that the BWMP plan complies with all relevant environmental regulations, policies, or other applicable standards. Also, they are the direct contact for reporting the performance and development of the plan and possible non-compliance with the interested stakeholders.

SITE MANAGERS

Site managers are responsible for managing the day-to-day operations of their facilities. In wastewater management, site managers are responsible for ensuring that the wastewater management plan is implemented within their facility, providing resources and support to employees to ensure compliance with the plan, and identifying and addressing issues related to wastewater management at their site with the EHS officers and coordinators.

EHS COORDINATORS

EHS coordinators are responsible for coordinating the implementation of procedures within the organization. In the context of wastewater management, EHS coordinators are responsible for implementing the wastewater management plan within their area of responsibility, developing, and providing training to employees on safe and responsible wastewater management practices, providing guidance and support to employees on the proper handling and disposal of wastewater and organizing the necessary monitoring, risk assessment studies and reporting to ensure compliance with the wastewater management plan.

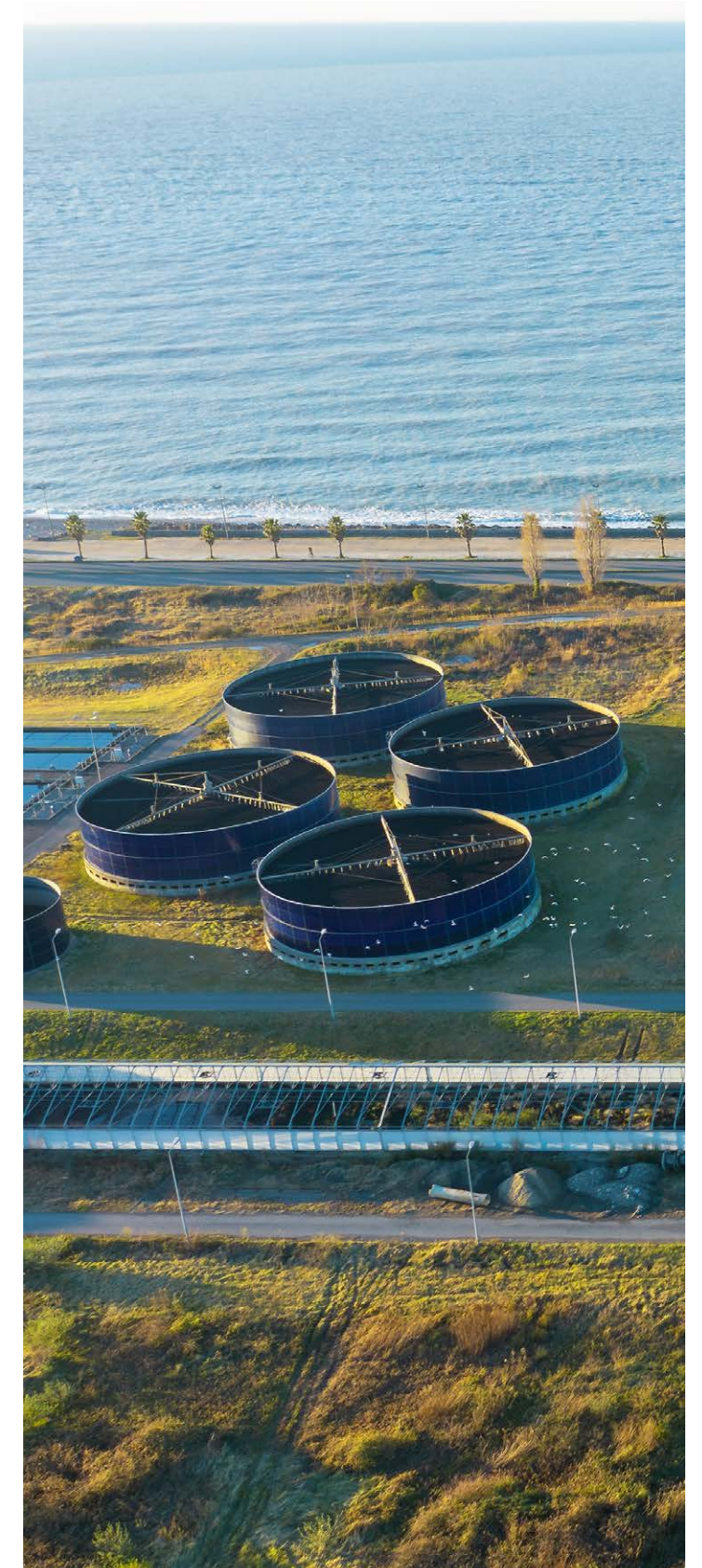
WWTP OPERATORS

WWTP operators operate and maintain wastewater treatment plants according to established WWTP manuals and procedures. Among other tasks, they monitor daily and maintain the equipment used for wastewater treatment. Also, operators report any issues or deviations from the established manuals or procedures to site managers or EHS coordinators.

3.2.2 IMPORTANCE OF A POLLUTION PREVENTION BWMPs PLAN

The BWMPs should be incorporated into a comprehensive facility BWMPs plan to maximize their effectiveness. In order to do so, the first step should involve developing a site-specific pollution prevention BWMPs plan (as described in **Section 4.2**), which includes an initial assessment and continuous implementation of measures and opportunities to address potential pollution sources at the site.

This initial step is critical as it identifies and mitigates potential pollution sources, which can then effectively address all aspects of wastewater treatment technology implementation and management. By implementing an effective facility BWMPs plan, organizations can minimize their environmental impact, comply with regulations, and improve their reputation as responsible and sustainable entities.



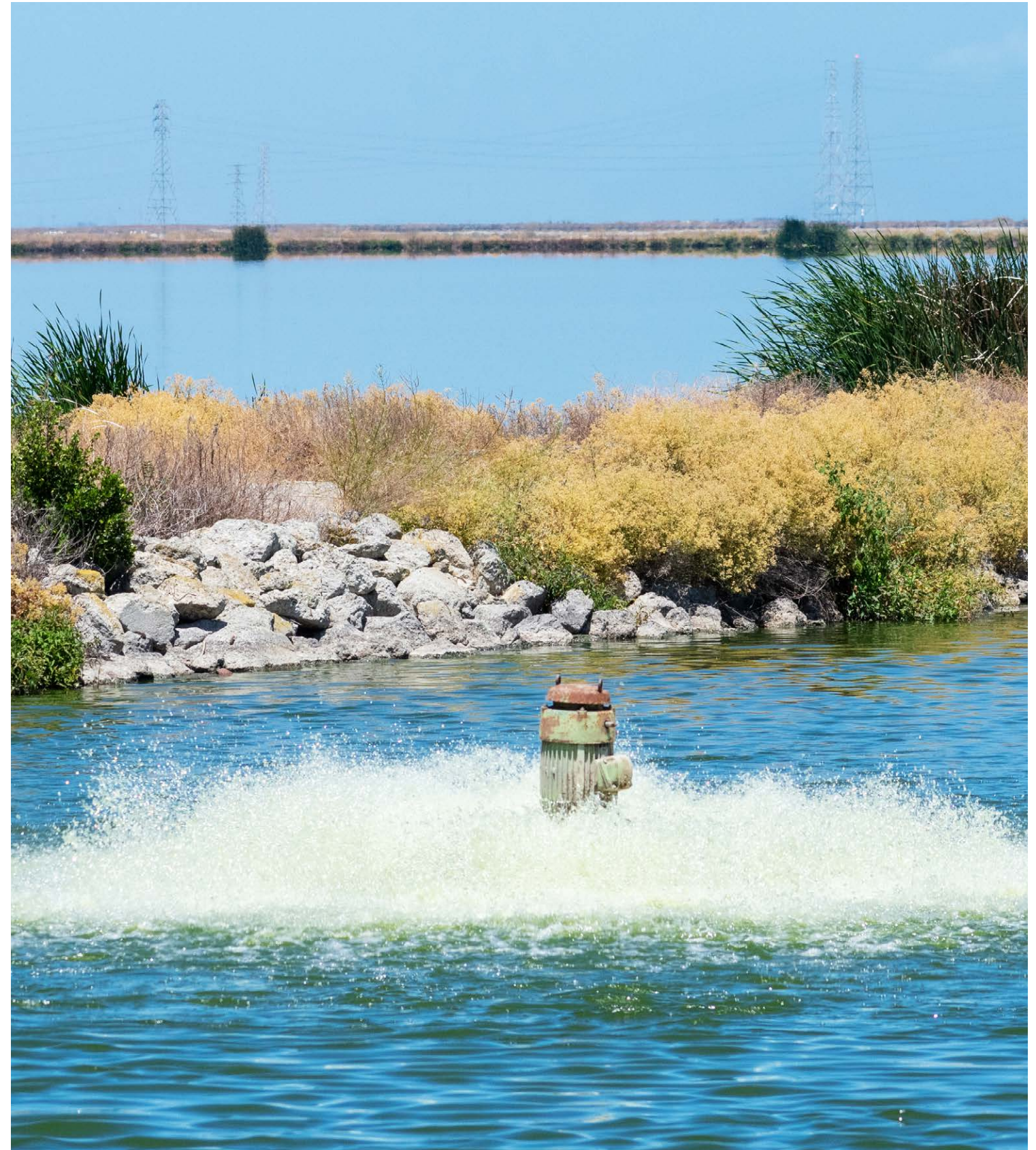
3.3 MAIN BARRIERS TO THE ADOPTION OF BWMPs

When addressing agribusiness performance related to wastewater, it is important to acknowledge that most of their processes are intricate and multifaceted, and, therefore, there may be difficulties when attempting to implement optimal management practices. It is essential to understand these obstacles to determine effective strategies for addressing them and promoting a culture of continuous improvement. Many of the technical barriers are addressed in this document; however, other barriers are non-technical. This section summarizes the typical challenges and barriers that agribusiness encounters.

- **Awareness and vision:** Companies have the opportunity to discover the numerous benefits of adopting best practices. Implementing environmental practices can become a strategic business opportunity, leading to enhanced profitability, mitigated liability, improved access to finance, and minimized risks. It is essential to recognize that even smaller companies can reap the rewards of such practices by having the notion that cost-saving opportunities are exclusive to larger enterprises
- **Time and human resources optimization:** Companies continuously seek opportunities to enhance their operations and efficiency in agribusiness. While senior management focuses on short-term business survival and growth, they also actively explore ways to improve processes. The plant engineering priorities are centered on production, looking for more efficient practices. Although human resources may be limited, the company remains dedicated to overcoming challenges,

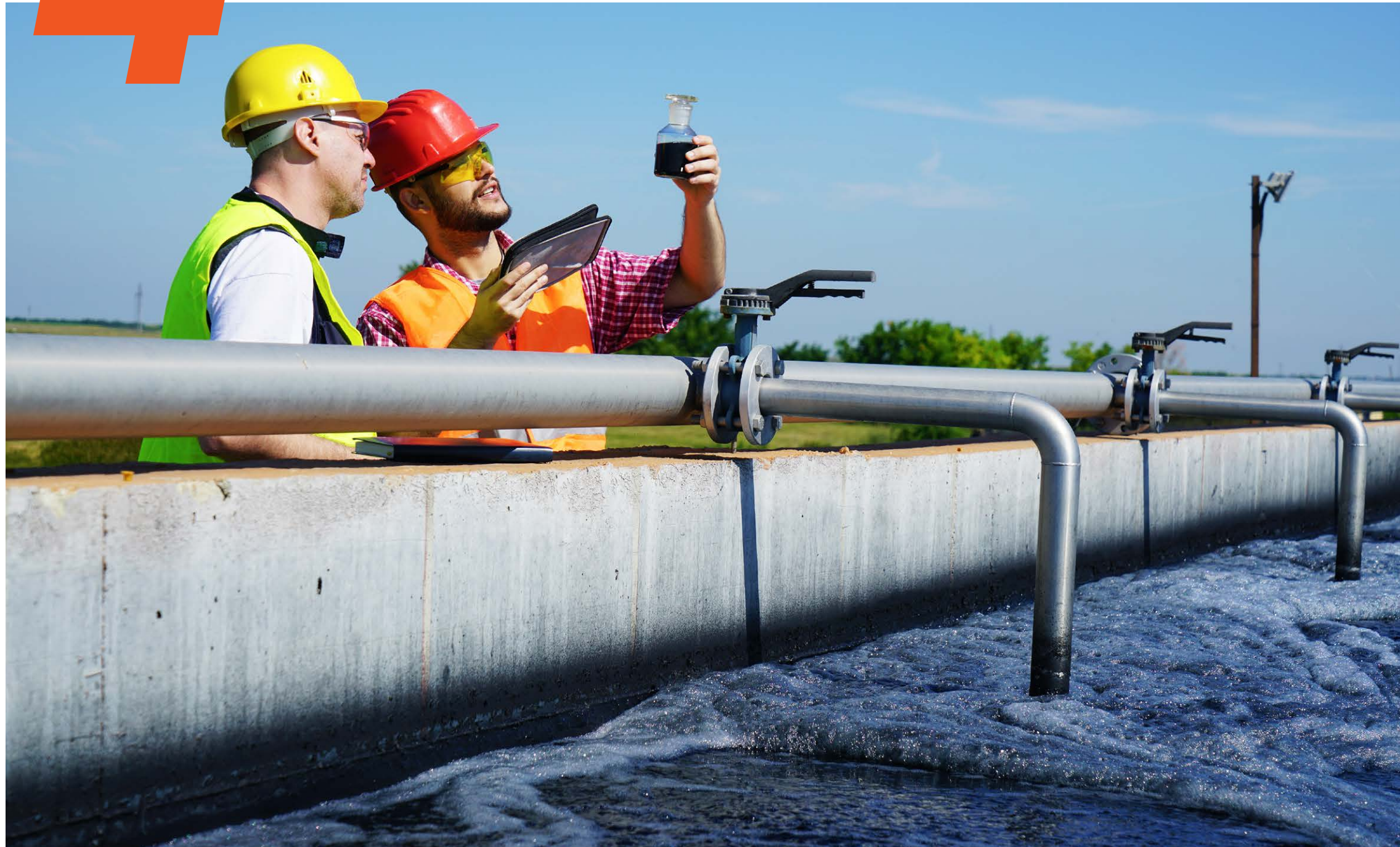
but all of these factors exacerbate the challenges of implementing best practices.

- **Technical knowledge and expertise:** In agribusinesses, there are opportunities to enhance knowledge and expertise to implement best practices. Sometimes, companies can be aware of potential opportunities but lack the technical skills or engineering resources to undertake a comprehensive evaluation to identify, prioritize, and implement best practices.
- **Financial resources:** Agribusinesses often face challenges when seeking internal financing and capital to pursue best practice projects. While most available capital is allocated to production, facility expansion, and marketing, companies are exploring avenues to allocate funds to other important initiatives. Even for well-managed companies with adequate cash flow to support investments in best practices, an effort has to be made to raise awareness and encourage senior financial decision-makers to prioritize such projects. Further reducing the gap between plant management and finance is a key goal to garner support for investments in improving environmental performance.
- **Relevant information and supportive networks:** Companies often lack information regarding the financial and operational advantages of implementing best practices in agribusiness. They require practical case studies demonstrating how such improvements can be applied to their operations and quantifying the benefits. With the availability of such examples, businesses can confidently evaluate the potential value and embrace the implementation of best practices, leading to further success and growth.



4

Pollution Prevention BWMPs



4.1. WHAT DO POLLUTION PREVENTION BWMPs ENCOMPASS, AND WHAT ARE THEIR BENEFITS?

Preventing pollutants from entering a treatment plant is usually less expensive than treating water after it has been polluted. Definitions and examples in the following sections should encourage pollution prevention at the source. Overall, pollution prevention BWMPs encompass:

REDUCING OVERALL WATER USE

The reduction of wastewater generation can be achieved by following a hierarchy that involves reducing the volume of wastewater, recycling water within the operational process, and reusing treated wastewater through controlled and sustainable mechanisms. To reduce water use, organizations can adopt practices such as minimizing wet transport and exploring feasible mechanical transportation options. Water recycling can be achieved by using condensates instead of fresh water for cleaning activities or recycling cleaning water, among other options.

PROCESS AND EQUIPMENT MODIFICATIONS

These practices are linked to the organizations' strategies and policies to invest in new technologies, thus requiring a higher capital investment. Examples of these practices include modifying process equipment to reduce water usage by retrofitting spray nozzles or replacing open tanks with closed-loop systems that recycle water. Another example is using Clean-in-Place (CIP) systems to clean equipment without requiring large volumes of water. In addition, organizations can adopt automatic control equipment, such as solenoid valves, to stop water flow when equipment is not in use and install flow meters to monitor water usage.

OPERATIONAL AND HOUSEKEEPING

These practices require a low capital investment and are relatively easy to implement. They can include checking operational procedures periodically, making process modifications, continuously training employees, improving inspections, developing maintenance prevention practices, and replacing simple equipment. Examples of these practices include monitoring wastewater quality and flow rates, implementing regular maintenance and cleaning schedules for equipment and pipelines, and properly disposing of hazardous waste materials. Other examples include using biodegradable cleaning products and preventing the disposal of non-biodegradable materials in sinks and toilets.

4.2 IMPLEMENTING A POLLUTION PREVENTION BWMPs PLAN

4.2.1 IMPORTANCE OF MANAGEMENT COMMITMENT AND OTHER KEY IMPLEMENTATION ASPECTS

As described in Section 3.2, implementing a pollution prevention BWMPs plan requires a strong commitment from management and other key stakeholders. Management commitment is critical for successfully implementing the plan, as it sets the organization's tone and helps provide the necessary resources and support.

Another key aspect of implementing pollution prevention BWMPs plan is the establishment of clear goals and objectives. These should be measurable and specific and align with the organization's sustainability strategy. Regular monitoring and reporting progress towards these goals is also important, as it allows for adjustments to ensure the plan remains on track.

Organizations should also consider using incentives and recognition programs to encourage employees to adopt sustainable practices and contribute to the plan's success.

4.2.2 STEPS FOR PRODUCING A POLLUTION PREVENTION BWMPs PLAN

STEP

1 Develop a water balance

As shown in Figure 1, the first step for producing a pollution prevention BWMPs Plan is to develop a water balance, which requires an updated process flow diagram. This diagram should identify all the flow paths and water usage in each step, including all water inputs, and explicitly show where wastewater is generated. Available sub-metered data should be identified for all water sources to help quantify the uses.

Each flow path of the water balance should have a monitoring program to help monitor flow rates. If there are some points in the water system where it is not practical to monitor the flow rates, flow rates may be estimated through mass balance calculations. The volumetric method is a valid approach to make a quick and rough estimate of equipment flow rate, although it is important to pay attention to drain lines that are plumbed to floor drains as this may alter measurements.

VOLUMETRIC METHOD

Use a container of known volume, like a bucket or a beaker. First, fill this container with water from the source you want to measure. Second, measure the time it takes to fill up the container completely. Once you have that time and the volume of the container, you can calculate the flow rate of water. The flow rate is how much water passes through a specific point in a given amount of time. To calculate it, you divide the volume of water in the container by the time it took to fill it:

$$\text{FLOW RATE} = \text{VOLUME OF WATER} / \text{TIME}$$

The influence of production schedules and cleaning shifts should be considered when developing a monitoring program. Monitoring water consumption outside production periods to identify water leaks is also recommended. Water data should be monitored to make interpretations of water consumption trends related to production and seasonal fluctuations. For unmetered water and end uses, estimates of water use from equipment capacity or process knowledge should be developed.

The complete water balance should be presented in a format that is easy to update with new information. Compare the sum of the end-use water consumption ($W_{\text{consumption}}$) to the total water supply (W_{supply}). The difference between these two values represents the possible losses in the system (w_{losses}). The losses can represent water leaks, inaccurate estimates, and accounting errors such as poorly calibrated meters.

WATER BALANCE

$$W_{\text{SUPPLY}} - W_{\text{CONSUMPTION}} = W_{\text{LOSSES}}$$

STEP 2 Contamination sources identification

Once the water balance is ready, identify for each one of the wastewater flows what pollutants are present and the potential sources of each of these pollutants. This information should be documented on a water flow diagram.

Analytical means should be used to measure pollutant concentrations, if possible. Water flows must be characterized based on their physical, chemical, and biological composition to prepare a pollutant mass balance that can be integrated into the overall water balance. This step is crucial for effectively implementing a pollution prevention BWMPs plan because it enables organizations to identify pollutant sources and take appropriate measures to prevent their discharge into the environment. The information obtained from this process also helps organizations make informed decisions about selecting suitable treatment technologies and optimizing wastewater treatment processes (See Section 5).

STEP 3 Identify and implement operational and housekeeping activities

Once the water and pollutants balances are ready, the next step is to identify the operational and housekeeping activities that contribute to adding undesirable pollutants to the water system. See Section 4.3 for more examples.

A good starting point is to review the SDS for chemical composition and hazard information of chemical products used in the facilities. Chemical products purchased that may contain toxic substances or other non-conventional pollutants may be replaced by less hazardous chemicals or products. For implementation, validating any proposed operational and housekeeping changes with the personnel involved, including production, quality control, maintenance, and any other relevant stakeholders, is crucial. By involving all stakeholders in the process, organizations can ensure that any changes made will not negatively impact the product's quality or the efficiency of the process.

STEP 4 Identify and implement water use efficiency opportunities

An integrated water use efficiency strategy with specific water conservation goals should be developed. A site assessment of the facility is necessary to identify all major water-using processes and their operating characteristics, including flow rate, condition, and model of each piece of equipment used. Additionally, all facility areas should be assessed for water recycling and reuse opportunities.

During the assessment, the water quality requirements for each process should be defined to determine the potential for water reuse. Recycling methods should consider treated and untreated water, and less contaminated water should be kept separate for potential reuse after treatment.

STEP 5 Identify and implement process and equipment modifications

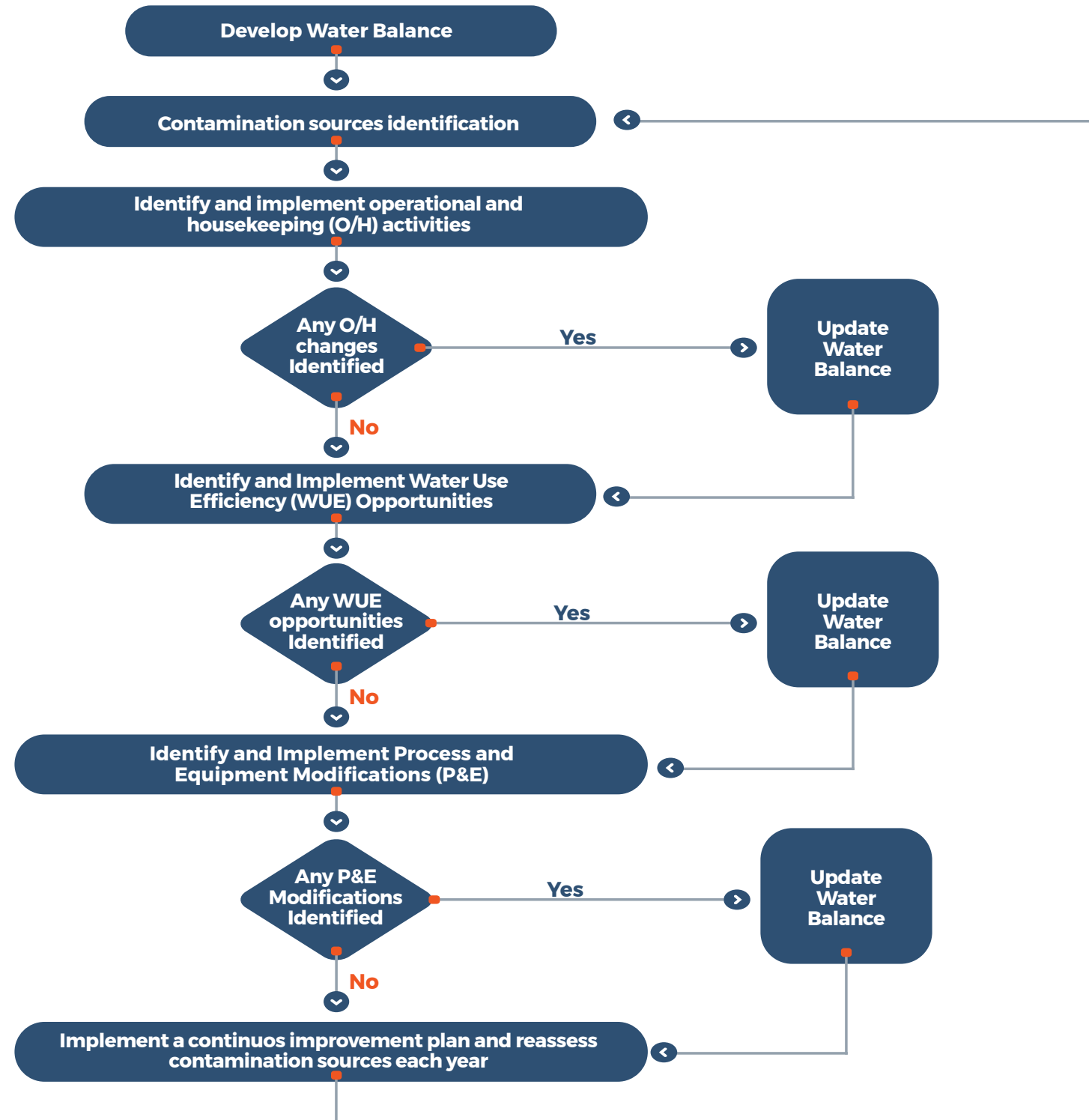
Evaluate the performance of existing processes and equipment to identify areas to improve wastewater quality and quantity. Consider the implementation of new technologies or the modification of existing equipment to optimize processes and reduce pollution.

A cost-benefit analysis should be conducted to assess the feasibility of each option under consideration. It is important to consider the impact of process and equipment modifications on the overall efficiency and productivity of the facility, as well as the potential for increased maintenance and operational costs. Modifications should be carefully planned and managed to ensure a smooth transition and optimal results.

Continuous improvement cycle

A pollution prevention plan includes an iterative continuous improvement cycle. Pollution prevention measures, such as improved housekeeping and operational practices, water use efficiency strategies, and modifications to existing equipment must be prioritized and implemented iteratively, as seen in the previous five steps, before implementing new capital projects at the treatment level. This iterative implementation will ensure that the capability of existing facilities and equipment is optimized before new capital investments are considered. If, at any stage, the process indicates that capital expenditure is required, top management must ensure that resources become available.

FIGURE 1 Implementing a pollution prevention BWMPs plan (OCETA, 2005).

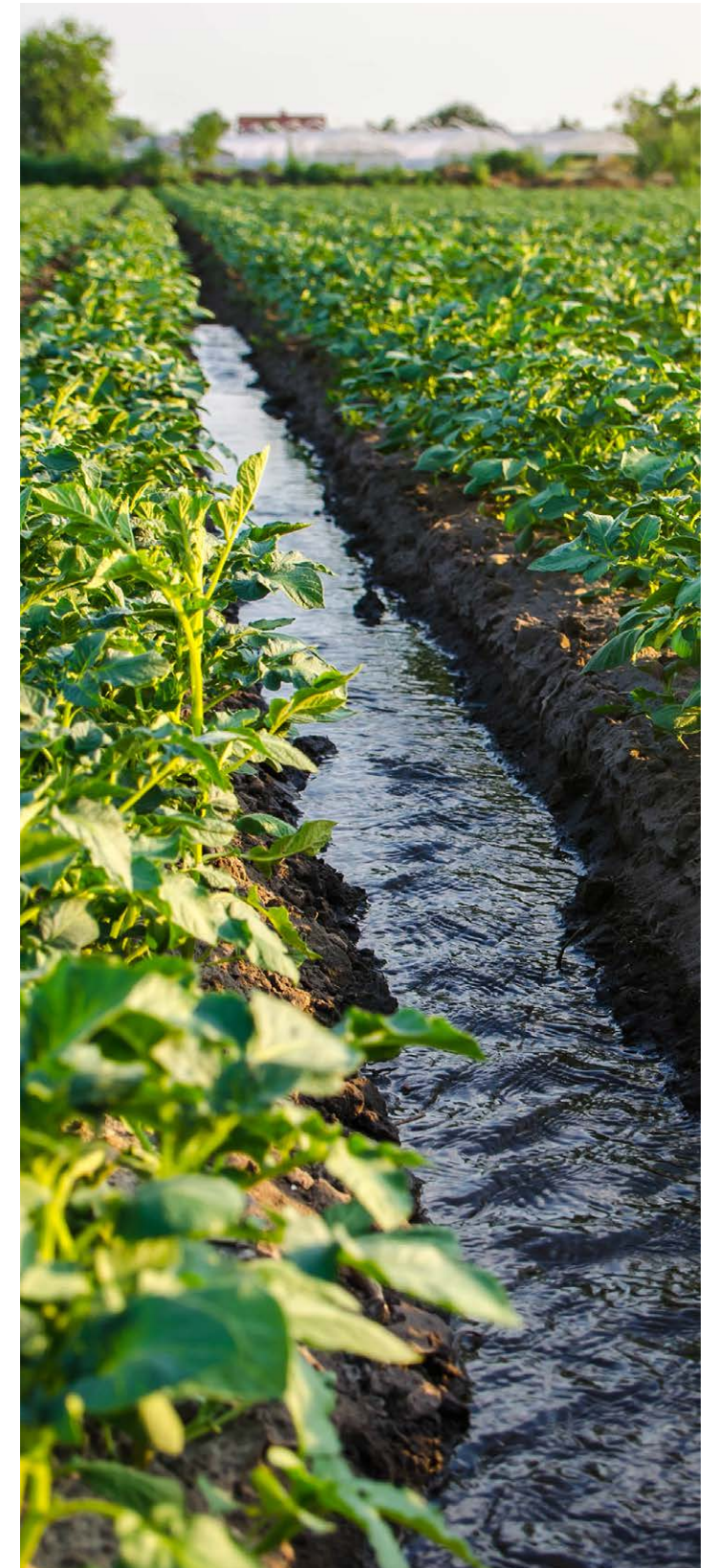


4.3 EXAMPLES OF POLLUTION PREVENTION BWMPs FOR AGRIBUSINESS

4.3.1 FOREWORD

The examples presented below will guide industries to improve their management practices based on IFC's Performance Standard 3 requirements, Good International Industry Practices (GIIP), and World Bank's Pollution Prevention Handbook (World Bank, 1999) and EHS Guidelines. These BWMPs provide a voluntary set of standards and procedures for improving productivity while reducing pollution in the effluent, but they are not definite. Each industry must review its specific working conditions and adapt to necessary changes.

The selected agribusinesses include aquaculture (Section 4.3.2), dairy processing (Section 4.3.3), food and beverages (Section 4.3.4), and meat processing (Section 4.3.5).



4.3.2 AQUACULTURE

OPERATIONAL AND HOUSEKEEPING PRACTICES

- Ensure that pellet feed has a minimum number of fines or dust. Aquatic species do not consume fines and add to the nutrient and organic loads in the wastewater.
- Monitor feed uptake to determine whether it is being totally consumed and adjust feeding rates according to field observation.
- After harvest, hold the remaining water in the pond for several days before discharge; this will let solids settle again.
- Provide a littoral zone in the pond's perimeter to encourage aquatic vegetation that can assist in reducing nutrients and trapping solids.
- Clean nets and cages manually. Do not use chemical products like antifoulants, as these are very poisonous and highly stable in aquatic environments. Check the Safety Data Sheets before considering using a Safety Data Sheet (SDS).
- It is recommended to use lower N and P and higher digestibility feeds to reduce nutrient concentrations in the effluent.
- Limit the crop biomass and feeding rate within the carrying capacity of the water body to prevent excessive accumulation of nutrients.

WATER USE EFFICIENCY OPPORTUNITIES

- Use partial draining techniques to empty a percent of the ponds harvested, as the last 15% of pond water contains the highest quantities of organic matter. Otherwise, reuse this water by pumping it into adjacent ponds to help complement their primary productivity.

PROCESS AND EQUIPMENT MODIFICATIONS

- Use properly designed discharge systems and erosion control prevention at the discharge point to minimize settling solids concentration in the effluent.
- Use aeration to improve water quality, as this will increase dissolved oxygen concentrations and de-stratify deep ponds. Oxygenation will also minimize pond soil erosion and water turbidity.

4.3.3 DAIRY PROCESSING

OPERATIONAL AND HOUSEKEEPING PRACTICES

- Avoid foaming of fluid dairy products. The foam contains high concentrations of OD and TSS that affect the wastewater treatment system efficiency.
- Use proper seals on pumps and proper line connections to prevent the air inflow when lines are under a partial vacuum.
- Milk and product spillage can be restricted by regular maintenance of fittings, valves, and seals and by equipping fillers with drip and spill savers. Spilled solid material such as curd from the cheese production area and spilled dry product from the milk powder production areas should be collected and treated as solid waste rather than flushed down the drain.
- For cleaning, use approved chemicals or detergents with minimal environmental impacts.
- Collect waste products for use in lower-grade products such as animal feed, where feasible, without exceeding cattle feed quality limits.
- Pollution levels could also be limited by allowing pipes, tanks, and transport tankers adequate time to drain before being rinsed with water.

WATER USE EFFICIENCY OPPORTUNITIES

- Reuse water from the reverse osmosis to wash equipment or purge lines, if any. This water is commonly used to concentrate whey.
- Segregation of effluents from sanitary installations, processing, and cooling systems; facilitates the recycling of water currents and the reuse of treated wastewater.
- Use of condensates instead of fresh water for cleaning activities, meeting potable water standards where food and human contact may occur.

PROCESS AND EQUIPMENT MODIFICATIONS

- Install grids and sieves within facilities to avoid the introduction of gross solids and materials into the wastewater pipes system.
- Adopt best-practice methods for facility cleaning, which may involve automated CIP systems.

4.3.4 FOOD AND BEVERAGE

OPERATIONAL AND HOUSEKEEPING PRACTICES WATER USE EFFICIENCY OPPORTUNITIES

- Procuring clean raw fruit and vegetables where feasible will reduce the effluent's concentration of dirt and pesticides in the effluent.
- Minimize water leakages and cooling water used for pumps by installing mechanical seals and proper maintenance of pumps.
- Increase the lifetime of caustic cleaners by collecting them in an insulated settling tank and reusing them for washing equipment.
- When using water, use counter-current wash techniques for the primary wash of raw materials to enable better separation of solids for water reuse.
- Brewing: Remove grain from the tun with dry methods, like raking or brushing. Clean tun, copper, and whirlpool with wash water from other cleaning operations, ensuring that hygienic conditions are not compromised.
- Brewing: Use of spent grain as animal feed, either 80% wet or dry after evaporation. Disposal of wet hops and trub by adding them to the spent grain.
- Coffee Wet Mills: If mucilage removal equipment is installed, separate it from the wastewater stream and look for alternatives to treat it or use it as a by-product.

PROCESS AND EQUIPMENT MODIFICATIONS

- Install screens/sieves at strategic locations in the facilities to prevent solids from entering the wastewater stream.
- Install an auto-level control system at the service water pump to check the overflow from the overhead tanks.
- Assess using CIP methods for decontaminating equipment.
- Use high-pressure and low-volume hoses for equipment cleaning.
- Coffee Wet Mills: Where possible, install water-efficient de-pulping and mucilage removal equipment.
- Sugar mills: Install holding tanks for storing highly polluted water during mill cleaning to avoid shock loading to WWTP.

- Minimize wet transport. Look for mechanical transportation options that are feasible.
- Install water recirculation units with filters, especially for processing wash water.
- Separate and recirculate cooling water from process and wastewater streams.
- Reuse process water not filtered or treated as a first rinse in wash cycles, or for primary cleaning of floors and gutters.
- Use dry methods, such as vibration or air jets, to clean raw fruit and vegetables instead of water.
- Sugar mills: Use excess water condensate for melting, making magma, diluting massecuite, and cleaning evaporator systems, among others. In addition, the excess condensate may be cooled and used to replace freshwater, meeting potable water standards if food or human contact occurs.
- Brewing: Use the rinse water of bottles for crate washing.

4.3.5 MEAT PROCESSING

OPERATIONAL AND HOUSEKEEPING PRACTICES

- Aim to use water below 30°C in carcass washing to reduce fat removal from surfaces.
- Maximize the segregation of blood and water by designing suitable blood collection facilities. Recover blood for use in other industries as a by-product.
- Separate manure from the main waste stream and treat it as solid waste.
- Remove FOGs from wastewater at the start of the treatment process and handle them as solid waste or by-products.

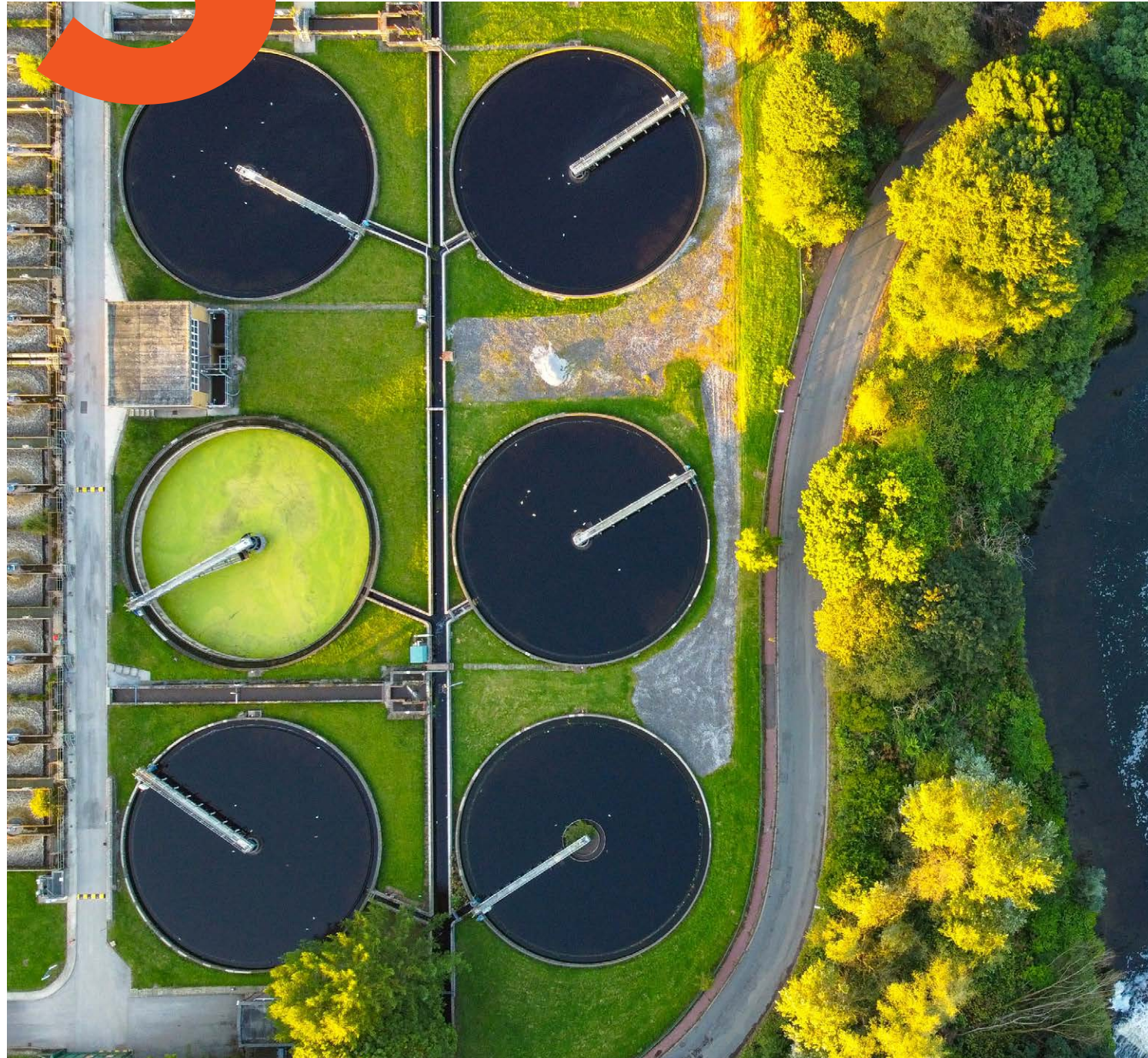
WATER USE EFFICIENCY OPPORTUNITIES

- Avoid the use of water streams as a transport medium. Look for mechanical transportation of solids and particulate matter.
- Minimize, as much as possible, water consumed in production by using taps with automatic shutoff, using higher water pressures, and improving the process layout.
- Separate and recirculate cooling water. And reuse clean wastewater from cooling systems for washing livestock if possible.

PROCESS AND EQUIPMENT MODIFICATIONS

- Use automated control systems to operate the water flow at knife sterilization and hand-wash stations.
- Implement dry pre-cleaning of equipment and production areas before wet cleaning.
- Remove solid waste before it enters the wastewater stream: use floor drains and collection channels with grids, screens, or FOGs traps to reduce the number of solids entering the treatment plant.

5 Wastewater Treatment BWMPs

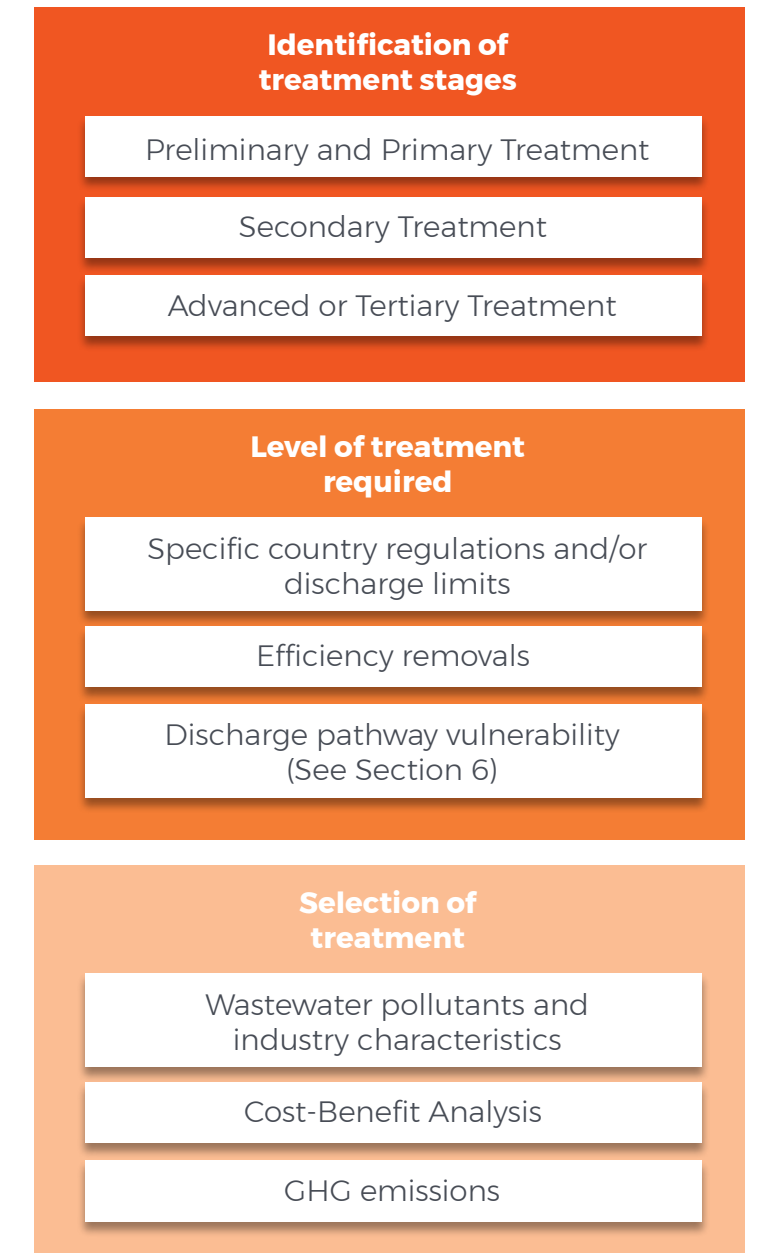


5.1 WHEN TO APPLY WASTEWATER TREATMENT BWMPs

After implementing of pollution prevention practices, the remaining pollutants in the wastewater must be removed or reduced to meet the quality objectives. BWMPs can involve various physical, chemical, and biological processes that aim to remove or reduce pollutants. These processes include screening, sedimentation, filtration, chemical treatment, biological treatment, and disinfection. The specific wastewater treatment processes used will depend on the characteristics of the treated wastewater and the quality objectives that need to be met. In some cases, advanced treatment technologies may be required to comply with water quality standards.

Implementing the stages presented in Figure 2 and described in **Sections 5.1.1 to 5.1.3** is crucial to selecting the BWMPs wastewater treatment technologies.

FIGURE 2 Steps to implement wastewater treatment BWMPs.

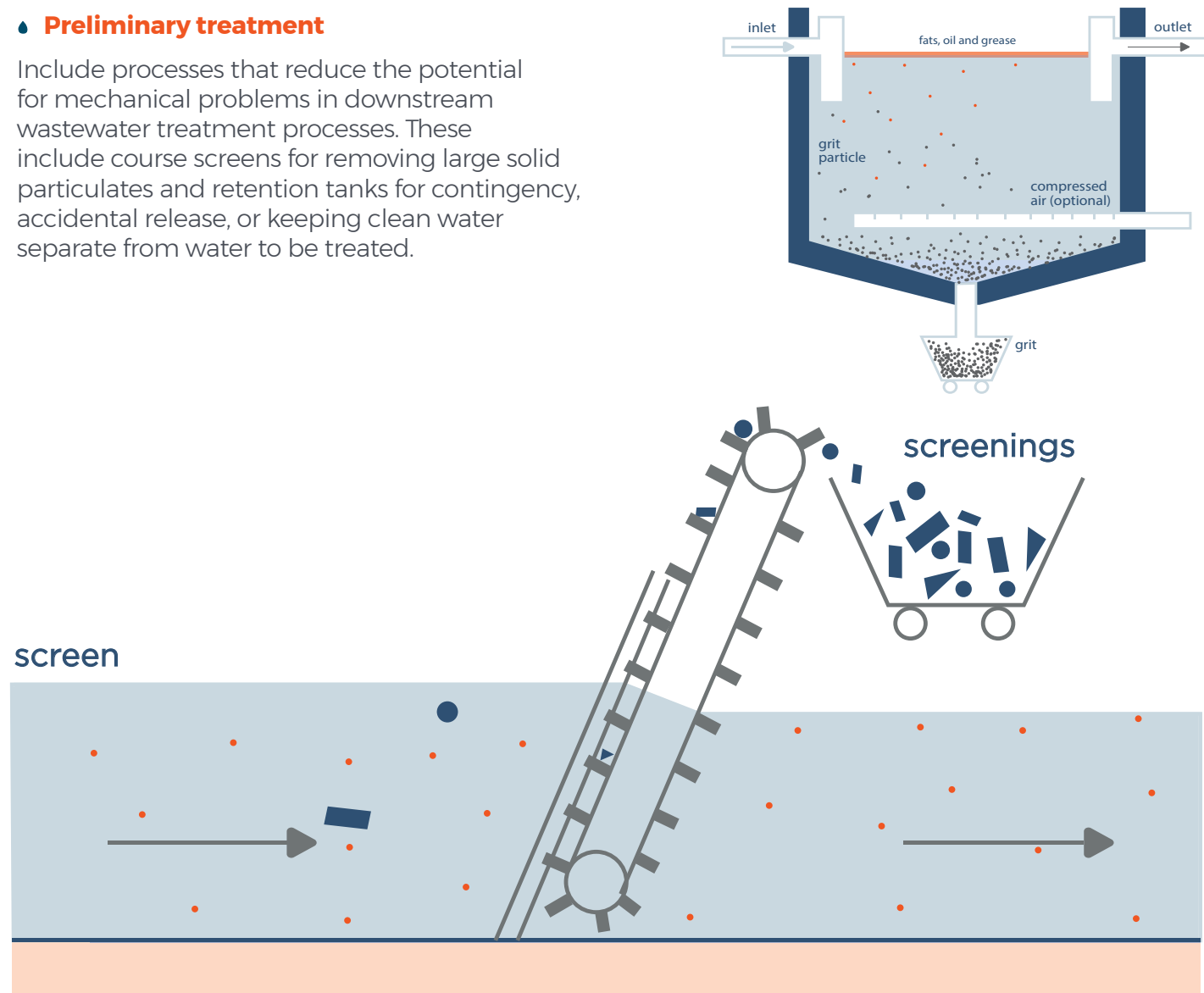


5.1.1 CLASSIFICATION AND IDENTIFICATION OF TREATMENT STAGES

Wastewater treatment falls into four main categories; each one will result in the removal of specific pollutants from the wastewater stream:

Primary treatment

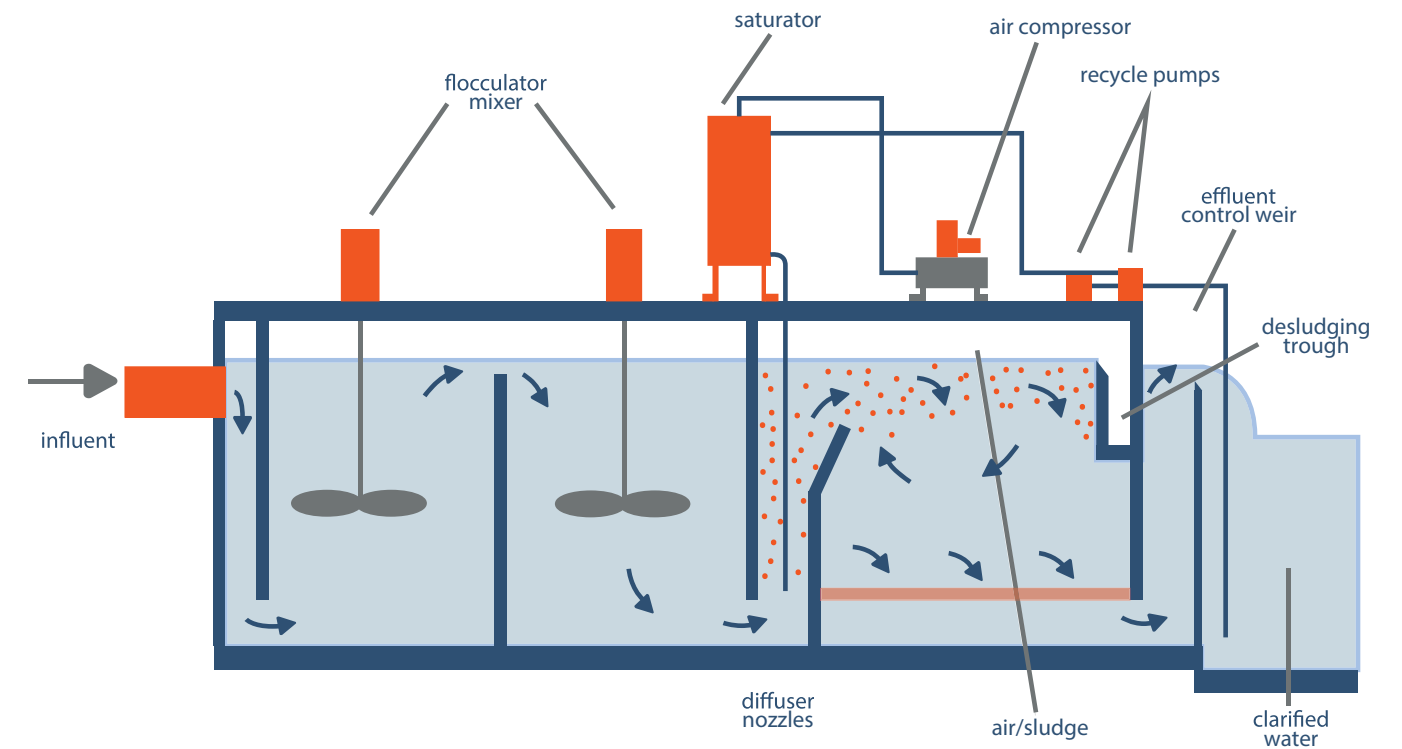
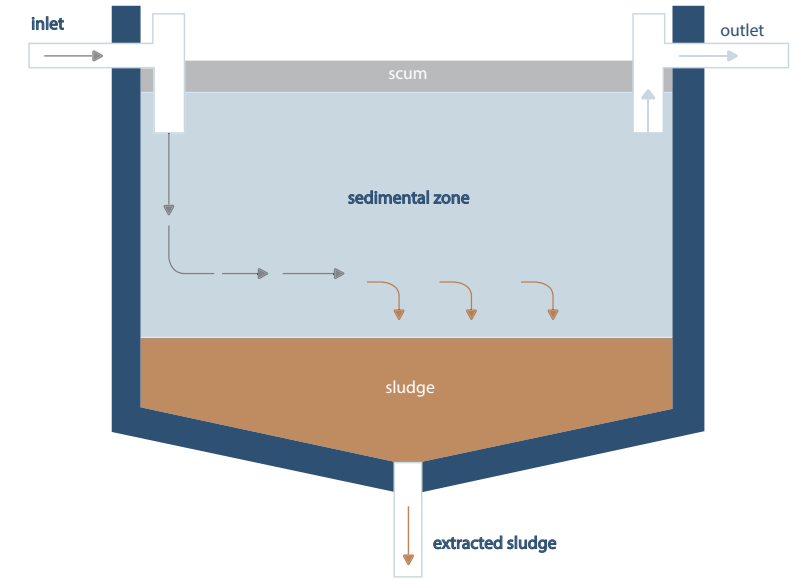
Include processes that reduce the potential for mechanical problems in downstream wastewater treatment processes. These include course screens for removing large solid particulates and retention tanks for contingency, accidental release, or keeping clean water separate from water to be treated.



Source: (Tilley et al., 2014)

Primary treatment

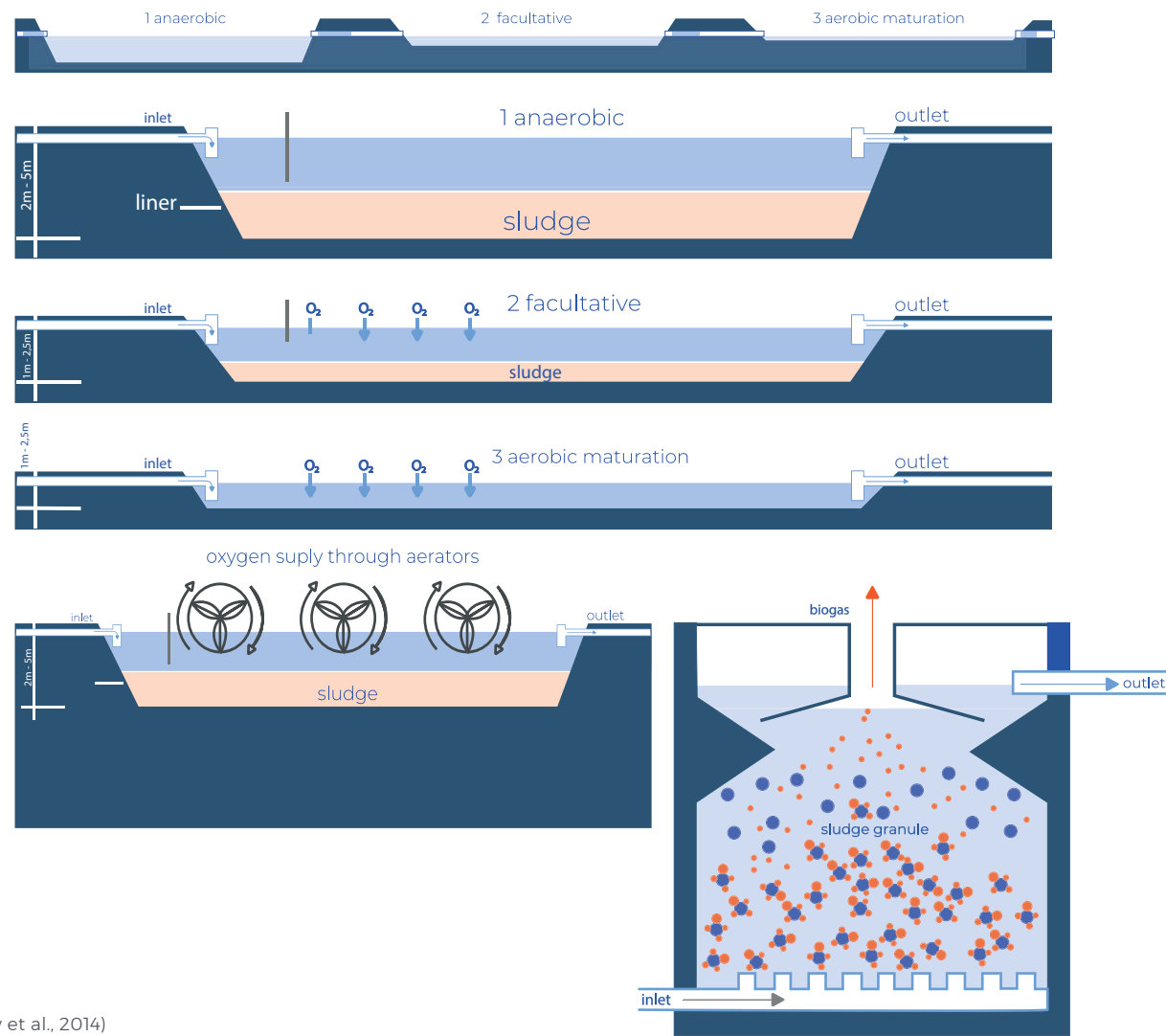
It has two objectives (i) the reduction of suspended solids and BOD loads to subsequent unit processes, and (ii) the recovery of residues that can be converted into products through repurposing. The typical unit processes used for primary treatment are screening, sedimentation basins, dissolved air flotation, and flow equalization tanks. Chemicals are often added to improve the treatment unit's performance in processes using flocculants or polymers.



Source: (Tilley et al., 2014) | Source: Colic et al., 2005

Secondary treatment

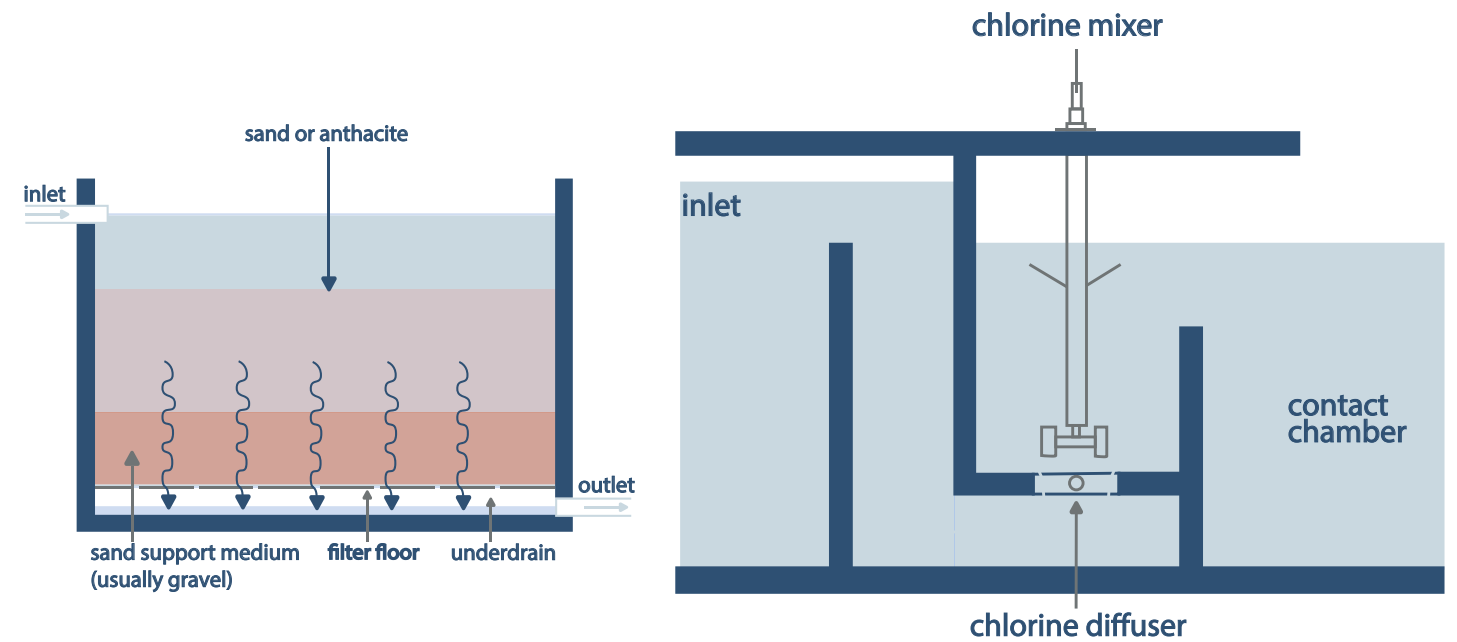
Secondary treatment aims to reduce the remaining BOD mainly in soluble organic compounds after primary treatment. Although secondary wastewater treatment can be performed using a combination of physical and chemical unit processes, biological processes have remained the preferred approach. If managed correctly, the biological approach can achieve efficiencies greater than 90% of wastewater pollutant removal. Treatments can be anaerobic or aerobic; in the anaerobic fermentation of these liquid wastes, biogas, an alternative energy source, is produced. Table 5 provides a high-level comparative summary of advantages and drawbacks for diverse types of biological treatment, including treatment ponds, activated sludge systems, extended aeration, sequencing batch reactors, anaerobic reactors, and others.



Source: (Tilley et al., 2014)

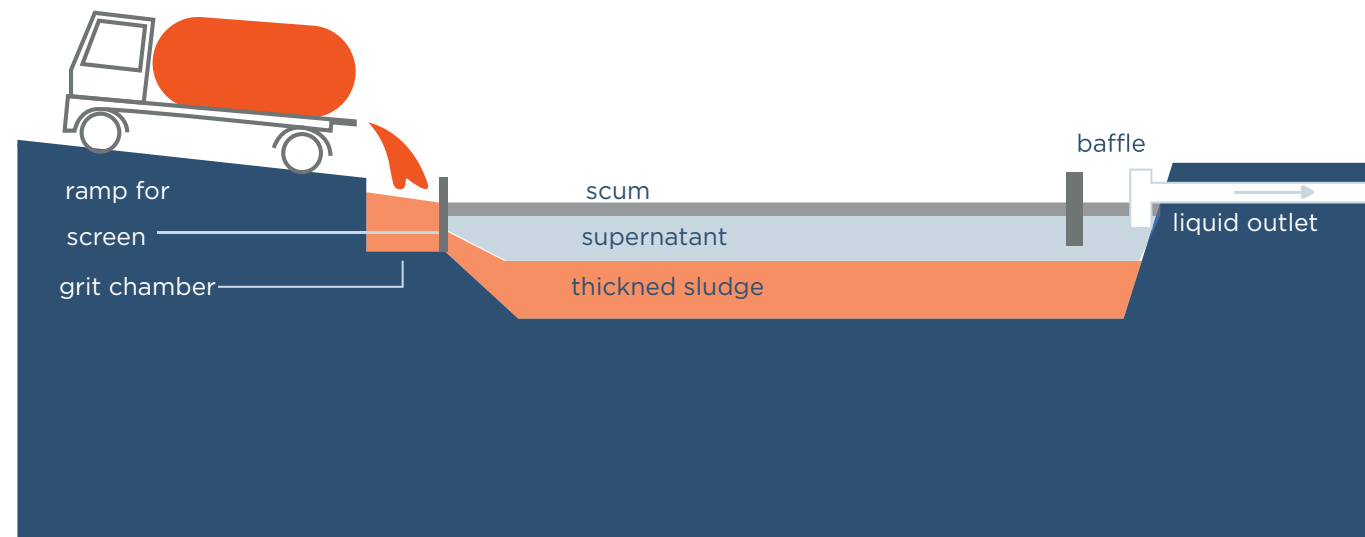
Tertiary treatment

Tertiary or advanced wastewater treatment is any treatment beyond conventional secondary treatment to remove further suspended or dissolved substances, like soluble refractory, toxic, dissolved inorganic substances, and other non-conventional pollutants known as emerging pollutants (EP), including metals, pesticides, veterinary drugs, and disinfection by products. N and P removal are also common for tertiary wastewater treatment objectives. Disinfection is also part of the tertiary treatment that aims to remove pathogenic microorganisms; chlorine injection is the most used method. However, ultraviolet light, ozone injection, and combinations of UV and ozonation are attractive disinfection alternatives.



Sludge treatment

Sludge is a mixture of solids and liquids, containing mostly organic matter and water, in combination with all or any of the following: sand, grit, metals, trash and various chemical compounds. In sludge treatment processes, the most common treatment stages are thickening and dewatering, aimed at reducing the water content in the sludge and consequently diminishing its volume. The initial step, thickening, mainly relies on gravity but can also be accomplished using moving belts or rotating drums. Dewatering, the



Source: (Tilley et al., 2014)

TABLE 5 Bioreactors used for wastewater treatment and biogas production (CO₂ and CH₄)

Type of Bioreactor	Bioreactor Features	Retention time (days)	COD removal efficiency (%)	Advantages	Drawbacks	References
Pond system	It consists of up to 12 ponds for cooling, mixing, anaerobic, and facultative treatment, depending on effluents	20-200	97	Low cost, simple operation, CH ₄ concentration up to 55%	Biogas production depends on weather stations, large areas needed; difficult gas capture	(Poh & Chong, 2009)
Anaerobic filtration	A bioreactor with airtight vessel, digester, and temperature control	15	94	CH ₄ concentration up to 63%; pH and T control (°C)	High cost	(Borja & Banks, 1994)
Modified anaerobic baffled bioreactor	A device with a feed tank, magnetic stirrer, peristaltic pump, and water jacket	5-10	93.3 ± 3.8	CH ₄ concentration 67-71%, T and pH control	High cost	(Sung et al., 2019)
Fluidized bed reactor	A compact bed system with up or down flow	70	98-80	High organic loading rates, large contact area, high flow velocity	It needs large amounts of input power	(Borja et al., 2001)
Up-flow anaerobic sludge blanket (UASB)	A system with a pump, a sludge blanket, a gas separator, and a gas collector	Up to 200	60-97	Versatile equipment, it can handle high-suspended solids	Long start-up period (2-4 months)	(Ohimain & Izah, 2017)
Anaerobic baffled reactor	A set of vertical baffles for effluent flow, no moving parts or mixing devices	3-5	82-92	Simple and inexpensive, CH ₄ concentration 50-75%	Inconvenient with high-viscosity effluents	(Faisal & Unno, 2001; Wang et al., 2004)
Up-flow anaerobic sludge fixed-film	A hybrid of UASB and up-flow fixed-film, with pumps, feed tanks, gas separators, and brackets	4-40	89-97	Rapid biotransformation of organic matter, CH ₄ concentration 62-82%	A complex system requiring large input power	(Najafpour et al., 2006)
Continuous stirred tank reactor (CSTR)	A mechanically agitated closed tank reactor to increase contact area with biomass	4	60-83	Easy operation, CH ₄ concentration 65-67%	It contains mechanical systems, and requires significant energy input	(Ohimain & Izah, 2017)

5.1.2 LEVEL OF TREATMENT REQUIRED

As indicated, the wastewater treatment categories listed above will remove specific pollutants from the wastewater stream. The different combinations of the four will help achieve the effluent quality requirements. Each technology has been designed to remove specific pollutants and achieve different reduction levels for different substances. As presented in **Section 1.2** and Annex 1, each country has its regulatory framework, and different institutions regulate the treatment specification for the quality parameters.

The assessment and requirements are based on management policies, and treatment efficiency removals will be defined concerning the final disposal of the effluent; for example, parameters will depend on the capacity of the receiving body of water or the soil infiltration capacity when reusing the effluent for fertigation (See Section 6.1).

5.1.3 SELECTION OF TREATMENT

The concentration of the target pollutants and organic loads in the effluents cannot be defined within a narrow band of concentrations and flow rates. The wastewater profile depends on pollutants generated in each industrial process, the concentration, and the mass discharge rate of each pollutant; and wastewater flow rate includes the volume of wastewater generated and the fluctuation over

time (significant fluctuations happen due to daily shifts, hours of operation and seasonal variation in production).

Estimated pollutant reductions for each industrial process are based on a combination of information available from the literature and study team experience. Reduction efficiencies reported for primary and secondary treatment technologies in these industries are generally limited to BOD, COD, TSS, nutrients, and FOGs. A relatively wide range of reduction efficiencies is reported depending on the types of technologies used. The range of efficiencies reflects the differences from one facility to another in design capacities, variation of input pollutant loadings, the operator experience, and the wastewater management systems installed.

When selecting the appropriate level of wastewater treatment, it is important to consider the technical feasibility and economic viability of treatment options. Cost-benefit analysis helps determine the most cost-effective treatment option that meets the effluent quality requirements. Additionally, it is crucial to consider the potential greenhouse gas (GHG) emissions associated with the treatment process; the selection of treatment technologies and processes should strive to minimize GHG emissions. If not managed correctly, some wastewater treatment technologies, such as anaerobic reactors, could significantly contribute to global GHG emissions.

5.2 REVIEW OF WASTEWATER CHARACTERISTICS AND TREATMENT APPROACH FOR DIFFERENT AGRIBUSINESS

5.2.1 AQUACULTURE

TARGET POLLUTANTS AND ORGANIC LOADS

Aquaculture generates high amounts of wastewater containing organic matter and high COD, TSS, N, and P levels, as presented in **Table 6**. These last two are considered important waste components of fish farming, which can cause serious environmental problems. The high organic characteristics come from the food pellets leftover, fish feces, and dead bodies of organisms. Also, the presence of feed, hormones, and supplements used to enhance productivity and often antibiotics are very common (Turcios & Papenbrock, 2014). The best way to reduce the quantity of discharged waste is to improve feed management (Maryland Aquaculture Coordinating Council, 2007).

COMMONLY AGREED TREATMENT METHODS TO TREAT AQUACULTURE WASTEWATER

Water treatment in aquaculture includes solids removal, oxidation of organic matter, and nitrification. Biological processes such as submerged biofilters, trickling filters, rotating biological contactors, and fluidized bed reactors are commonly used to oxidize organic matter and nitrification. Also, bead filters or expandable granular biofilters can operate as mechanical and biological filters, so they have been used in recirculating systems (Turcios & Papenbrock, 2014). The wetland technology is a well-established and cost-effective method that can use halophytic plants and is becoming increasingly crucial in recirculating aquaculture system treatments. Passing wastewater through a constructed or natural vegetated filter strip before reuse in another pond is acceptable; this strip allows the capture of sediments, organic matter, and other pollutants by deposition, infiltration, absorption by vegetation, and decomposition. Other treatment options, such as lagoons and settling basins, have been used effectively (Maryland Aquaculture Coordinating Council, 2007).

Researchers have demonstrated that wetland systems can remove significant amounts of TSS, organic matter, N, P, trace elements, and microorganisms contained in wastewater. The advantages of constructed wetlands are moderate capital costs, low energy consumption and maintenance requirements, landscape aesthetics, and increased wildlife habitat. In a recirculation aquaculture system, treating effluents by passing wastewater through a constructed or natural vegetated filter strip before reuse in another pond is an acceptable practice. It allows for capturing sediments, organic matter, and other pollutants by deposition, infiltration, absorption by vegetation, decomposition, and volatilization (Maryland Aquaculture Coordinating Council, 2007).

WHAT TO EXPECT OF THE GENERATED WASTEWATER

High organic characteristics come from the food pellets left over, feces, and dead bodies of organisms, while protein comes from using hormones or supplements to enhance productivity. COD can be 500-800 mg/L on average. Generally, solid concentrations in the untreated effluent from flow-through farms are around 50-80 mg/L, and these solids can commonly carry 7%–32% of the total N and 30%–84% of the total P in wastewater. Other compounds and emerging pollutants (EP) in aquaculture wastewater are feed-derived waste, antibiotics, and hormones (Turcios & Papenbrock, 2014).



5.2.2 DAIRY PROCESSING

TARGET POLLUTANTS AND ORGANIC LOADS

Dairy processing generates wastewater containing elevated levels of COD, BOD, inorganic and organic particles like carbohydrates, dissolved sugars, proteins, FOGs, and nutrients like N, P, and K, and possibly residues of additives (Qasim & Mane, 2013). Wastewater may also contain a microbiological load, pathogenic viruses and bacteria from contaminated materials or production processes. High levels of FOG may be present due to the processing of milk and dairy products, which can cause problems with sewer lines and wastewater treatment systems. Wastewater may often generate odors that need to be controlled.

Sources of these substances come from milk or dairy products lost in the process, for example, spilled milk, starter cultures used in manufacturing milk products, chemical reagents applied in CIP procedures, and sanitary needs. Other polluting substances may come from additives used during manufacturing, such as the salting process in cheese production, which can lead to elevated salinity levels in wastewater. The primary pollutant in dairy processing wastewater is whey, attributed to its high organic content (Kolev Slavov, 2017).

WHAT TO EXPECT OF THE GENERATED WASTEWATER

The key parameters of a milk/milk powder processing facility are BOD with an average of 1,200 mg/L and up to 4,000 mg/L. COD usually is about 1.5 times the BOD level with an average of 2,000 mg/L, up to 6,000 mg/L. TSS can be up to 1,000 mg/L, P can be present in 50-60 mg/L primarily from wasted detergents and cleaners, and N concentration is about 5-6% of the BOD level. Typical FOG concentrations in dairy plant wastewater range from 100 to 500 mg/L. The quality values of wastewater from dairy plants can vary depending on the specific processes used and the type of dairy products being produced, as seen in Table 6.

COMMONLY AGREED TREATMENT METHODS TO TREAT DAIRY PROCESSING WASTEWATER

The water treatments in dairy processing include applying mechanical, physical-chemical, and biological methods, as seen in **Table 7**. Mechanical treatment, like clarifiers, is necessary to equalize volumetric and mass flow changes and helps reduce the concentration of suspended solids. Additionally, grease traps, skimmers, or oil water separators can separate floatable solids. Physical-chemical processes effectively remove emulsified compounds by reducing milk fat and protein colloids; however, reagent addition increases water treatment costs. Dissolved air flotation is an effective treatment method because it reduces organic loading via protein and fat colloid destabilization with coagulants and flocculants. Still, this method implies using expensive and synthetic chemicals that can result in environmental issues such as the release of harmful chemicals into the environment, pollution of water bodies, and potential harm to aquatic life (Kolev Slavov, 2017).

Due to their reliability and capacity to effectively degrade highly biodegradable pollutants, biological wastewater treatment systems, such as anaerobic and aerobic reactors, are preferred. It is essential to consider that fatty acids from milk fat in wastewater may cause an inhibitory action during anaerobic treatment mainly due to decreased pH. Aerobic processes are highly energy-intensive and should be combined with anaerobic processes to achieve discharge standards. An UASB reactor is a typical and suitable configuration due to its ability to treat large volumes quickly. Also, anaerobic filters are commonly applied in the anaerobic stage (Hassan & Nelson, 2012). Sequencing batch reactors and moving bio bed reactors are standard in aerobic treatment because of their various loading capabilities and effluent flexibility (Kolev Slavov, 2017). Membrane processes such as microfiltration, electrodialysis, and reverse osmosis are very promising methods. These offer effective solid-liquid separation, high yields of effluent, smaller plant sizes, and low sludge production (Yonar, Sivrioğlu, and Özençin, 2018).



5.2.3 FOOD AND BEVERAGE

TARGET POLLUTANTS AND ORGANIC LOADS

The effluents from the food and beverage industries mainly contain a high amount of sugar, flavorings, and coloring additives, which indirectly contribute to the spike of BOD and COD (Muhamad Ng et al., 2021). Also, cleansing blanching agents, salts, and TSS such as fibers and soil particles are present in wastewater composition. They may sometimes contain pesticide residues washed from raw materials (OCETA, 2005).

Overall, soft drink processing facilities, breweries, wineries, and distilleries wastewaters are generally characterized by high BOD, TSS, P, and N concentrations. Other specific industries, such as sugar and coffee mills, are characterized by wastewater loaded with organic matter from the process, such as sugar, bagasse, and molasses (for the sugar mills) and pulp and mucilage (from the coffee wet mills). These types of organic matter cause very high levels of BOD, and TSS as well as high levels of nutrients, particularly N and P. Due to the nature of these wastewaters, it is expected to have dark brown and acidic effluents that need to be treated accordingly before their release into the environment.

WHAT TO EXPECT OF THE GENERATED WASTEWATER

Wastewater from frozen food processing, and fruit and vegetable facilities have average BOD values between 100-3,500 mg/L, average COD values between 500-5,000 mg/L, and TSS concentrations between 50-1,500 mg/L.

Wastewater from breweries contains BOD in the range of 1,000-30,000 mg/L, COD in the range of 2,000-40,000 mg/L, and N in the range of 30-100 mg/L, P in concentrations of the order of 5-100 mg/L, and TSS values in the range of 10-500 mg/L.

Sugar manufacturing and coffee wet mills effluents typically have COD values of 110,000-190,000 mg/L, BOD values of 50,000-60,000 mg/L, TSS values of 13,000-15,000 mg/L, N has values of 5,000-7,000 mg/L, P can be around 2,500-2,700 and pH values ranging from 3.0-4.0; **Table 6** shows a summary of these pollutants loads.

COMMONLY AGREED TREATMENT METHODS TO TREAT DAIRY PROCESSING WASTEWATER

The variability in food and beverage processors' wastewater quality and quantity makes it impractical to recommend one specific generic wastewater treatment process as the BWMPs for the food and beverage industries or its sub-sectors. Depending on the type of food processing industry, wastewater contains carbohydrates, proteins, inorganic and organic salts, grease, oil, and fats. The specific wastewater treatment process at a facility should be determined based on the facility's wastewater profile and the level of treatment required. To define technologies, an iterative process is typically used to determine the optimum configuration of the treatment steps. This process considers such factors as baseline wastewater profiles, individual treatment steps' removal efficiencies, existing treatment equipment capability, and the final effluent specifications (OCETA, 2005). Factors such as sludge handling and disposal may also have to be included in the analysis.

Single or a group of technologies can be used to meet the discharge criteria established for the various physical, chemical, and biological parameters. **Table 7** lists common treatment technologies used in food and beverage industries. A preliminary treatment consisting of a screen and pH-neutralization vessels is commonly needed. Also, a treatment train combining physical, chemical, and biological techniques (especially anaerobic reactors/digestion or wetlands) allows high reduction percentages of the main contaminants. DAF systems could be implemented as they allow high COD, color, and turbidity removal rates. Still, it is important to consider their high energy costs and possible limited disposal of sludge because of their toxicity. Electrochemical, chemical oxidation and electro-oxidation, microfiltration, and reverse osmosis are other emerging treatment technologies reported in the food and beverage industries that achieve high removal efficiencies of COD, BOD, and TSS (Shrivastava et al., 2022).

Many food and beverage industries also use treatment ponds as they can be a cost-effective way to treat the water. However, it is advisable to include proper design, monitoring, and maintenance to ensure the continued performance of the treatment pond and to prevent negative impacts on the environment.



5.2.4 MEAT PROCESSING

TARGET POLLUTANTS AND ORGANIC LOADS

The wastewater effluents from other animal protein industries composition largely depend upon the type of animal slaughtered. The wastewater contains pollutants such as blood, pouches (stomach and intestine), dung, urine, meat trimmings, hairs, feathers, fat, and disinfectants. (Kharat, 2019). Wastewater generated as a result of slaughtering and processing units has an elevated amount of organic matter, FOGs, nutrients, pathogens (especially *E. Coli* and *Salmonella*), and sometimes antibiotics and heavy metals such as copper, chromium, molybdenum, nickel, titanium, zinc, and vanadium (World Bank Group, 2007).

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 BOD concentration in meat processing wastewater. The degree to which manure -especially from receiving areas- (urine and feces) is handled separately as solid waste is a significant factor determining the BOD of meat processing wastewater (US EPA, 2002).

WHAT TO EXPECT OF THE GENERATED WASTEWATER

In meat processing facilities, considering blood separation, BOD can be between 150-5,500 mg/L, COD can be between 500 - 16,000 mg/L, and TSS levels can be between 0,1-10,000 mg/L. The N can be between 50-850 mg/L and P between 25-200 mg/L; Table 6 summarizes pollutant values. Pathogens such as *Salmonella*, *E. Coli*, *Shigella* bacteria, parasite eggs, and amoebic cysts may also be present. Pesticide residues may be present from the treatment of animals or their feed. Foul odors are also commonly present. The presence and concentration of pathogens will depend on the effectiveness of the sanitation and disinfection practices used during processing operations.

COMMONLY AGREED TREATMENT METHODS TO TREAT DAIRY PROCESSING WASTEWATER

The type of treatment depends upon the wastewater characteristics, availability of treatment facilities, and effluent discharge standards. **Table 7** presents a list of treatment technologies used in meat processing facilities. Overall, biological treatment (especially anaerobic digestors/reactors) is usually employed over other treatment options such as electrocoagulation, membrane separation, and advanced oxidation for the slaughterhouse process effluent. Chemical treatments, especially non-biodegradable ones, are not recommended as the addition of chemicals increases the cost of treatment, and the difficulty in disposing of chemical sludge makes that process economically unfavorable. Prioritizing these facilities' screening and sedimentation stages to reduce organic loads and gross solids as much as possible is important. Most treatment facilities must also implement disinfection stages to kill or inactivate harmful pathogens in the wastewater before discharging it into the environment (Kharat, 2019).

DAF systems could be implemented as they allow high COD, color, and turbidity removal rates. However, it is important to consider their high energy costs and possible limited disposal of sludge because of their toxicity (Bustillo-Lecompte et al., 2016).

While implementing biodigesters, it is important to consider that the wastewater input should be carefully controlled to prevent high levels of inhibitory substances such as heavy metals and antibiotics. The biodigester's (digestate) water outlet should be further treated since it still contains organic matter, pathogens, odor, and nutrients such as N and P that could pollute water if not managed appropriately. It is recommended to continue the treatment of the digestate with aerobic reactors and filtration systems. Should the biogas outlet be considered for energy generation or heating applications, desulfurization and moisture removal must be done.

Table 6 shows a comparative summary of pollutant loads in wastewater from the four industries mentioned above, and **Table 7** summarizes common treatment technologies for these different Agro-industrial processes.

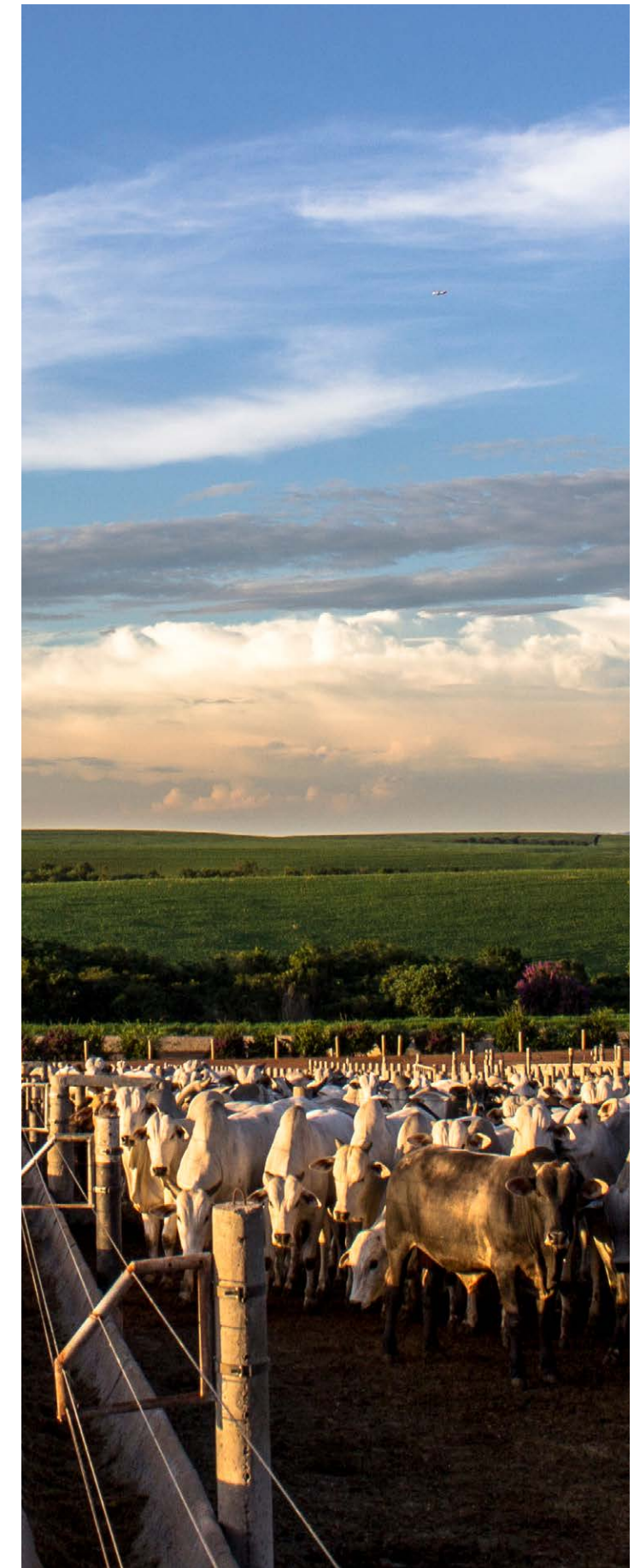


TABLE 6 Comparative summary of pollutant loads in wastewater from different industries.

Sector	Example	COD (mg/L)	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	TP (mg/L)	pH
AQUACULTURE	Aquaculture processing facility (Igwegbe & Onukwuli, 2019)	50-350	500-800	50-80	5.0-20	18-50	6.0-8.0
DAIRY PROCESSING	Cheese processing factories (Hung & Britz, 2006)	5,000-60,000	2,300-30,000	2,000-12,000	100-170	40-100	3.5-5.5
	Milk/milk powder processing factories. (Hung & Britz, 2006)	2,000-6,000	1,200-4,000	350-1,000	100-170	50-60	8.0-11.0
	Whey processing factories (Hung & Britz, 2006)	68,800	35,000	1,300	1,400	370-640	4.6
MEAT PROCESSING	Slaughterhouse plant** (Bustillo-Lecompte et al., 2016)	500-16,000	150-8,500	0.1-10,000	50-850	25-200	4.9-8.1
FOOD AND BEVERAGE	Sugar mills with distilleries spent wash water (Dhote et al., 2021)	110,000 - 190,000	50,000-60,000	13,000 - 15,000	5,000 - 7,000	2,500 - 2,700	3.0-4.0

**Maximum values shown depend on blood and manure separation. Blood has a COD of approximately 375,000 mg/L and a BOD of approx. 150,000-200,000 (Yetilmezsoy et al., 2022).

TABLE 7 Summary of common treatment technologies for Agro-industrial Process

Industry	Preliminary treatment	Primary treatment	Secondary Treatment	Tertiary Treatment	Sludge treatment
AQUACULTURE	Screens, mechanical filters	Sedimentation basin, clarifier, centrifuge	Submerged biofilters, trickling filters, rotating biological contactors, fluidized bed reactors	Constructed wetlands	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.
DAIRY PROCESSING	Flow equalization, screens, mechanical filters, grease traps, skimmers, or oil water separators	Coagulation and Flocculation, DAF, and pH regulation (if needed)	Aerobic/Anaerobic biological treatments include aerobic/anaerobic lined ponds, aerobic reactors, anaerobic filters, UASB, and biofilters	Chlorine, UV (if pathogens are present)	
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, UV (if pathogens are present, especially if wastewater is irrigated)	
FOOD AND BEVERAGE	Flow equalization, screens, and mechanical filters	Sedimentation basin, DAF, and pH regulation (if needed)	Aerobic/Anaerobic biological treatments include aerobic/anaerobic lined ponds, aerobic reactors, anaerobic filters, UASB, and biofilters	Chlorine, UV (if pathogens are present, especially if wastewater is irrigated), Multimedia filter, sand filter, fabric filter, ultrafiltration, and microfiltration	

6

Effluent Management



6.1 EFFLUENT MANAGEMENT AND RISK ASSESSMENT

When deciding how to discharge wastewater, the following factors are typically considered: proximity to receiving water courses, sewer access, and convenience. The decision-making process often involves evaluating different discharge pathways based on which have the least strict discharge parameters that apply to the specific industry.

While proximity to water courses and access to sewers are important considerations for selecting wastewater discharge pathways, facilities must be aware of the potential environmental impacts that their discharges may cause. It is recommended that all facilities engaging in wastewater discharge carry out a risk-based assessment of the discharge to address this issue, and utilize a risk assessment methodology to manage potential risks effectively. **Section 6.4** provides general guidelines on how to conduct a discharge risk assessment.

In this context, risk is defined as the likelihood of an undesirable event occurring, and it is commonly assessed when choosing between alternative courses of action. Various industries and organizations use risk assessment, including engineering, economics, public health, medicine, natural resource management, irrigation, and biosecurity. Environmental risk assessment involves evaluating the interactions between environmental values, stressors, and management actions to safeguard these values; its purpose is to assess the potential impacts of stressors on environmental values.

6.2 GENERAL CONSIDERATIONS FOR WASTEWATER DISCHARGES

6.2.1 GENERAL CONSIDERATIONS FOR DISCHARGE TO SURFACE WATER

- Wastewater temperature before discharge should not exceed three °C of ambient temperature at the edge of a scientifically established discharge mixing zone (DMZ), which considers ambient water quality, receiving water use, and assimilative capacity among others.
- Do not discharge sludge produced in the wastewater treatment into the surface waters.

6.2.2 GENERAL CONSIDERATIONS FOR DISCHARGE TO SANITARY SEWER SYSTEMS (INDIRECT DISCHARGE)

- The discharge should not interfere, directly or indirectly, with the operation and maintenance of the collection and treatment systems, pose a risk to workers' health or safety, or adversely impact characteristics of residuals from wastewater treatment operations.
- The wastewater should be discharged into municipal or centralized wastewater treatment systems that have adequate capacity to meet local regulatory requirements for the treatment of wastewater generated from the project.
- Even if municipal or centralized wastewater treatment systems receiving wastewater from the project have adequate capacity to maintain regulatory compliance, pretreatment of wastewater to meet regulatory requirements before discharge from the project site should be implemented.
- Do not discharge any sludge produced in the wastewater treatment into the sanitary sewer systems.

6.2.3 GENERAL CONSIDERATIONS FOR DISCHARGE TO COASTAL WATERS (ESTUARIES, BAYS) OR OPEN SEA

- Avoid areas with high coastal erosion rates to prevent soil degradation and habitat destruction.
- Choose a discharge location away from sensitive areas like coral reefs, marine reserves, and fishing grounds.
- Be aware that estuaries are less able to accept and disperse effluents due to their shallow and confined nature, and they can also trap particles where fresh and saline waters meet, potentially leading to toxic accumulation (National Research Council (U.S.), 1993).
- Do not discharge any sludge produced in wastewater treatment into coastal waters or harbors.
- Typically, there are no specific discharge parameters for discharging wastewater into coastal waters in the LAC regulation framework. Therefore, conducting a discharge risk assessment study considering the DMZ (See Section 6.4) is important to ensure responsible wastewater discharge practices and minimize their impact on coastal ecosystems.

WHEN TO APPLY DISCHARGE RISK ASSESSMENT TO COASTAL WATERS

- The DMZ is a designated geographical area or volume of water in the receiving environment of a discharge where initial dilution of the effluent occurs. It is where exceedance of water quality standards and limits may be permitted, contributing to the sustainable management of discharge activities and minimizing their effects on the environment and human health (Campos et al., 2022).
- Various factors determine the magnitude and extent of effects from the wastewater into the DMZ (Campos et al., 2022), such as the quality and quantity of the effluent discharged, the health of the receiving environment before the effluent is mixed (for new discharges, these background characteristics are best determined before consenting), the proximity of the discharge to 'sensitive' receptors, including protected habitats and other natural resources and human uses of the environment, the hydrodynamics of the water body (including those within the mixing zone) and the physical, chemical, and biological interactions between the discharge and the receiving environment and the capacity of the receiving environment to assimilate the pollutants in the discharge.

6.2.4 GENERAL CONSIDERATIONS FOR LANDSCAPE IRRIGATION, FERTIGATION, OR INFILTRATION OF TREATED WASTEWATER FOR AGRICULTURAL PURPOSES.

- As with discharge to coastal waters, due to the lack of conclusive regulations regarding wastewater irrigation, fertigation, or infiltration in many LAC countries, conducting a **comprehensive discharge pathway risk assessment is crucial.**
- As a guideline, selecting a benchmark site per 0.1 km², within the irrigation area is recommended, as the soil in this area is a comprehensive indicator of all applied materials. To monitor the accumulation of metals and potential surface or groundwater contamination, soil samples should be collected before irrigation begins and annually at the start of the application season. According to UNEP (2005), for systems with a daily water flow of over 567,000 L, it is advisable to collect soil samples twice a year. Annual soil testing from the same location can serve as an early warning system for potential environmental hazards.
- According to FAO (1992) guidelines, a range of essential parameters and potential consequences associated with fertigation, landscape irrigation, or infiltration are detailed below. For additional specifications regarding these parameters, refer to Annex 3.

WATER QUALITY FACTORS

- ◆ **Electrical Conductivity (EC) and Ion Concentrations:** Parameters such as sodium, calcium, and magnesium ion concentrations, along with electrical conductivity, play a crucial role in water quality assessment for irrigation purposes. High EC values suggest a higher salt content in the water. Excessive salt accumulation in soils can reduce plant growth, hinder plant water uptake, and result in soil degradation through salinization. Sodium is a cation that, when present in excess, can lead to soil dispersion and subsequent compaction, affecting soil structure and reducing water infiltration and root penetration.
- ◆ **Suspended Solids:** These solid particles tend to accumulate in soil and require periodic drying for proper infiltration recovery. In soils with different textures, the penetration depth of suspended solids varies. Coarser soils allow fine and colloidal particles to penetrate more deeply. However, in most cases, soils act as effective filters, removing suspended solids from sewage effluent after percolation through the vadose zone.
- ◆ **BOD₅ (Biochemical Oxygen Demand):** Landscape irrigation, fertigation, and infiltration systems can manage high BOD loadings, often reducing BOD levels to negligible amounts after a relatively short distance of percolation through the soil. When untreated wastewater with elevated BOD₅ levels is used for irrigation, fertigation, or infiltration, it can lead to adverse effects such as nutrient imbalances, groundwater contamination, reduced water infiltration, and increased susceptibility to crop diseases.
- ◆ **Pathogenic Microorganisms:** Wastewater may contain harmful bacteria, such as *salmonella*, *shigella*, mycobacterium, and *E. Coli*. Soil is a natural filter, effectively removing these microorganisms from wastewater effluents. Bacteria are physically strained out, while viruses are adsorbed, with pH, salt concentration, and specifications influencing this adsorption process. Effective measures include reducing bacterial levels in sewage effluent before infiltration and ensuring proper soil characteristics in the irrigation system.

NUTRIENTS

- ◆ **Nitrogen:** Wastewater contains various forms of N, including organic, ammonium, and nitrate nitrogen. The composition depends on prior treatment processes. The appropriate form and concentration of N in treated wastewater must align with crop requirements, groundwater protection, and potential alternate uses. Controlled management of N form and concentration can be achieved through hydraulic loading rates and infiltration flood-dry cycles.
- ◆ **Phosphorus:** Effluents from agro-industrial processes may contain significant P content. This element can undergo biological conversion to phosphate. Factors like soil pH and composition influence its mobility and availability in soil. In calcareous soils, phosphate may precipitate with calcium, while in acid soils, it reacts with iron and aluminum oxides to form insoluble compounds. Phosphate mobility varies in different soil types.

TRACE ELEMENTS

- ◆ **Heavy Metals:** Heavy metals, fluorine, and boron are trace elements. In most cases, metals are retained in soil, with pH playing a role in immobilization. Fluoride interacts with soil components, forming insoluble compounds like calcium fluoride. Boron's mobility is influenced by soil texture, with adsorption on clay particles.
- ◆ When engaging in irrigation or fertigation of treated wastewater, it is crucial to consider having wastewater storage capacity before irrigation. The storage is especially important due to irrigation during non-growing seasons, where the application method is not continuous. The recommended safety percentage for storing water in this context can vary based on several factors, including the local climate, crop types, soil conditions, and specific irrigation/fertigation practices. Generally, a safety percentage of around 20-30% of storage could serve as a starting point, allowing for unforeseen fluctuations in water demand and supply and giving a buffer against variations in factors such as rainfall, evaporation, and changes in crop water needs.

WHEN TO APPLY THE DISCHARGE RISK ASSESSMENT FOR LANDSCAPE IRRIGATION, FERTIGATION, OR INFILTRATION OF TREATED WASTEWATER

- The discharge risk assessment will help determine the capacity of the intended irrigation field to receive the wastewater. It is important to note that the benefits of using wastewater for irrigation include improved levels of N, P, K, soil organic matter, enhanced soil microbial activity, and better physical structure. However, it is equally important to acknowledge the potential disadvantages, such as increased soil and food contamination, raised pathogen levels, increased antibiotics, and elevated levels of heavy metals in soil and plant produce (Singh, 2021).
- The risk assessment study should also consider several factors, such as Sodium Adsorption Ratio (SAR) analysis (See Annex 3 and Table A-3.2 for more detail), BOD loading transit models, and infiltration studies. By conducting a thorough risk assessment, it is possible to identify potential risks and implement effective measures to mitigate them.
- Several key outcomes arising from the risk assessment process will aid in establishing the maximum allowable volume of wastewater for irrigation or infiltration, defining the permissible wastewater quality for such purposes, developing an appropriate irrigation or infiltration schedule, selecting the suitable irrigation or infiltration technique, determining upper limits for salt concentrations, regulating groundwater table levels, and implementing an effective monitoring framework.
- Overall, as a standard control measure, it is advisable to ensure that irrigation/infiltration systems do not contaminate groundwater; monitoring both up-gradient and down-gradient areas is crucial. Monitoring wells should be installed, and water samples should be taken at the commencement and conclusion of the irrigation season to check for any signs of wastewater contamination (UNEP, 2005). **Note:** Adhering to the ASTM D5092/D5092M-16 standard is recommended for the construction and monitoring of wells. This standard provides guidelines and best practices for designing, constructing, and monitoring groundwater monitoring wells.

6.3 EFFLUENT REUSE

While discharging wastewater is a commonly accepted and regulated practice, it is important to note that promoting measures for reusing treated wastewater is becoming increasingly recognized as a positive step towards achieving SDGs and promoting sustainable practices.

Additionally, it is important to recognize that the utilization of treated wastewater, whether reintroduced into the production process or employed for other human activities, is a

significant and beneficial practice in contrast to releasing it directly into watercourses with no apparent purpose. When appropriate policies, technologies, and financial incentives are implemented, wastewater can be a valuable resource.

Some potential benefits of reusing treated wastewater are the following:

- Water conservation: Reusing treated wastewater reduces the demand for potable water.

- Environmental management: Reusing treated wastewater can help reduce the pollution of water bodies and prevent the release of harmful substances into the environment.
- Industrial use: Treated wastewater can be used in some industrial processes, such as cooling systems or for cleaning purposes, which can reduce the need for freshwater and lower operating costs.
- Agriculture use: Treated wastewater can be used for irrigation, fertigation, and other agricultural purposes, reducing the need for freshwater.
- Cost savings: Reusing treated wastewater can be cost-effective compared to other water sources, especially when fresh water is scarce or expensive.
- Energy savings: Treating and transporting freshwater requires energy, and reusing treated wastewater can help reduce energy consumption and greenhouse GHG emissions.

Some important considerations when reusing treated wastewater are:

- Health and safety: the treated wastewater may need to be disinfected to prevent the spread of pathogens, depending on the intended use.
- Wastewater treated quality of the: effluent needs to meet the standards and requirements for its intended use.
- Water availability and demand: reusing treated wastewater can help conserve freshwater resources but should not lead to over-reliance on treated wastewater or compromise other essential water uses, like human consumption.
- Public perception: Reusing treated wastewater can be perceived as unappealing or unhygienic

by the public. Therefore, it is important to communicate the benefits and safety measures of using treated wastewater to gain public acceptance.

- Regulatory and legal requirements: The use of treated wastewater is subject to regulatory and legal requirements that vary by location and intended use. It's important to note that some countries are still developing guidelines or establishing regulations to control the safe reuse of wastewater, considering both environmental and human health.
- Monitoring and maintenance: Continuous monitoring and maintenance of the wastewater treatment and reuse systems are necessary to ensure treated wastewater quality and safety and prevent system failures or malfunctions.

6.4 RISK-BASED ASSESSMENT OF THE WASTEWATER DISCHARGE

6.4.1 DECISION TO CONDUCT A RISK ASSESSMENT

The risk-based selection of wastewater discharge pathways should consider various factors such as the volume and quality of the wastewater, the sensitivity of the receiving environment, and the potential impacts on human health and aquatic

life. In addition, a risk assessment methodology, such as the one developed by EPA Victoria (2009), can be used to identify and evaluate the potential hazards and risks associated with wastewater discharge and to develop appropriate mitigation measures.

When considering the irrigation, fertigation, or infiltration of treated wastewater for agricultural or landscape use, it is crucial to acknowledge the possibility of groundwater presence and its sensitivity to water features. Thus, appropriate measures should be taken to ensure that any potential groundwater contamination is managed properly. **Figure 4** summarizes a quick review of a pathway-sensitive receptor for wastewater irrigation.

The decision to conduct a risk assessment should be initiated, in most cases, directly by the wastewater discharger whenever (EPA Victoria, 2009):

- There are no established regulations on the discharge of wastewater into a particular water body or for purposes like irrigation.
- The body of water into which wastewater will be released holds significant ecological importance and can be readily identified as such, such as being an aquatic reserve, a RAMSAR wetland, a heritage river, a coastal plain, or a local community river. Certain types of water bodies, such as estuaries, lakes, and wetlands, are highly vulnerable to impacts and should be carefully considered regarding their susceptibility to environmental harm.

- The potential level of impact according to the discharge constituents, their concentrations, level of toxicity, and persistence in the environment, and the dilution capacity of the water body is under low-flow conditions, particularly if low-flow conditions are predicted to increase due to climate change, impacting the size of the mixing zone.

When the necessary level of assessment is uncertain, a tiered approach can be employed to gradually increase the complexity and resources dedicated to better understanding the risks involved, as further explained in **Section 6.4.2**. By conducting a risk assessment with increasing levels of analysis, sufficient information can eventually be obtained. This approach ensures that resources and time are invested appropriately to acquire the necessary knowledge to make informed management decisions.

6.4.2 CONDUCTING A RISK ASSESSMENT

If a risk assessment is going to be conducted, a third-party consultant/subject expert or company with technical experience must perform it. Annex 4 contains a set of guidelines outlining key factors to take into account when selecting a risk assessment consultant or expert. The process includes four tiers, as shown in **Figure 3** and further described below. An example of a risk assessment is described in **Annex 5**.

TIER 1- INFORMATION GATHERING AND DEFINITION OF POTENTIAL RISKS

Gather and integrate all available data and information on a water body's beneficial uses and characteristics and the potential stressors from the discharge. For this, monitoring of the effluent, modeling estimations of the effluent, literature review, and local plans would be needed.

Within Tier 1 assessment, an essential step involves assessing the potential impact on the watercourse from the stressors originating from discharges. This evaluation is key in understanding and quantifying the risks associated with the discharge activities. Various sensitive uses of the watercourse must be considered during this process. These include but are not limited to aquatic ecosystems, primary or secondary recreational activities, indigenous cultural-spiritual values, and aquaculture. To comprehensively represent the intricate interplay between parameters, threats, and contributing factors, it might be helpful to represent this relationship visually. Figures 4 and 5 provide illustrative examples of such relationships, clarifying the complexities involved.

In cases where neighboring discharges or other existing influencing factors are identifiable, it is recommended that a cumulative risk assessment approach be considered following the guidelines outlined by the U.S. Environmental Protection Agency in the "Framework for Cumulative Risk Assessment (EPA, 2003).

TIER 2- SCREENING

It includes, as default, complying with the applicable established or calculated discharge parameters, if any, and may include particular company disclosures such as maintaining a healthy aquatic ecosystem (i.e., macroinvertebrate communities, biodiversity, or native fish populations) or ensuring that there is no significant impact in the watercourse, caused by the discharge.

TIER 3- ADDITIONAL INFORMATION GATHERING

If there is a plan for direct discharge into surface water or coastal water, it may be necessary to conduct discharge mixing zone studies or initial water quality testing. On the other hand, conducting several tests, such as permeability tests, water table measurements, and groundcover assessments for irrigation, is recommended.

TIER 4- SCOPING

Assess the level of risk by utilizing the information collected to evaluate the potential risks associated with the discharge pathway. Prioritize the pathways based on the level of risk identified. If the data indicates that the level of risk is acceptable, the site can be utilized for wastewater discharge or irrigation. The personnel responsible for the site must ensure that the necessary control measures are in place, including monitoring and controlling measures identified during the scoping phase, besides those specific to the site. However, if the data reveals that the level of risk is unacceptable, personnel from the site should consider alternative discharge pathways or carry out more advanced modeling studies.

REPORTING AND MONITORING MEASURES

Compiling a report that outlines the identified risks and risk management strategies to mitigate them is necessary upon completion of the risk assessment. These strategies may involve modifying the wastewater treatment process or implementing control measures to minimize exposure.

It is also crucial to regularly monitor and review the effectiveness of the risk management strategies and update the risk assessment as necessary. In addition to water quality monitoring parameters, monitoring may include groundwater and salinity assessments (in the case of wastewater irrigation), analyzing and interpreting biological data, calculating the change of water quality index of the river to track any changes over time, conducting ecotoxicity testing, and monitoring the diversity of macroinvertebrate or plankton communities.

FIGURE 3 Review of tiered risk analysis procedure for discharge pathways

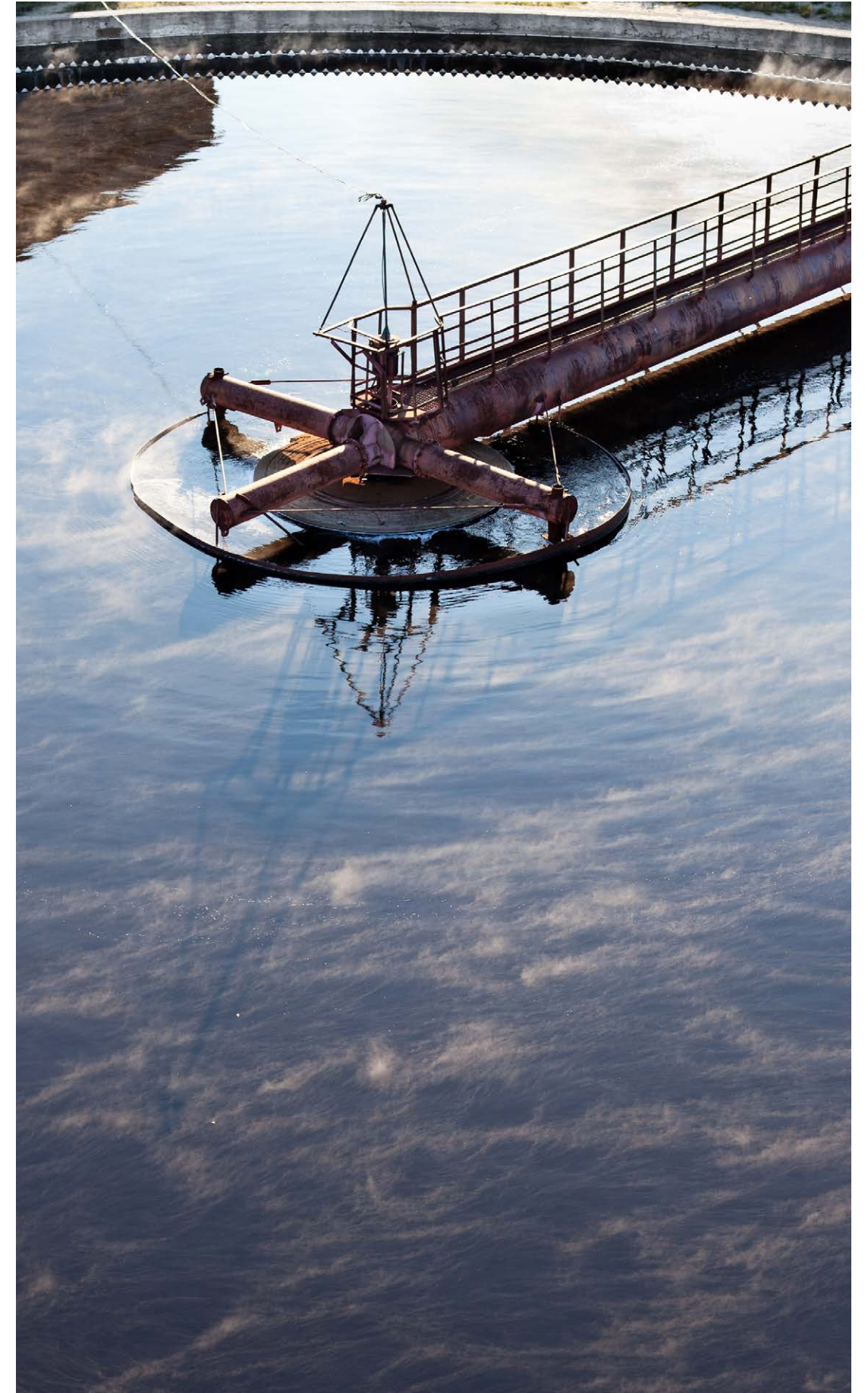
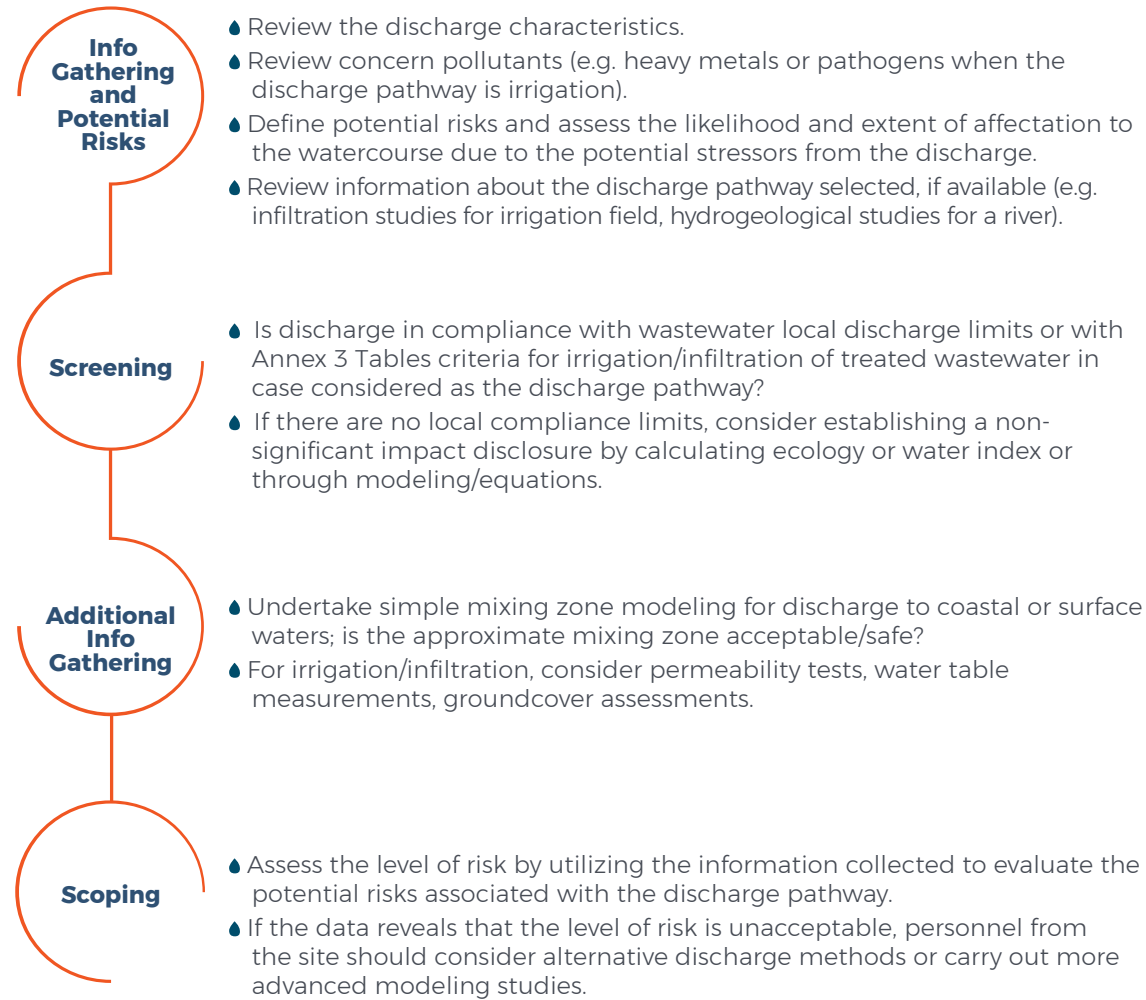


FIGURE 4 Example of pathway-sensitive receptor review for wastewater irrigation

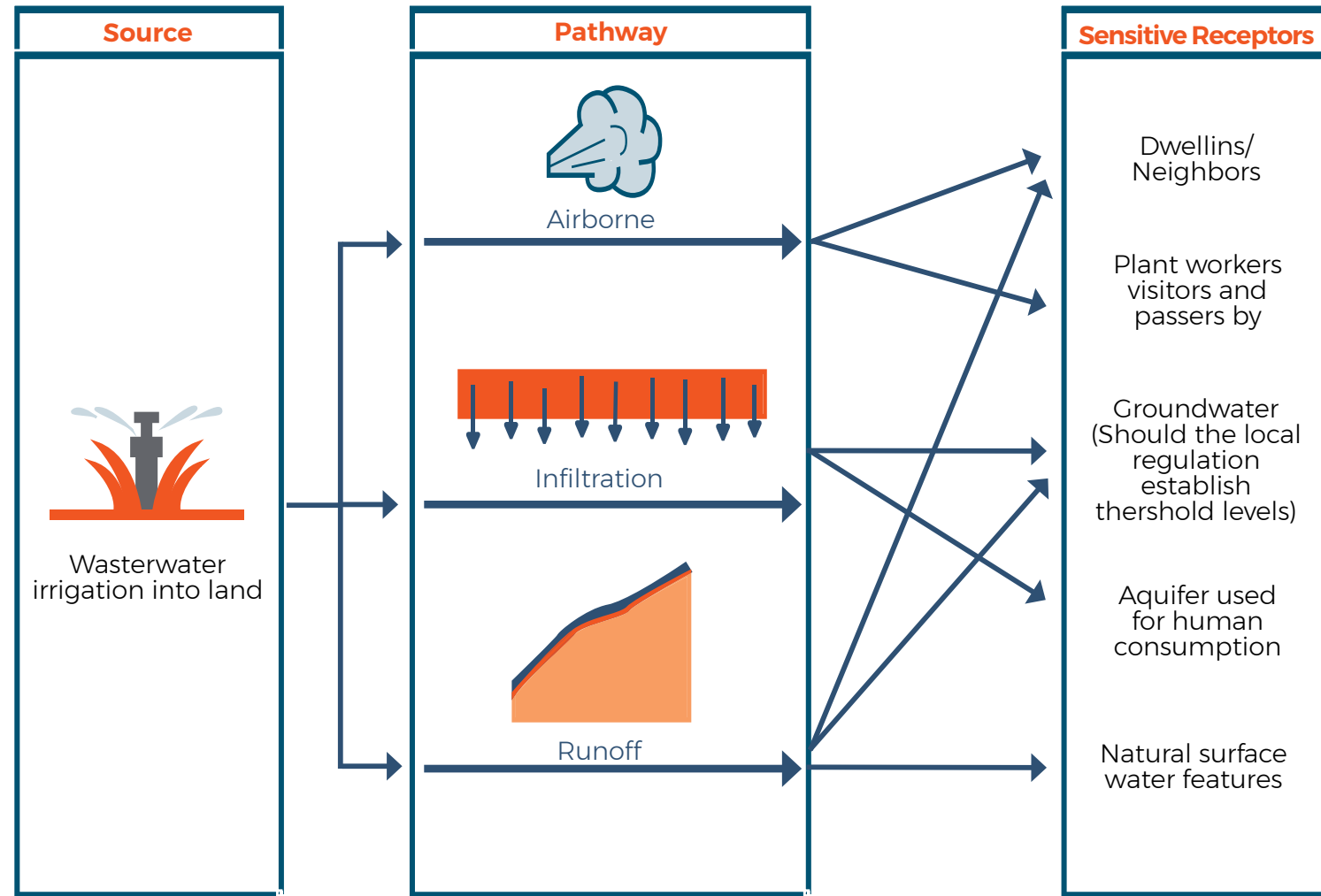
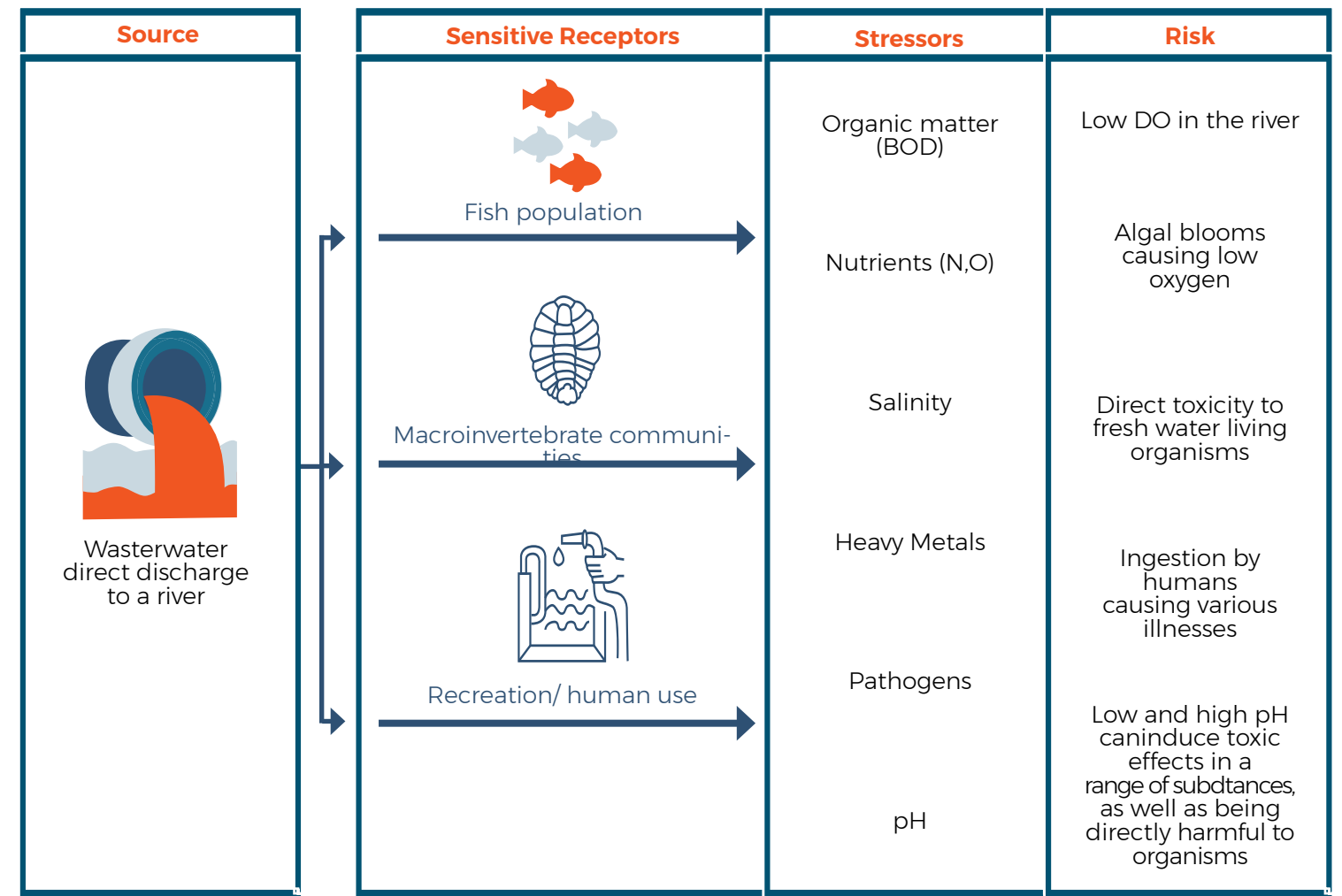


FIGURE 5 Example of stressor and risk definition for a direct discharge to a river



6.5 EFFLUENT MONITORING

6.5.1 MONITORING PROGRAM

Developing and implementing a program with sufficient resources and management oversight is essential to achieve the objective(s) of a wastewater and water quality monitoring program. The program should encompass the elements described in the following sections:

DATA QUALITY

Monitoring programs that adhere to internationally sanctioned sample collection, preservation, and analysis protocols are recommended. Overall, the Standard Methods for the Examination of Water and Wastewater, 24th ed. Washington DC: APHA Press; 2023 are suggested as the best analytical methodology for wastewater parameters. The main parameters and analytical methods for wastewater are summarized in Table 8: Conventional parameters for wastewater adapted from (ZDHC Wastewater Guidelines, 2022).

The collection of samples ought to be carried out by trained personnel or under their supervision. Additionally, the analysis of the samples must be performed by authorized or certified laboratories for this particular purpose.

PARAMETER SELECTION

When selecting monitoring parameters, choosing those indicative of the pollutants of concern from the process is crucial, including the ones regulated under compliance requirements.

SAMPLING WASTEWATER

Wastewater monitoring should account for the discharge characteristics from the process over time. When monitoring discharges from processes that involve batch manufacturing or seasonal process variations, the time-dependent variations in discharges must be considered (e.g., coffee wet mills and sugar mills). As such, monitoring such discharges is more intricate than monitoring continuous discharges.

Effluents from highly variable processes may need more frequent sampling or composite methods. Grab samples or, if automated equipment is available, utilize composite samples to better understand average concentrations of pollutants over 24 hours. However, composite samplers may not be suitable for short-lived analytes of concern, such as quickly degraded or volatile ones (e.g., FOGs and fecal coliforms).

Local regulations and other requirements for monitoring wastewater and water quality should always be the top priority and supersede 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.

A quick reference for suggested performance and control parameters for treatment plants is summarized in Table 8.

TABLE 8 Conventional standard methods for analysis and testing of wastewater parameters

Parameter	Unit	Standard methods (SM) for analysis and testing
Alkalinity	mg/L CaCO ₃	SM 2320
Ammonium-Nitrogen (NH₄-N)	mg/L	SM 4500 NH ₃ - D/E/F/G/H
Biochemical Oxygen Demand 5-days concentration (BOD₅)	mg/L	SM 5210-B
Chemical Oxygen Demand (COD)	mg/L	SM 5220-D
Colour (436nm; 525nm; 620nm)	m ⁻¹	SM 2120B/C/D/E
Electrical Conductivity (EC)	uS/cm	SM 2510
Dissolved Oxygen (DO)	mg/L	SM 4500-O-G
Escherichia Coli (E. Coli)	MPN/100mL	SM 9221-F/G
Total Coliforms	MPN /100mL	SM 9221-B
Oil & Grease	mg/L	SM 5520-B/C
Nitrates	mg (NO ₃ -N)/L	SM 4500-NO ₃ - B/C/D/E/F/H/I/J
pH	pH	SM 4500-H+
Settleable solids	mL/L	SM 2540F
Sodium (Na+), Calcium (Ca++), and Magnesium (Mg++)	mg/L	SM 3500-Na, 3500-Ca, 3500-Mg
Temperature difference	°C	SM 2550
Total Phenols / Phenol Index	mg/L	SM 5530-B/C
Total Chlorine	mg/L	SM4500-Cl-G
Total Dissolved Solids (TDS)	mg/L	SM 2540-C
Total Nitrogen (TN)	mg/L	SM 4500P/J SM 4500N/B SM 4500N/C
Total Phosphorus (TP)	mg/L	SM 4500P-J
Total Suspended Solids (TSS)	mg/L	SM 2540D
Total Volatile Suspended Solids (TVSS)	mg/L	SM 2540E
Turbidity	NTU	SM 2130B
Volatile Fatty Acids (VFAs)	mg/L	SM 5560D

SAMPLING LOCATIONS

The selection of the monitoring location should aim to provide monitoring data representative of the entire wastewater discharge. Effluent sampling stations may be placed at the final discharge point and strategic upstream locations before merging different discharges. Process discharges must not be diluted before or after treatment to meet discharge or environmental water quality standards.

Figure 6 summarizes a quick reference for sampling location across the WWTP.

FIGURE 6 Generic flow diagram for identifying process water and wastewater monitoring points.

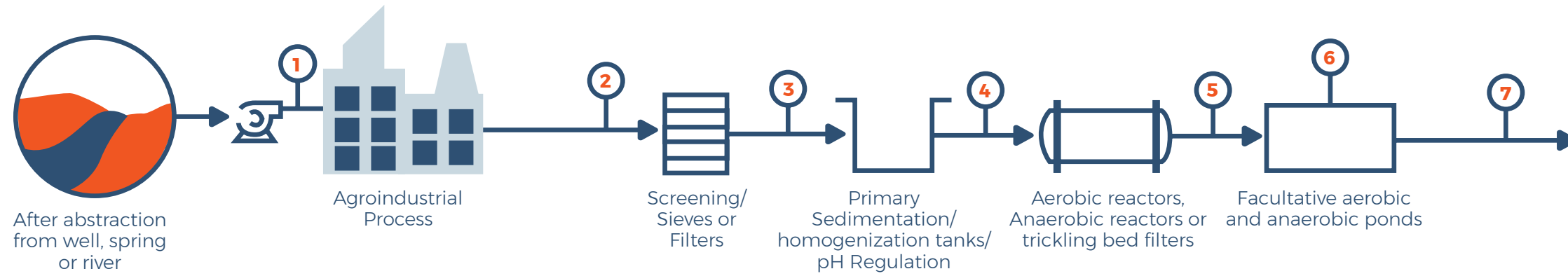


TABLE 9 Description of the sampling points and the analytical requirements for process water and wastewater samples (to be used in conjunction with Figure A-4.1).

Monitoring point	Description of the monitoring point	Performance Analysis*			Control Analysis (On-site) ***			
		Parameters	Type of sampling	Suggested Frequency	Parameters	Type of Sampling	Suggested Frequency	Suggested equipment
1) Input process water	The main water source for the process. For example, river water or water from a well.	Temperature (in situ), conductivity (in situ), and pH (in situ)	Grab/simple sample (At least six during the monitoring campaign)	Quarterly**	Flow rate (m ³ /day)	Direct measurement	Daily	Water meter
		COD, BOD, TSS, TP and TN	Composite (At least six sub-samples)		pH	Grab	Weekly	Digital pH meter
		Fecal Coliforms and FOGs	Grab/simple sample (one sample during the monitoring campaign)		Turbidity (NTU)	Grab	Weekly	Turbidimeter
					TDS (mg/L)	Grab	Weekly	Digital TDS meter or potable meter
2) Raw wastewater	Wastewater input to the treatment system (usually before sieving or in wastewater storage tanks) or before disposal (if there is no treatment)	pH (in situ)	Simple (for each one of the six sub-samples)	Quarterly**	Flow rate (m ³ /day)		Daily	Water meter
		COD, BOD, and TSS. Total Suspended Volatile Solids and Alkalinity.	Composite (six sub-samples)		pH	Grab	Daily	Digital pH meter
		Fecal Coliforms and FOGs	Simple		Settable Solids (ml/L)	Grab	Daily	Imhoff cone
					COD (mg/L)	Grab	Daily	Spectrophotometer
3) After screens, rotary sieves, or filters*	Screens, rotary sieves, or filters	Solids (in situ).						
		COD, BOD and TSS.	Composite (six sub-samples)		TDS (mg/L)	Grab	Daily	Digital TDS meter or potable meter

Monitoring point	Description of the monitoring point	Performance Analysis*			Control Analysis (On-site) ***			
		Parameters	Type of sampling	Suggested Frequency	Parameters	Type of Sampling	Suggested Frequency	Suggested equipment
4) Homogenization tanks, pH regulation tanks, and primary sedimentation tanks*	Wastewater output of the homogenization tanks, pH regulation tanks, and primary sedimentation tanks	Temperature (in situ), pH (in situ), and settleable solids (in situ).	Simple (for each one of the six sub-samples)	Quarterly*	pH	Grab	Daily	Digital pH meter
		COD, BOD, TSS, Nitrates, and Alkalinity.	Composite (six sub-samples)		Settable Solids (mL/L)	Grab	Daily	Imhoff cone
5) Aerobic reactors, anaerobic reactors, or trickling bed filters*	Wastewater output of aerobic reactors, anaerobic reactors, or trickling bed filters.	pH (in situ)	Simple (for each one of the six sub-samples)	Quarterly*	pH	Grab	Weekly	Digital pH meter
		DO (Aerobic reactors), COD, BOD, TSS and VFAs (anaerobic reactors)	Composite (six sub-samples)		COD (mg/L)	Grab	Daily	Spectrophotometer
					DO (mg/L or %)	Grab	Daily	DO Meter
					Temperature (°C)	Grab	Daily	Digital Thermometer
					Biogas flow (Anaerobic reactors) (m ³ /day)	Direct measurement	Daily	Biogas meter
6) Aerobic lagoons, anaerobic lagoons, or facultative lagoons	Wastewater output of Aerobic Lagoons, Anaerobic Lagoons, or Facultative Lagoons.	pH (in situ)	Simple (for each one of the six sub-samples)	Quarterly	pH	Grab	Weekly	Digital pH meter
		DO (Aerobic reactors), COD, BOD, TSS and VFAs (anaerobic reactors)	Composite (six sub-samples)		COD (mg/L)	Grab	Daily	Spectrophotometer
					DO (mg/L or %)	Grab	Daily	DO Meter
					Temperature (°C)	Grab	Daily	Digital Thermometer
7) Wastewater effluent	At wastewater discharge	Temperature (in situ), conductivity (in situ) and pH (in situ),	Simple (for each one of the six sub-samples)	Quarterly*	Flow rate (m ³ /day)	Direct	Daily	Water meter
		COD, BOD, TSS, TP and TN.	Composite (six sub-samples)		pH	Grab	Daily	Digital pH meter
		If water is used for irrigation or infiltration, include the following analysis: Sodium (Na+), Calcium (Ca++), and Magnesium (Mg++)	Simple		Turbidity (NTU)	Grab	Weekly	Turbidimeter
					TDS (mg/L)	Grab	Daily	Digital TDS meter or potable meter
					Chlorine residual (ppm)	Grab	Daily	Residual chlorine checker
					EC (uS/cm)	Grab	Daily	Electronic conductivity meter

7 *Business Case Review for Good Wastewater Management Practices within the Agribusiness Sector*



7.1 BACKGROUND AND RATIONALE

The agro-industrial processes generate vast amounts of wastewater with important polluting characteristics, as seen in the last section. Therefore, applying the best wastewater management practices is critical for improving environmental sustainability, complying with regulations, protecting public health, and ensuring long-term business success.

A written questionnaire was administered to different agribusiness industries in the LAC region to gain insights into current wastewater management practices in the agribusiness sector. The responses to the questionnaire were analyzed, and three industries that have applied BWMPs were selected.

This section aims to provide an overview of the current state of wastewater management in these industries and identify areas of improvement. Through this business case review, the GPN hopes to provide useful information to stakeholders in the agribusiness sector, including business owners, to encourage the adoption of BWMPs and promote continuous improvement in alliance with sustainable operations.

Each business case includes a short process description, a list of successful pollution prevention and wastewater treatment BWMPs, a description of critical controls in the process, and further opportunities identified in this review.

7.2 CASE 1: LEMON JUICE PROCESSING PLANT

7.2.1 PROCESS DESCRIPTION

This lemon juice processing facility processes around 250 thousand tons of lemons annually from March until August. This industry obtains industrialized products like oil, juice, pulp, and peel. The processing involves various stages that use water, such as washing, juice extraction, oil extraction, pulp and juice separation, and Clean-in-Place (CIP) of the equipment. Activities generate substantial amounts of wastewater containing organic matter, sugars, acids, and other pollutants. To purify wastewater, a treatment plant with a maximum capacity of 8,500 m³/day operates 24 hours a day, seven days a week.

7.2.2 BEST WASTEWATER MANAGEMENT PRACTICES

POLLUTION PREVENTION BWMPs IN PLACE

- CIP methods for decontaminating equipment.
- Reuse of water generated in fruit condensate, in the rejection of the osmosis equipment, and cooling water used in towers and tanks within the process to minimize the amount of wastewater generated.
- Automatic control equipment in the wastewater treatment plant for gathering, analyzing and displaying real-time data on water levels, flow, pH and temperature values.
- Inspections carried out in the WWTP by performing daily measurements of water quality parameters for internal control. These inspections imply having dedicated personnel.
- Flow meters to monitor water usage and installing solenoid valves to stop water flow when equipment is not in operation and no water is required.
- Effluent reuse to irrigate the field with lemon trees.

WASTEWATER TREATMENT BWMP IN PLACE

- Initially, the WWTP commenced its operations by employing only the preliminary and primary stages. During this phase, solid materials were separated through static filters, and subsequently, a physicochemical process utilizing DAF equipment was implemented to reduce TSS and BOD loads. Nevertheless, the requirement to further enhance the wastewater quality prompted the incorporation of two additional stages, thereby establishing the secondary treatment phase.
- Installing a UASB with a 7,500 m³ (secondary treatment) capacity became necessary to increase the removal efficiency of pollutants.
- Afterwards, a third stage was incorporated consisting in installing a 10,000 m³ activated sludge system, which helped increase the treatment efficiency and the irrigation field's size. Also, a biogas boiler was installed; this increased COD removal efficiency in the UASB as the reactor was now heated.

7.2.3 CRITICAL CONTROLS AND MONITORING

- Given that the raw water has a very low pH, using high amounts of lime water is essential to neutralize water before it enters the anaerobic stage.
- Performance of biological treatments is strongly affected by frequent and large disturbances in the influent flow and loads. Hence, controlling the outlet of the DAF is a critical step to ensure an optimum treatment in the UASB.
- As water is reused for irrigation of lemon trees, daily control of the effluent quality is vital to prevent soil contamination.
- Analyzing parameters like soil salinity, permeability, and groundwater levels are adequate to ensure the effluent is not causing negative effects on soil composition.

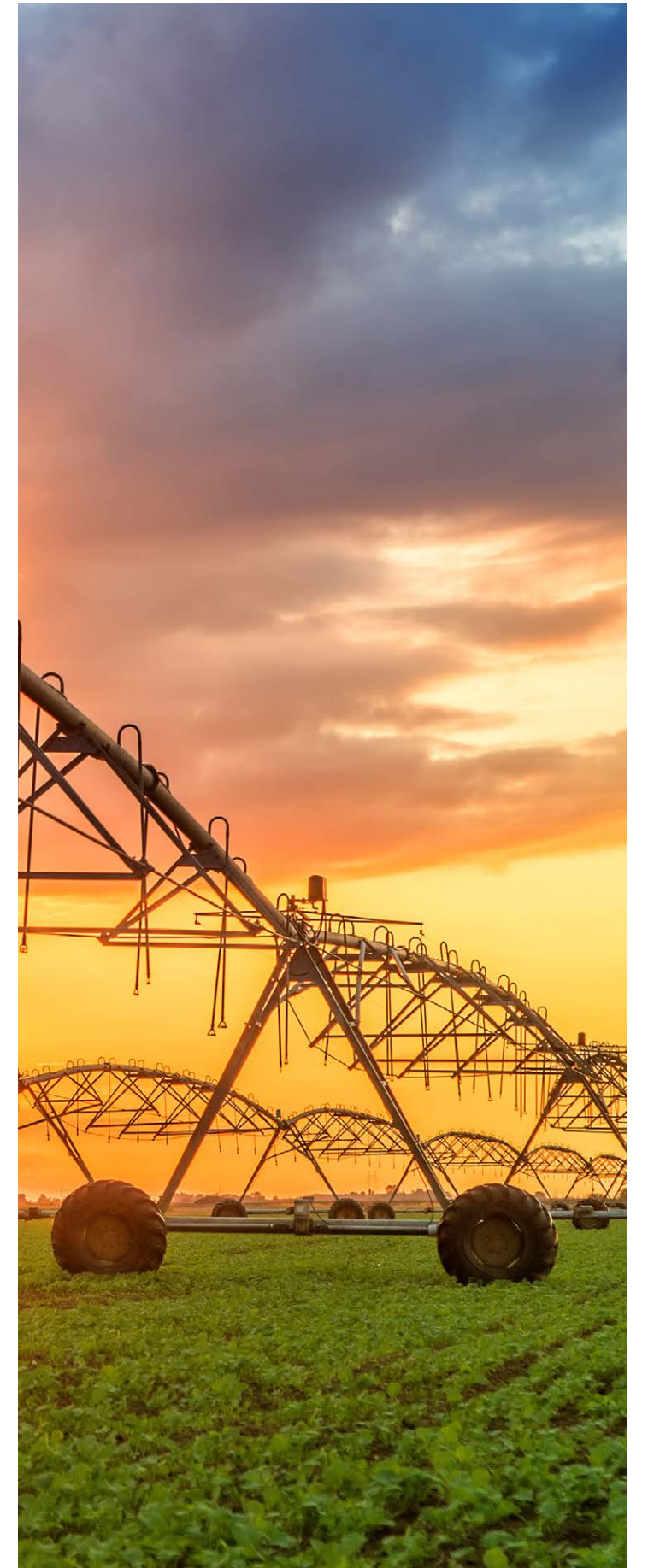
7.2.4 FURTHER OPPORTUNITIES

- As a DAF is used as a physicochemical stage in water treatment, controlling the dosage of coagulant and flocculant and selecting the right chemical products is vital to ensure the correct settleability of suspended solids. The facility could assess the possibility of using alternative organic or less dangerous products to prevent pollution.
- In the aerobic reactor, controlling the airflow rate, sludge recirculation, and sludge purge flow is essential for optimal operating conditions. The reuse of biogas generated for cogeneration could reduce GHG emissions.
- Minimize wet transport in the facility by using mechanical transportation.
- Install water recirculation units with filters, especially for processing wash water.
- Install high-pressure and low-volume hoses for equipment cleaning.

7.3 CASE 2: POULTRY PROCESSING COMPANY

7.3.1 PROCESS DESCRIPTION

This leading poultry processing company generates wastewater from live chicken reception, slaughtering, evisceration, disinfection/cooling, packaging, and storage. Additionally, it has a flour plant that processes different residues generated by poultry processing, such as blood, feathers, non-conforming products, and non-edible viscera for animal feed production. The company's monthly water consumption is around 70,000 m³, and it recirculates water for cleaning the live chicken reception area. The WWTP can handle a maximum of 3,000 m³/day.



7.3.2 BEST WASTEWATER MANAGEMENT PRACTICES

POLLUTION PREVENTION BWMPs IN PLACE

- The facility has water recirculation to reuse it in cleaning activities.
- The by-products and solid wastes are adequately separated from the water current before entering the WWTP.
- The facility has dedicated personnel to oversee the plant and has hired a laboratory analyst to improve plant operations monitoring.
- New equipment improvements over time, including installing a DAF tank and changing the plate filter to a belt filter.

WASTEWATER TREATMENT BWMP IN PLACE

- Equalization tank with a mixer receives wastewater from the facility.
- A preliminary treatment conformed by a coarse screen eliminates large solids, and a grease trap separates floating FOGs, which is manually cleaned.
- A primary system, specifically a DAF tank, receives the water and eliminates suspended solids.
- A secondary system of three aerated lagoons with varying capacities helps to reduce organic loads.
- A tertiary treatment made up of disinfection with chlorine helps the effluent meet international standards before it is discharged.
- Sludge is separated and concentrated for disposal.

7.3.3 CRITICAL CONTROLS AND MONITORING

- The correct operation of the treatment plant depends on a high frequency of cleaning the screens and the FOGs in the grease trap to eliminate these pollutants before the biological treatment in the lagoons.
- Daily monitoring of the DO concentration in the aerated lagoons is necessary to ensure correct oxygen levels and avoid consuming electricity in vain.
- Daily monitoring of pH and temperature adequately prevents undesirable values affecting microorganisms involved in the secondary treatment process.

- Controlling the dosage of coagulant and flocculant and the right selection of chemical products is vital to ensure a correct settleability of suspended solids in the DAF equipment.

7.3.4 FURTHER OPPORTUNITIES

- The performance of the biological treatments is strongly affected by the frequent and large disturbances in the influent flow. Controlling a correct homogenization in the equalizer and the pH value may help obtain optimal operating conditions in the lagoons.
- The facility could assess the selection of alternative organic or less dangerous products as a pollution prevention measure.

7.4 CASE 3: SWINE BREEDING AND PRODUCTION

7.4.1 PROCESS DESCRIPTION

This industrial complex includes two pig breeding farms with a population of 8,000 pigs and a breeding farm with a maximum capacity of approximately 16,000 piglets. Activities related to biosecurity (disinfection of trucks and showers), cleaning, and disinfection of sheds are carried out at the three facilities. Quaternary ammonium is used for cleaning, loosening feces, and washing. Wastewater generated by the cleaning activities is around 900 m³/day. Its composition comprises high organic loads, nutrients, and pathogens. Feces and cleaning water are directed first to storage tanks and then are pumped to the WWTP.

7.4.2 BEST WASTEWATER MANAGEMENT PRACTICES

POLLUTION PREVENTION BWMPs IN PLACE

- Automatic control for different equipment, including pumps, electro valves, mixers, and compressors.
- Dry-cleaning process in the sheds, where solids are collected to manage them separately, which results in less water being used for cleaning afterward.
- Dedicated personnel to perform monthly measurements of water quality parameters for internal control.

WASTEWATER TREATMENT BWMPs IN PLACE

- The first stage comprises a pre-treatment for solids separation, including sedimentation channels and mechanical filtration equipment.
- Primary and secondary treatments are conformed by a biodigester that produces biogas, two anaerobic lagoons, two physicochemical treatments, two decanters, and an aerated nitrification-denitrification tank. There is a chlorination system as a tertiary stage.
- Treated water meets the regulatory quality criteria to irrigate 38 hectares of pasture.

7.4.3 CRITICAL CONTROLS AND MONITORING

- Removal of large solids and grit from wastewater in the pre-treatment units prevents damaging equipment and impacting downstream processes.
- The daily monitoring of DO is necessary to ensure nitrification (the biological oxidation of ammonia to nitrite and then nitrite to nitrate).
- Monitoring the disinfectant dosage and contact time to ensure effective disinfection is critical when reusing wastewater for irrigation.
- Analyzing parameters like soil salinity, permeability, and groundwater levels are adequate to ensure that the effluent is not causing negative effects on soil composition.

7.4.4 FURTHER OPPORTUNITIES

- Controlling the pH value, the water level, and the gas level in the biodigester is vital to ensure the correct operation of the system.
- Having control of the quality of the effluent at least once a week helps to take corrective actions in the short term.

7.5 SUMMARY AND LEARNINGS FROM CASE STUDIES

Hybrid treatment methods with biological and physicochemical treatment processes have been highly efficient in agribusiness wastewater treatment plants. Usually, preliminary, primary, secondary, and tertiary treatments are implemented to ensure the effluent quality meets the criteria for disposal or reuse.

The DAF method has proven effective in treating wastewater of different characteristics generated by activities in the agro-industrial sector. Its bubble technology helps eliminate difficult-to-remove pollutants such as FOGs, organic matter, and fine particles that are problematic in water reclamation processes. Although using physicochemical treatments when the water has high organic loads implies using high volumes of coagulants and polymers as flocculants, which results in high consumption of chemical products and a non-biodegradable sludge as a by-product, using natural coagulants may be an opportunity to evaluate since these compounds tend to be environmentally friendly and could replace conventional dangerous chemicals as a pollution prevention practice.

Reusing the biogas generated in the anaerobic systems to heat the reactors is a way to improve the system's overall efficiency, as COD removal increases and reduces the need for external energy sources, leads to cost savings, and supports the circular economy by turning waste into a resource.

Measuring the key parameters, such as pH, DO, temperature, flows, and TSS of these WWTPs, is crucial for ensuring the systems are operating efficiently and effectively, as these parameters provide critical information on the status of the treatment process and the quality of the effluent. This practice allows operators to identify potential problems before they become significant, such as excessive nutrient levels or toxic compounds in the effluent.

As these wastewaters contain high levels of pollutants, treated water can be reused when using an efficient wastewater treatment system. When the facility uses water to irrigate, monitoring soil salinity, permeability, and groundwater level is a critical control. This monitoring means investing in equipment and personnel to have data and take action if needed.



8

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Annex 1

Wastewater Regulatory references for LAC as of may 2023

TABLE A-1 Description of the sampling points and the analytical requirements for process water and wastewater samples (to be used in conjunction with Figure A-4.1).

Country	Wastewater Norms and Regulations	Institution
Argentina	<p>Decree No. 674/89 - Wastewater Discharge (1989): Establishes a regime to which the industries and special establishments that produce continuously or discontinuously wastewater discharges or mud originated by the treatment of those into the sewer, rain conduits, or at a water course; Reference: https://www.argentina.gob.ar/normativa/nacional/decreto-674-1989-16713/texto.</p> <p>Resolution No. 242/93 - Rules for discharges from industrial or special establishments covered by Decree No. 674/89 that contain dangerous substances of an ecotoxic nature (1993): Establishes the rules that must govern discharges from industrial or special establishments that contain dangerous substances that are ecotoxic in nature; Reference: https://www.argentina.gob.ar/normativa/nacional/resoluci%C3%B3n-242-1993-34562/texto</p> <p>Resolution 79179/1990 Reference: https://www.argentina.gob.ar/normativa/nacional/resoluci%C3%B3n-79179-1990-93051/actualizacion</p>	Ministry of the environment and sustainable development
Belize	S.I. No. 102 Environmental Protection (Effluent Limitations) (Amendment) Regulations (2009): Establishes effluent standards and effluent limitations for industries and commercial activities; Reference: https://faolex.fao.org/docs/pdf/blz129031.pdf	Ministry of Natural Resources and the Environment
Bolivia	Law No. 2066 - Law of Provision of Potable Water and Sanitary Sewerage Services (2000): Establishes the rules that regulate the provision and use of potable water and sanitary sewage services; Reference: https://faolex.fao.org/docs/pdf/bol28709.pdf Supreme Decree No. 24176 - Regulation of the Environmental Law. Regulation on water pollution (1995); Reference: https://faolex.fao.org/docs/pdf/bol179887.pdf	Ministry of Environment and Water
Brazil	<p>Resolution No 503 (2021): Defines criteria and procedures for reuse in effluent fertigation systems from food, beverage, and dairy; Reference: http://conama.mma.gov.br/?option=com_sisconama&task=arquivo.download&id=813</p> <p>Resolution No 430 (2011): Provides for the conditions and rules of release of effluents, complements and alters the resolution in 357 of March 17; Reference: https://www.saude.mg.gov.br/images/documentos/RE%20CONAMA%20403-2011_Lancamento%20de%20Efluentes.pdf</p> <p>Change of resolution Conama 357/05 for the Ocean disposal of Sanitary effluents. Art. 20. O lançamento de efluentes efetuado por meio de emissários submarinos. Reference: http://conama.mma.gov.br/index.php?option=com_sisconama&task=documento.download&id=21963</p>	National Water Agency (ANA) Ministério do Medio Ambiente (CONAMA)
Chile	<p>Decree No. 90 - Emission standard for regulating pollutants associated with liquid waste discharges into marine and continental surface waters (2000): Seeks to prevent the contamination of surface marine and inland waters by controlling contaminants associated with liquid waste that is discharged to these receiving bodies; Reference: https://dga.mop.gob.cl/administracionrecursoshidricos/Documents/DTO_90_07_MAR_2001.pdf</p> <p>Decree No. 609 - Regulation of pollutants associated with the discharge of liquid industrial waste to sewage systems (2004): Establishes emission standard for regulating pollutants associated with the discharge of industrial liquid wastes to sewerage systems; Reference: https://www.bcn.cl/leychile/navegar?idNorma=230064&idVersion=2004-09-08</p> <p>Decree No. 3 - Regulation for the management of sludge from effluent treatment plants of the fruit and vegetable processing industry (2012): Regulates the management of sludge from effluent treatment plants; Reference: https://faolex.fao.org/docs/pdf/chi112978.pdf</p> <p>Decree No. 46/02 Standard for the Emission of Liquid Waste to Groundwater (2003): Determines the maximum concentrations of contaminants allowed to be discharged by the emitting source, through the soil, to the saturated areas of the aquifers, through works designed to infiltrate it; Reference: https://faolex.fao.org/docs/pdf/chi50299.pdf</p>	General Directorate of Water (DGA)

Country	Wastewater Norms and Regulations	Institution
Colombia	<p>Decree No. 3930 - Regulates the uses of water and the discharge of liquid waste (2010): Provisions related to the uses of water resources, the ordering of water resources and discharges into water resources, the soil, and sewers; Reference: https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=40620#:~:text=Fija%20las%20zonas%20en%20las,superficiales%2C%20subterr%C3%A1neas%2C%20o%20marinas</p> <p>Resolution No. 631 - Parameters and maximum permissible limit values in punctual discharges to surface water bodies and public sewage systems (2015): Establishes parameters and maximum permissible limit values of discharges to water bodies and public sewerage systems and dictates other provisions; Reference: https://fenavi.org/wp-content/uploads/2018/05/Resolucion-631-2015.pdf</p> <p>Resolution No. 330 - Technical Regulations for the Drinking Water and Sanitation Sector (2017); Reference: https://minvivienda.gov.co/normativa/resolucion-0330-2017-0</p> <p>Resolution No. 1256 Regulates the use of wastewater and adopts other provisions (2021) by which the use of wastewater is regulated and other measures are adopted. Reference: https://www.minambiente.gov.co/wp-content/uploads/2021/12/Resolucion-1256-de-2021.pdf</p>	Ministry of Environment and Sustainable Development
Costa Rica	<p>Decree No. 33601-S-MINAE - Wastewater Discharge and Reuse Regulations (2006): Aims to protect public health and the environment, through environmentally sound wastewater management; Reference: http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?nValor1=1&nValor2=59524</p> <p>Decree No. 42128 - Regulation of the Environmental Canon for Water Discharges (2019): Regulates the fee for the usage of water resources for discharging polluting substances that will be called Environmental Canon for Discharges; Reference: http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?param1=NRTC&nValor1=1&nValor2=90961&nValor3=120004&strTipM=TC</p>	Ministry of Environment and Water
Dominican Republic	<p>Environmental regulation on control of discharges to surface waters, sanitary sewerage, and coastal waters (2012); Reference: https://ambiente.gob.do/files/Norma-Ambiental-sobre-Control-de-Descargas-a-Aguas-Superficiales-alcantarillado-sanitario-y-aguas-costeras.pdf</p> <p>Environmental regulation on the quality of surface and coastal waters (2012); Reference: https://ambiente.gob.do/files/Norma-Ambiental-de-Calidad-de-Aguas-Superficiales-y-Zonas-Costeras.pdf</p>	Ministerio de Medio Ambiente y Recursos Naturales
Ecuador	<p>Unified text of Secondary Legislation of Environment - Executive Decree N° 3516: Establishes the basic environmental policies of Ecuador; Annex 1. of the VI Book of the unified text of the secondary legislation of the Ministry of the Environment: Environmental quality and effluent discharge to water resources Norm (2015): Establishes general rules for discharge of effluents to the sewage system and includes maximum limits, also regulates water quality criteria for agricultural or irrigation use. Reference: https://www.gob.ec/sites/default/files/regulaciones/2018-09/Documento_Registro-Oficial-No-387-04-noviembre-2015_0.pdf</p> <p>Ministerial Agreement No. 097/A: Annex I. Environmental quality standard and effluent discharge: Establishes the basic principles and general approach to water pollution control Reference: http://www.quitoambiente.gob.ec/images/Secretaria_Ambiente/Documentos/calidad_ambiental/normativas/acuerdo_ministerial_97a.pdf</p>	Ministry of Environment
El Salvador	<p>Agreement No. 249 - NSO 13.49.01:09 on characteristics of wastewater discharged to a receiving body (2009): Establishes the permissible physical-chemical, microbiological, and radioactive characteristics and values that wastewater must present to protect and rescue the receiving bodies; Reference: https://faolex.fao.org/docs/pdf/els87596.pdf</p> <p>Decree No. 39 - Special wastewater regulation (2019): Its purpose is to ensure that wastewater does not alter the quality of the receiving media to contribute to the recovery, protection, and sustainable use of water resources concerning the effects of pollution; Reference: https://cidoc.marn.gob.sv/documentos/reglamento-especial-de-aguas-residuales-decreto-n-39/</p> <p>RTS 13.05.01:18 Wastewater, wastewater quality parameters for discharge and management of sewage sludge (2020): Establishes permissible limits for wastewater quality parameters and their sludge; Reference: https://members.wto.org/crnattachments/2018/SPS/SLV/18_6511_00_s.pdf</p>	Ministry of Environment and Natural Resources
Guatemala	<p>Governmental Agreement No. 236/06 (2006) - Regulation of the Discharges and Reuse of Residual Waters and the disposal of sludge: Authorizes and defines the limits of water reuse for agricultural irrigation, irrigation of edible crops, irrigation of aquaculture, pastures, and other crops, and recreational reuse; Reference: https://www.anacafe.org/uploads/file/04e16f-7fbff3466584ed340e5be0d362/Acuerdo-Gubernativo-236-2006.pdf</p> <p>Ministerial Agreement No. 105-2008 - General Manual for the Regulation of the discharge and reuse of wastewater and sludge disposal (2008): Its purpose is the implementation of the Regulation established by Agreement No. 236/06; Reference: https://www.vestex.com.gt/uploads/medioambiente/regulaciones/Manual-General-del-RARL.pdf</p> <p>Governmental Agreement No. 51 (2010) - Regulation of wastewater discharge in the Lake Atitlán basin and its surroundings: Sets the parameters and maximum limits permissible for the discharge of wastewater to water bodies of the Lake Atitlán basin, either directly or indirectly to rescue, protect and prevent the hydric system contamination; Reference: https://www.anacafe.org/uploads/file/e35acc5284e344748928ad5d283e6a67/Acuerdo-Gubernativo_12-2011.pdf</p>	Ministry of Environment and Natural Resources
Honduras	<p>Agreement No. 58-96 - Technical standards for wastewater discharges to receiving bodies and sanitary sewers (1997): Regulates wastewater discharges to water bodies and sanitary sewers; Reference: https://faolex.fao.org/docs/pdf/hon175670.pdf</p> <p>Agreement No. 467-2017 - Transitory Technical Standard to reuse wastewater generated by the sugar agroindustry for irrigation in sugarcane crops (2017): Establishes the maximum permissible limit values of pollutants for wastewater generated in sugarcane industrialization processes that are reused in irrigation of sugarcane cultivated areas; Reference: https://faolex.fao.org/docs/pdf/hon176145.pdf</p> <p>Decree No. 003-2020 - National regulation of discharge and reuse of wastewater (2020): Regulates every entity that operates in the national territory that carries out activities that generate discharges of wastewater and sludge from wastewater treatment systems; Reference: https://www.tsc.gob.hn/web/leyes/Acuerdo_Ejecutivo-003-2020.pdf</p>	Secretariat of Natural Resources and Environment (SERNA)

Country	Wastewater Norms and Regulations	Institution
Jamaica	Regulations 2013 (S.I. No. 69A of 2013): Provides the framework for the operation of treatment facilities, their monitoring and the reporting mechanisms required, as well as issues related to compliance and a discharge fee system; Reference: https://www.nepa.gov.jm/sites/default/files/2021-12/Wastewater-and-Sludge-Regulations-2013.pdf	Ministry of Water, Land, Environment and Climate Change
Mexico	Rules for the Potable Water, Sewage and Sanitation and Wastewater Treatment Programs under the National Water Commission (2016). Reference: https://dof.gob.mx/nota_detalle.php?codigo=5421649&fecha=29/12/2015#gsc.tab=0 Official Mexican Norm NOM-002-ECOL-1996: Establishes maximum permissible limits on pollutants in wastewater discharged into urban or municipal sewer systems (1998); Reference: https://dof.gob.mx/nota_detalle.php?codigo=4881304&fecha=03/06/1998#:~:text=NORMA%20Oficial%20Mexicana%20NOM%20D002,que%20dice%3A%20Estados%20Unidos%20Mexicanos. Official Mexican Norm NOM-003-ECOL-1997: Establishes the maximum permissible limits of contaminants for treated wastewater reused in public utilities to protect the environment and the population's health; Reference: https://www.gob.mx/cms/uploads/attachment/file/311363/NOM_003_SEMARNAT.pdf Official Mexican Norm NOM-001-SEMARNAT-2021 (2021): Establishes the permissible limits for effluents which are based on the nature of the receiving body where it is discharged: rivers, streams, canals, and drains; reservoirs, lakes and lagoons, marine zones, and floors; Reference: https://www.dof.gob.mx/nota_detalle_popup.php?codigo=5645374	National Water Commission (CONAGUA)
Nicaragua	Decree No 21-2017 - Regulation that establishes the provisions for wastewater discharge (2017): Regulates and establishes maximum limits for water quality to discharge to sewage systems and water bodies, depending on the activity that produces the wastes; Reference: http://www.inaa.gob.ni/sites/default/files/inline-files/Decreto%2021-2017.pdf Technical standard No. NTON 05 031-07 - Technical standard for reusing the wastewater effluents from the sugar industry and alcohol distilleries to irrigate sugar cane plantations (2007); Reference: http://legislacion.asamblea.gob.ni/normaweb.nsf/(\$All)/B648272FD35AB76D062577A6005C6332?OpenDocument Technical standard No. NTON 05 028-06 - Environmental technical standard for protecting water bodies affected by liquid and solid spills from wet processed coffee wet mills (2006); Reference: http://legislacion.asamblea.gob.ni/normaweb.nsf/9e314815a08d4a6206257265005d21f9/363673e06aa24f4b0625757e0061d6d2?OpenDocument Nicaraguan Mandatory Technical Standard on the design of precision lagoons and aerated lagoons (1999): Establishes the criteria and the technical basis for the design of stabilization ponds and aerated ponds for treating wastewater of municipal origin; Reference: https://faolex.fao.org/docs/pdf/nic23128.pdf	National Water Authority (ANA) The Ministry of the Environment and Natural Resources (MARENA) Ministry of Development, Industry and Commerce
Panama	Resolution No. 49 - Technical Regulation DGNTI-COPANIT 24-99 Reuse of Treated Wastewater (2000): Establishes the maximum microbiological, physical, and chemical limits requirements and the treatment processes to be used in water for animal consumption, irrigation, recreation and aesthetics, aquatic life and aquaculture, urban use, aquifer recharge, habitat restoration, and industrial and mining use; Reference: https://www.asep.gob.pa/wp-content/uploads/agua/legislacion/dgnti_24-99.pdf Resolution No. 350 - Technical Regulation DGNTI-COPANIT 39-2000 on the discharge of liquid effluents directly to wastewater collection systems (2000): Approves the technical regulation that establishes the characteristics that liquid effluent discharges from domestic, commercial, and industrial activities must meet directly into wastewater collection systems; Reference: https://www.asep.gob.pa/wp-content/uploads/agua/legislacion/dgnti_39-2000.pdf Resolution No. 351 - Technical Regulation DGNTI-COPANIT 35-2000-Discharge of liquid effluents directly to water bodies and surface and groundwater masses (2000): Establishes the characteristics that effluents must comply to discharge them to collection sewage systems, generated from domestic, commercial and industrial activities; Reference: https://www.asep.gob.pa/wp-content/uploads/agua/legislacion/dgnti_35-2000.pdf its modifications made in Resolution No. 10, Resolution No. 193, Resolution No. 332 and Resolution No. 276. Resolution No. 352 - Technical Regulation DGNTI-COPANIT 47-2000-Use and Final Disposal of Sludge (2000): Establishes maximum permissible limits, the requirements for treatment methods, and the confinement, sampling, and type of analysis for sludges; Reference: https://www.asep.gob.pa/wp-content/uploads/agua/legislacion/dgnti_47-2000.pdf	Ministry of Commerce and Industries
Paraguay	Law No. 5428 - Of sewage effluents (2015): Regulates the treatment, purification, discharge, control, and supervision of sewage effluents before the final discharge to receiving bodies; Reference: https://www.bacn.gov.py/leyes-paraguayas/8189/ley-n-5428-de-efluentes-cloacales Resolution No. 770/14 - Standards and Procedures for Management Systems and Treatment of Industrial Liquid Effluents of Compulsory Compliance for Industrial Complexes (2014): Rules that govern the operation of industrial liquid effluent management and treatment systems, compliance with which is mandatory for the industry. Reference: http://www.mades.gov.py/wp-content/uploads/2019/05/Resoluci%C3%B3n-N%C2%BA-770_14-Efluentes-Liquidos-Industriales.pdf	Secretariat of the Environment Sanitary Services Regulatory Entity (ERSSAN)
Perú	Supreme Decree No. 001-2010-AG (2010): Regulates wastewater reuse. Reference: https://www.midagri.gob.pe/portal/download/pdf/marcolegal/normaslegales/decretosupremos/2010/ds01-2010-ag.pdf Resolution No. 274-2010-ANA □ Measures for the implementation of the Wastewater Discharge Adaptation and Reuse Program (2010): Establishes the measures for the implementation of the Program for the Adequacy of Discharges and Reuse of Residual Water (PAVER), whose purpose is the adaptation to the provisions of the Water Resources Law of the discharges and reuse of wastewater; Reference: https://faolex.fao.org/docs/pdf/per94255.pdf Supreme Decree No. 005-2011-AG (2011): Regulates the reuse of wastewater treated by a person other than the owner of the treatment system to protect and preserve the quality of natural water sources; Reference: https://www.midagri.gob.pe/portal/download/pdf/marcolegal/normaslegales/decretosupremos/2011/ds05-2011-ag.pdf No. 004-2017-MINAM (2017): Regulates the environmental quality standards for water; Reference: https://www.minam.gob.pe/wp-content/uploads/2017/06/DS-004-2017-MINAM.pdf	National Water Authority (ANA) Ministry of the Environment Ministry of Agrarian Development and Irrigation
Trinidad and Tobago	ENVIRONMENTAL MANAGEMENT ACT, CHAPTER 35:05 - THE WATER POLLUTION RULES (2019): These Rules set out application procedures and principles for a permit to release water pollutants within the permissible levels and the evaluation of the application request by the Authority; Reference: https://faolex.fao.org/docs/pdf/tri209647.pdf	Minister of the Planning and Development
Uruguay	Decree No. 253/979 - Regulations to prevent environmental pollution through water control (1979): Standards to prevent environmental pollution by controlling water pollution. Reference: https://www.impo.com.uy/bases/decretos/253-1979	National Directorate of Water (DINAGUA)
Venezuela	Decree No. 883 - Dictates the Standards for the classification and quality control of water bodies and liquid discharges or effluents (1995): Establishes the norms for the quality of the water bodies and liquid discharges. Reference: https://faolex.fao.org/docs/pdf/ven174040.pdf Resolution No. 31 - Standards on liquid effluents (1985): Dictates two different groups of quality standards to which effluents from a determined number of well-identified sources must comply if they are discharged a) into bodies of water or b) into sewage networks. Reference: https://faolex.fao.org/docs/pdf/ven3797.pdf	Ministry of Popular Power for the Environment

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Annex 2 Regulatory context of three key countries

Mexico, Brazil, and Honduras are three Latin American countries that have made significant progress in wastewater regulations in recent decades. A general overview of each country's progress in this area is provided in the following section.

A. Mexico

The wastewater regulatory framework derives from Mexico's water-related legislation and environmental law. The National Waters Act of 1992, which was last amended in 2020, is the primary legislation regulating the use and disposal of wastewater. This law effectively governs the prevention and control of water pollution. The National Water Commission (CONAGUA) is responsible for enforcing regulations related to wastewater discharge and regulating, controlling, protecting, and sustainably using Mexico's waters. The National Program for the Integral Management of Water Resources includes measures to improve wastewater treatment and reuse. The Institutional Framework for Water Management comprises various federal, state, and local government agencies. In 2012, the Mexican Constitution was amended to include the fundamental right to wastewater regulation.

Mexico has established and maintained an extensive and detailed wastewater monitoring program. In addition to generating data and reporting on annual progress, the Mexican authorities have used this data to inform sector strategy, investment, targeting, and planning. Consequently, significant and consistent progress has been made in increasing sewerage and safely treated wastewater coverage (Alabaster et al., 2021).

Recently, the NOM-001-SEMARNAT was reformed

to broaden its concepts and scope. The new federal norm, published in March 2023, updates various aspects, including specifications, test methods, sampling, temperature parameters, toxicity measurement, conformity assessment procedure, classification of receiving bodies, and subsequent use approach. The update aims to improve the management and protection of water bodies and ensure compliance with the law that establishes that everyone has the right to access, dispose of, and sanitize water for personal and domestic consumption in a sufficient, healthy, acceptable, and affordable manner (SEMARNAT, 2022). The permissible limits for BOD, settleable solids, and fecal coliforms are now established according to the nature of the receiving body. This norm also includes regulations for wastewater disposal in coastal waters and soil disposal, including infiltration and reuse for irrigation.

B. Brazil

Brazil has established comprehensive legislation on environmental information, water and waste management, and biodiversity. The National Water Agency (ANA, in its Portuguese acronym), responsible for enforcing wastewater management regulations, oversees several laws and regulations governing wastewater management. These laws include the National Water Resources Policy Law, National Sanitation Policy, National Water Resources Policy, and National Environmental Policy, which delineate responsibilities for water policy-making at all levels of government and establish mechanisms for coordination and public engagement (OECD, 2021). The Institutional Framework for water management comprises various federal, state, and local government agencies.

A notable development in the past decade was the

revision of the National Sanitation Law in 2007, which provided guidelines for municipal sanitation plans and required municipalities to provide essential sanitation services, including wastewater treatment. In addition, Brazil adopted the Sustainable Development Goals in 2015 to provide universal access to safe and affordable drinking water and sanitation by 2030. To achieve this goal, Brazil has implemented several programs and initiatives to enhance access to sanitation, including the "Sanitation for All" program. In 2017, Brazil established the National Water Resources Management System, which promotes integrated water resources management and provides a framework for allocating and using water resources, including wastewater (OECD, 2021).

While Brazil has established maximum discharge parameters for wastewater in Resolution No. 430 of 2011, exceptions may be made following progressive goals and risk analysis of the receiving body, including studying its capacity and concentrations of unobserved effects. Reusing wastewater for irrigation is regulated by Resolution No. 503 of 2021, which requires compliance with parameter measurements and studies before irrigation, such as soil infiltration capacity and SAR studies.

Brazil has also strengthened its solid waste regulations, including enacting the Solid Waste Policy in 2010, which requires the environmentally sound management of solid waste, including wastewater sludge. For several years, the Companhia de Saneamento Ambiental do Distrito Federal (CAESB, in its Portuguese acronym), the water and wastewater utility of Brazil's capital district, has been reusing biosolids from its wastewater treatment plant operations to recover degraded areas in its railway operation areas and agriculture (World Bank Group, 2019, p. 019).

C. Honduras

Honduras has undergone significant changes in its wastewater management over the past two decades. The country has implemented new laws, regulations, and policies to address the issue of wastewater management more effectively. In 2003, Honduras adopted the Water and Sanitation Sector law, which

served as the basis of the sector's modernization process. This law readjusted the sector's legal and institutional framework by separating the main functions (regulations, planning, and technical assistance) from service provision. It also established the National Water and Sanitation Council (CONASA in its Spanish acronym) and the Regulatory Entity for Drinking Water and Sanitation Services (ERSAPS in its Spanish acronym). This law was part of a state decentralization process as it granted ownership of services to the municipalities instead of the central government continuing as a service provider through ANASA (Mairena et al., 2011).

In 2010, the Republic of Honduras implemented a comprehensive water law to safeguard its water resources and ensure their long-term sustainability. This legislation laid the foundation for an integrated framework for water resources management, including provisions for wastewater management. Subsequently, in 2016, the Honduran government formulated the National Wastewater Policy to enhance wastewater management nationwide. Moreover, Honduras has undertaken significant institutional strengthening efforts to bolster its capacity for wastewater management. Most recently, in 2020, the National Regulation for Discharge and Reuse of Wastewater was approved to regulate entities engaged in activities that generate wastewater and sludge from wastewater treatment systems.

In 2021, a legislative agreement was reached in which the process can be carried out in stages, with implementation deadlines for preventive measures. Three methods were established to set discharge limits: through a risk approach according to the quality of the water being discharged, according to the best available technology, and the percentage of removal achieved. Furthermore, the same agreement clarifies that the competent authority will have the final say regarding the required quality for wastewater reuse. These measures demonstrate the Honduran government's commitment to strengthening its institutional capacity to sustain its water resources while minimizing the environmental impact of its economic activities.

A **Annex 3**

More information for developing a discharge risk assessment procedure

TABLE A-3.1 Key Wastewater Quality Criteria for an Irrigation Risk Assessment and Rationale of Use

Key criteria	Compliance Condition	Reference	Rationale
Wastewater quality			
Effluent pH	6.5-8.4	(EPA, 2012)	pH affects the availability of nutrients and reduces soil structure problems.
Removal of FOGs	< 5 mg/L	N.A.	Prevent soil clogging and damage to vegetation.
Removal of gross solids	None	(EPA, 2012)	Prevent soil clogging. A 5mm mesh is standard.
Heavy metal concentrations	Chloride, < 30 mg/L Ammonia, < 30 mg/L as N Aluminium, < 5 mg/l Arsenic, < 0.1 mg/l Beryllium, < 0.1 mg/l Boron, < 0.5 mg/l Cadmium, < 0.01 mg/l Chromium, < 0.1 mg/l Cobalt, < 0.05mg/l Copper, < 0.2 mg/l Fluoride, < 1 mg/l Iron, < 5 mg/l Lead, <5 mg/l Lithium, < 2.5 mg/l Manganese, < 0.4 mg/l Molybdenum, < 0.01 mg/l Nickel, < 0.2 mg/l Selenium, < 0.02 mg/l Vanadium, < 0.01 mg/l Zinc, < 4 mg/l	(EPA, 2012; UNEP, 2005)	Avoid irreversibly contaminating the irrigation site in the long term.
Electrical Conductivity and Salinity Adsorption Ratio	It depends on soil type and other site characteristics that must be assessed individually. As a reference, according to EPA, a max EC to avoid the reduction in infiltration is 3,0 Deci siemens per meter (dS/m), coupled with a max SAR of between 20-30.	(EPA, 2012)	Prevent soil permeability loss.
BOD Loading	It depends on soil type and other site characteristics and needs to be assessed through contaminant transport modeling for site-specific.	N.A.	Prevent soil clogging--an indication of biological treatment effectiveness and indirect potential for bacterial regrowth in distribution systems.

TABLE A- 3.2 Guidelines for Interpretation of Wastewater Quality for Irrigation (UNEP, 2005)

Potential irri	Units	Degree of restriction on use		
		None	Slight to moderate	Severe
Salinity				
Ecw	dS/m	< 0.7	0.7 - 3.0	> 3.0
or				
TDS	mg/L	< 450	450 - 2000	> 2000
Infiltration				
SAR = 0 - 3 and EC	dS/m	> 0.7	0.7 - 0.2	> 0.2
3 - 6		> 1.2	1.2 - 0.3	> 0.3
6-12		> 1.9	1.9 - 0.5	> 0.5
12-20		> 2.9	2.9 - 1.3	> 1.3
20-40		> 5.0	5.0 - 2.9	> 2.9
Specific ion toxicity				
Sodium (Na)				
Surface irrigation	SAR	< 3	3 - 9	> 9
Sprinkler irrigation	me/l	< 3	> 3	
Chloride (Cl)				
Surface irrigation	me/l	< 4	4 - 10	> 10
Sprinkler irrigation	me/l	< 3	> 3	
Boron (B)	mg/L	< 0.7	0.7 - 3.0	> 3.0
Miscellaneous effects				
Nitrogen (NO ₃ -N) ⁵	mg/L	< 5	5 - 30	> 30
Bicarbonate (HCO ₃)	me/l	< 1.5	1.5 - 8.5	> 8.5

TABLE A-3.3 Recommended Microbiological Quality Guidelines for Wastewater Use in Agriculture (WHO, 1989)

Category	Reuse condition	Exposed group	Intestinal nematodes (arithmetic mean no. of eggs per liter)	Fecal coliforms (geometric mean no. per 100 mL)	Wastewater treatment is expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, public	≤ 1	≤ 1000	A series of stabilization ponds designed to achieve the microbiological quality indicated or equivalent treatment.
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture, and trees	Workers	≤ 1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and fecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

A

Annex 4

Guidelines to consider when hiring risk assessment consultations or subject matters experts

When hiring a third-party consultant or subject matter expert to conduct the risk assessment of wastewater discharges, there are several important considerations to remember. A comprehensive and well-executed risk assessment is crucial to identify potential hazards, assess their significance, and develop effective risk management strategies. Some general considerations to ensure a successful risk assessment are enlisted below:

EXPERTISE AND QUALIFICATIONS

Ensure the consulting team has the relevant expertise and qualifications in environmental engineering, wastewater management, toxicology, hydrogeology, and risk assessment methodologies. Only one trained individual may be needed to conduct the risk assessment for relatively narrowly scoped and well-defined risk assessments. Conversely, a risk assessment team is required for more complex risk assessments since one individual can rarely provide the scope or expertise needed (EPA Victoria, 2009). The consulting team must comprise at minimum one proficient expert with a background in overseeing risk assessment procedures. In addition, the team may benefit from including specialists possessing expertise, such as hydrogeologists, hydrologists, geologists, and biologists, whose expertise can contribute to a well-rounded assessment. The consulting team should showcase expertise in cleaner production and pollution mitigation within agro-industrial processes, specifically focusing on wastewater management, wastewater treatment technologies, and sludge disposal. Proficiency in World Bank policies and performance standards would be advantageous, as would the ability to employ modeling for projecting exposure scenarios. Moreover, a strong history of successful involvement in analogous projects would further enhance the team's qualifications.

DATA COLLECTION AND ANALYSIS

The risk assessors' team should have a robust plan for data collection and be able to analyze the data effectively to identify potential risks. When conducting a risk assessment for wastewater releases into waterways, it is necessary to collect and combine all the data and information available about how the water is used and valued and what things could harm it due to wastewater. It could involve data from monitoring, details from models, research conducted earlier, reviews of existing literature, any past incidents of pollution, and local plans and strategies. When performing a risk assessment for using treated wastewater in irrigation or infiltration, the team needs to gather and integrate all the available information and data to determine if the chosen land for irrigation can handle the wastewater, including collecting data from groundwater models, findings from previous research, reviews of existing literature, and even conducting on-site examinations to understand the state of the groundwater and the soil layers in that specific location. These on-site assessments might involve analyzing the soil profile, performing infiltration tests, and installing monitoring wells. The team should be capable of identifying potential hazards associated with wastewater discharges, including chemical pollutants, biological contaminants, and physical impacts on the ecosystems. This information should provide a sound basis for identifying and defining potential risks.

STAKEHOLDER ENGAGEMENT

An effective risk assessment should encompass the participation and active involvement of various stakeholders, including but not limited to local communities, regulatory bodies, managers of natural resources, non-governmental organizations (NGOs), and representatives from the agro-industrial sectors. The consulting team should have a planned approach and an ongoing dialogue with stakeholders to collaborate and consider their concerns (EPA Victoria, 2009).

REGULATORY COMPLIANCE

The consulting team should be well-versed in local and national environmental regulations and regulations on how wastewater can be discharged in the area where the assessment is taking place. Knowing these regulations will ensure that the assessment complies with the local requirements.

COMMUNICATION AND MITIGATION STRATEGIES

Effective communication is crucial for the consulting team, as it is essential to clearly and comprehensibly communicate the assessment findings to pertinent stakeholders. Also, the team should be able to communicate complex scientific information to non-experts. The consulting team must also propose realistic and achievable strategies for managing and reducing risks based on the assessment outcomes. The primary goal of these strategies should be the efficient reduction or elimination of the risks that have been identified.

A **Annex 5** Discharge Risk Assessment Application

MEAT PROCESSING PLANT, CASE STUDY: EFFECT OF A MEAT PROCESSING PLANT DISCHARGE ON THE PHYSICAL AND CHEMICAL COASTAL WATER (STUDY CONDUCTED BY CAMPOS ET AL., 2022)

A discharge pathway risk assessment was conducted to determine the impact of the wastewater discharge of a meat processing plant on coastal water quality. The assessment included a review of the water quality of the discharge and a sampled area of the consented 1,500 m DMZ, which is the designated mixing zone. The parameters reviewed included pH, salinity, color, concentration of fecal coliforms, TSS, TP, TN, and DO.

The study did not reveal any consistent

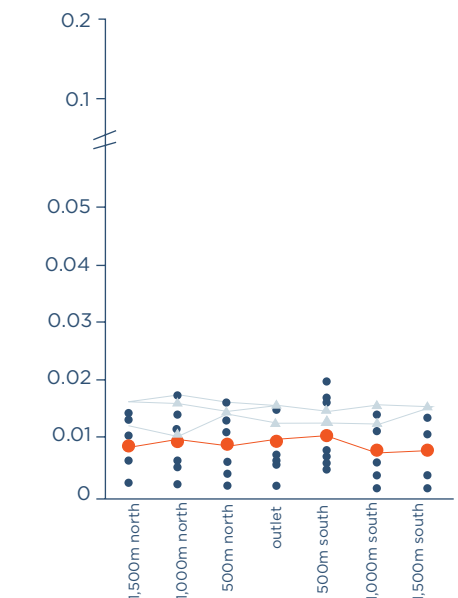
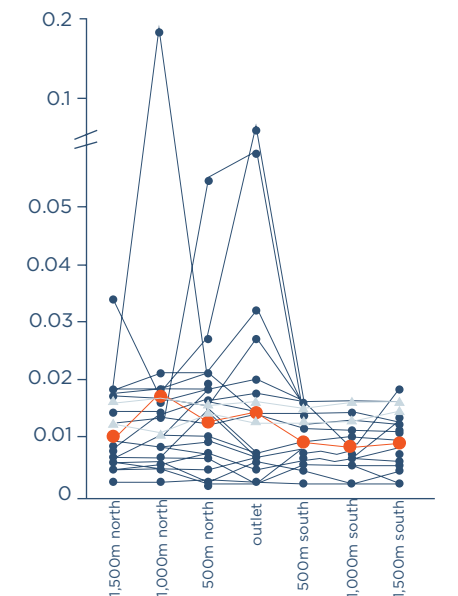
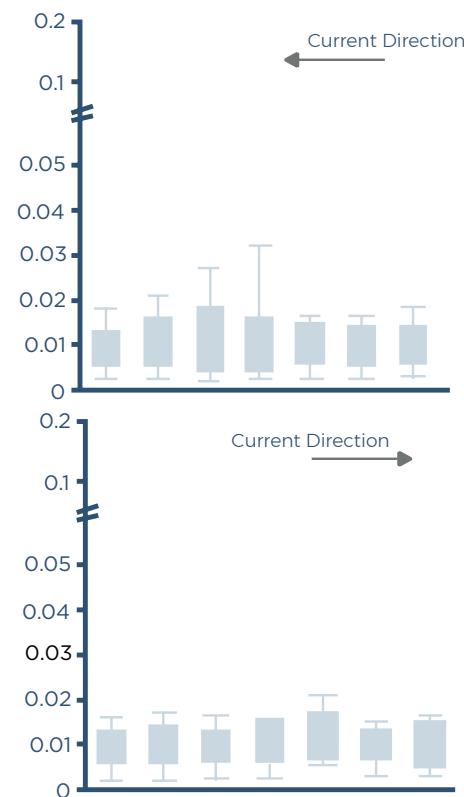
detectable impact of the discharge on surface water quality, except for minor effects on water temperature within the DMZ. The temperature variation between the edge of the mixing zone and the ambient water temperature at the boundaries of the DMZ was within one °C. It did not exceed two °C on any sampling.

To assess potential biological activity resulting from the discharge, nutrient markers (dissolved reactive phosphorus, ammoniacal-nitrogen, and total Kjeldahl nitrogen) were reviewed at the sampled area within the DMZ. The observed nutrient peaks did not significantly impact measured biological activity, such as chlorophylla. However, changes in biological activity would not be immediately noticeable near the outfall site due to the time lag between exposure to increased nutrient concentrations and phytoplankton growth and reproduction. Bacterial contamination was high and extended beyond the 1,500 m limit of the DMZ. Concentrations of fecal coliforms and enterococci were consistently higher down-current of the outfall and even higher at the down-current boundary of the mixing zone than at the up-current boundary, suggesting that the impact of the outfall on these variables extends beyond the DMZ.

A visual study of the plume was also carried out, which showed that the plume's visual effects were frequently visible in satellite and aerial images and observed to extend beyond the mixing zone on multiple occasions. Although the processing plant's monitoring of Hazen color did not detect any visual effects, a plume was still visible in satellite and aerial images in at least 40% of the analyzed images. The

visible plume was highly variable and, in 3 of the 33 analyzed images, extended beyond the edge of the mixing zone. The images suggest that near-shore monitoring may not be effectively represent optical water quality within the discharge plume.

FIGURE A-4.1 Seawater-dissolved reactive phosphorus (DRP) concentrations within the mixing zone of the meat processing plant discharge under north-flowing (left) and south-flowing (right) current flows. Box and whisker plots (top) indicate median values and upper and lower quartiles (grey box). Whiskers were set with a factor value of 1.5 (Campos et al., 2022)



● nearshore single surveys ● nearshore mean ▲ offshore

FIGURE A-4.2 Landsat 8 satellite image (captured USA time: 19 February 2015) shows a diffuse plume extending to the south, slightly beyond the mixing zone boundary.



A

Glossary and Key Terms

Abatement: Reducing the degree or intensity of, or eliminating, pollution.

Aeration: The, usually mechanical, addition of air or oxygen to water or wastewater to increase dissolved oxygen levels and maintain aerobic conditions.

Aerobic treatment: Process by which microbes decompose complex organic compounds in the presence of oxygen and use the liberated energy for reproduction and growth

Aerobic: Condition characterized by the presence of free oxygen.

Anaerobic digestion: Sludge stabilization process where the organic material in biological sludges is converted to methane and carbon dioxide in an airtight reactor.

Anaerobic: Condition characterized by the absence of free oxygen.

Aquaculture: The managed fish or shellfish production in a pond or lagoon aquifer. A subsurface geological formation containing a large quantity of water.

Average daily flow (ADF): The total flow past a point over a period divided by the number of days in that period.

Average flow: The arithmetic average of flows measured at a given point.

Base: (1) A substance that can accept a proton. (2) A substance that can react with an acid to form a salt. (3) An alkaline substance.

Baseline: A sample used as a comparative reference point when conducting further tests or calculations.

Best wastewater management practice (BWMP): The schedules of activities, methods, measures, and other accepted industry management practices to prevent pollution of waters and facilitate compliance with applicable regulations.

Biochemical oxygen demand (BOD): A standard measure of wastewater strength that quantifies the oxygen consumed in a stated period, usually five days and at 20°C.

Biogas: The gases produced by the anaerobic decomposition of organic matter.

Biological filter: A bed of sand, stone, or other media through which wastewater flows depending on biological action for its effectiveness.

Biological process: The metabolic activities of bacteria and other microorganisms break down complex organic materials into simple, more stable substances.

Biological treatment: A treatment technology that uses bacteria to consume organic waste.

Bio trickling filter: Odor treatment system where air is scrubbed with recirculating liquid flowing over high-porosity packing materials covered with a thin film of sulfur-oxidizing microbes.

BOD5: Five-day carbonaceous or nitrification-inhibited BOD.

Chemical oxygen demand (COD): A measurement of biodegradable and nonbiodegradable (refractory)

organic matter, widely used to measure the strength of domestic and industrial wastewater.

Clarifier: A quiescent tank used to remove suspended solids by gravity settling. They are also called sedimentation or settling basins. They usually have a motor driven chain and flight or rake mechanism to collect settled sludge and move it to a final removal point.

Clean-in-place (CIP): A method of cleaning a filter medium or membrane to restore its performance without removing it from the system.

Coagulant: A chemical added to initially destabilize, aggregate, and bind together colloids and emulsions to improve settleability, filterability, or drainability.

Coagulation: The destabilization and initial aggregation of finely divided suspended solids by adding a polyelectrolyte or a biological process.

Coliform bacteria: A group of rod-shaped bacteria living in the intestines of humans and other warm-blooded animals and shed in their fecal material, and whose presence in water indicates that the water has received contamination of an intestinal origin.

Colloid: Suspended solid with a diameter of less than one micron that cannot be removed by sedimentation alone.

Composting: Stabilization process relying on the aerobic decomposition of organic matter in sludge by bacteria and fungi

Contaminant: Any foreign component present in

another substance.

Cooling tower: An open water recirculating device that uses fans or natural draft to draw or force ambient air through the device to cool warm water by direct contact.

Detergent: Synthetic washing agent that helps to remove dirt and oil and may contain compounds that kill useful bacteria and encourage algae growth when present in wastewater that reaches receiving waters.

Direct discharger: A municipal or industrial facility that introduces pollution through a defined conveyance or system such as outlet pipes; a point source

Discharge: The release of any pollutant, by any means, to the environment.

Disposal: The discharge, deposit, injection, dumping, spilling, leaking, or placing of any liquid or solid waste on land or water so that it may enter the environment or be emitted into the air.

Dissolved air flotation (DAF): The clarification of flocculated material by contact with minute bubbles, then causing the air/floc mass to be buoyed to the surface, leaving behind clarified water. Using a gas other than air is called "dissolved gas flotation" or "DGF."

Dissolved oxygen (DO): the oxygen dissolved in a liquid.

Dissolved solids: Solids in a solution that cannot be removed by filtration with a 0.45-micron filter

Effluent: Partially or completely treated water or wastewater from a basin or treatment plant.

Electrocoagulation: A wastewater treatment process with a direct current to precipitate heavy metals with ferrous hydroxides as metal hydroxides.

Escherichia coli (E. coli): Coliform bacteria of fecal origin are used as an indicator organism in determining wastewater pollution.

Eutrophication: Nutrient enrichment of water, causing excessive growth of aquatic plants and eventual deoxygenation of the water body.

Evaporation pond: A natural or artificial pond used to convert solar energy to heat to accomplish evaporation

Evaporation: The process in which water is converted to a vapor that can be condensed.

Facultative lagoon: A lagoon or pond where wastewater stabilization occurs due to aerobic, anaerobic, and facultative bacteria.

Fatty acid: Any of a class of lipids consisting of organic acids having the general formula R.COOH

Fertigation: The injection of fertilizers used for soil amendments, water amendments, and other water-soluble products into an irrigation system.

Filter: A device utilizing a granular material, woven cloth, or other media to remove suspended solids from water, wastewater, or air.

Final effluent: The effluent from the final unit treatment process at a wastewater treatment plant.

Flocculant: An organic polyelectrolyte used alone or with metal salts to enhance floc formation and increase the strength of the floc structure.

Flocculation: Gentle stirring or agitation to accelerate the agglomeration of particles to enhance sedimentation or flotation.

Flora: Plants and plant life of a particular region or period.

Flow equalization: Transient storage of wastewater for release to a sewer system or treatment process at a controlled rate to provide a reasonably uniform flow.

Flush tank: A tank in which water is stored for rapid release.

FOG: Fats, oils, and grease.

Gray water: All nontilet household water, including sinks, baths, and showers.

Grease trap: A receptacle collects grease and separates it from wastewater flow

Grit chamber: A settling chamber that removes grit from organic solids through sedimentation or an air-induced spiral agitation.

Groundwater: Subsurface water found in porous rock strata and soil.

Heavy metals: Metals that can be precipitated by hydrogen sulfide in an acid solution and may be toxic to humans above certain concentrations.

Hydrogen sulfide: A toxic gas formed by the anaerobic decomposition of organic matter containing sulfur; the chemical formula is H₂S.

In situ: Treatment or disposal methods that do not require the movement of contaminated material.

Indirect reuse: The beneficial use of reclaimed water after releasing it for storage or dilution into natural surface waters or groundwater.

Infiltration: (1) Water entering a sewer system through broken or defective sewer pipes, service connections, or maintenance hole walls. (2) Wind-induced air movement into a building through openings in walls, doors, or windows.

Influent: Water or wastewater flowing into a basin or treatment plant.

Inhibitor: A chemical that interferes with a

chemical reaction.

Irrigation: The artificial application of water to meet the growing plants or grass requirements that rainfall alone does not meet.

Land application: The disposal of wastewater or municipal solids onto land under controlled conditions.

Leakage: (1) An ionic species in an ion exchanger effluent usually indicates bed exhaustion. (2) The uncontrolled loss of water from a tank or aquifer.

Mechanical aeration: The mechanical agitation of water to promote mixing with atmospheric air.

Membrane bioreactor (MBR): A modification of the activated sludge wastewater treatment process employing membrane filtration instead of conventional secondary clarifiers.

Microgram (ug): A unit of mass equal to one-millionth of a gram.

Milligrams per liter (mg/L): A common unit of measurement of the concentration of a material in solution.

Monitoring well: A well used to obtain analysis samples or measure groundwater levels.

Nitrate: A stable, oxidized form of nitrogen having the formula NO₃⁻.

Nitrogen: A colorless, odorless, gaseous element that makes up 78% of the earth's atmosphere and is a constituent of all living tissues combined. The chemical formula is N.

Ocean disposal: The discharge or disposal of wastes or sludges in ocean water.

Organic loading: The amount of organic matter applied to a treatment process osmosis Movement of water from a dilute solution to a more concentrated solution through a permeable membrane separating the two solutions.

Oxidation: (1) A chemical reaction in which an element or ion loses electrons. (2) The biological

or chemical conversion of organic matter into simpler, more stable forms.

Percolation test: A test used to determine the water-absorbing capacity of soil where the drop in water level in a test hole is measured over a fixed time period, also called "perc test.

Permeability: The property of a filter medium to permit a fluid to pass through it under the influence of pressure.

Phosphorous: (1) A non-metallic chemical element with the chemical symbol P. (2) A nutrient essential to all life forms whose overabundance can contribute to the eutrophication of a water body.

Physical treatment: A water or wastewater treatment process that utilizes only physical methods such as filtration or sedimentation.

Pollutant: A substance, organism, or energy form present in amounts that impair or threaten an ecosystem to the extent that its current or future uses are precluded.

Post-treatment: Treatment of finished water or wastewater to enhance its quality further.

Preliminary assessment: Collecting and reviewing available information about a known or suspected waste site or release.

Pre-treatment: (1) The initial water or wastewater treatment process that precedes primary treatment processes; (2) The treatment of industrial wastes to reduce or alter the characteristics of the pollutants prior to discharge to a POTW.

Reactor: The container or tank where a chemical or biological reaction occurs.

Residual: Amount of a pollutant remaining in the environment after a natural or technological process, including the sludge remaining after initial wastewater treatment and the particulates remaining in the air after it passes through a scrubbing or other treatment process.

Risk assessment: Qualitative and quantitative evaluation of the risk posed to human health, the environment, or both by the actual or potential presence, use, or both of specific pollutants.

Salmonella: An aerobic bacterium that is pathogenic in humans and chiefly associated with food poisoning.

Screening: (1) A treatment process using a device with uniform openings to retain coarse solids. (2) A preliminary test method used to separate according to common characteristics.

Secondary treatment: The treatment of wastewater through biological oxidation after primary treatment

Sedimentation: The removal of settleable suspended solids from water or wastewater by gravity in a quiescent basin or clarifier.

Septic: Condition characterized by bacterial decomposition under anaerobic conditions.

Settling tank: A quiescent tank used to remove suspended solids by gravity settling, also called clarifiers or sedimentation basins; they are usually equipped with a motor-driven rake mechanism to collect settled sludge and move it to a central discharge point.

Surface runoff: Precipitation, snow melt, or irrigation more than what can infiltrate the soil surface and be stored in small surface depressions.

Suspended solids (SS): Solids captured by filtration through a glass wool mat or 0.45-micron filter membrane.

Total solids (TS): The sum of dissolved and suspended solids in water or wastewater; Matter remaining as residue upon evaporation at 103 to 105°C.

Total suspended solids (TSS): The measure of particulate matter suspended in a water or wastewater sample. After filtering a sample of a known volume, the filter is dried and weighed to

determine the residue retained.

Turbidity: A qualitative measurement of water clarity resulting from suspended matter that scatters or otherwise interferes with the passage of light through the water.

Volatile organic compounds (VOC): Highly evaporative organic compounds often found in paints, solvents, and similar products.

Volatile suspended solids (VSS): Organic content of suspended solids in water or wastewater determined after heating a sample to 600°C.

Water Quality Index: WQI The Freshwater Quality Index, sometimes called the WQI, summarizes and presents water-quality data as a number ranging from 1 to 100, with a higher number indicating better water quality.

Well monitoring: Measurement by on-site instruments or laboratory methods of water quality in a well.

Well: A bored, drilled, or driven shaft or hole whose depth is greater than the largest surface dimension.

Wetlands: Surface areas, including swamps, marshes, and bogs, which are inundated or saturated by groundwater frequently enough to support a prevalence of vegetation adapted for life in saturated soil conditions

