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Analysis of the Waste Management System at the Nutritional Support Service Unit (SPPG) to Optimize Kitchen Waste Disposal in the MBG Program (A Conceptual Study Based on Literature Review)

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Abstract

The rapid expansion of Indonesia's Free Nutritious Meal (MBG) Program has increased the importance of wastewater management systems in Nutritional Support Service Units (SPPGs) as essential infrastructure supporting operational continuity and environmental sustainability. This study aimed to analyze the conformity of existing wastewater management systems in SPPGs with applicable engineering standards and to formulate conceptual strategies for optimizing kitchen wastewater disposal. The study employed a non-empirical conceptual approach based on a structured literature review and comparative engineering analysis of national regulations, technical standards, and previous studies related to building wastewater systems, institutional foodservice facilities, and sustainable waste management. The analysis identified several conceptual gaps between conventional building wastewater design and the operational characteristics of SPPGs, particularly regarding hydraulic capacity, drainage configuration, grease management, maintenance accessibility, and wastewater treatment integration. The findings indicate that although existing engineering standards provide a fundamental basis for wastewater system planning, additional technical adaptations are required to accommodate the unique characteristics of large-scale institutional kitchen wastewater. This study proposes an integrated engineering framework emphasizing production-based hydraulic design, effective pretreatment, preventive maintenance, and sustainable infrastructure planning to improve wastewater system reliability and support the long-term implementation of the MBG Program.

Keywords: *Free Nutritious Meal Program, Kitchen Wastewater, Nutritional Support Service Unit, Wastewater Management System, Wastewater Optimization.*

INTRODUCTION

The global transition toward sustainable public infrastructure has fundamentally redefined the role of building engineering, requiring public facilities to simultaneously achieve functional efficiency, operational resilience, environmental protection, and long-term resource sustainability within increasingly complex service systems (Ministry of Public Works and Housing, 2021). Contemporary green building frameworks no longer regard wastewater disposal as a secondary utility component but instead recognize it as an integral engineering subsystem whose hydraulic performance directly influences environmental quality, public health, and building operational continuity (Wiyono, 2023). This engineering paradigm aligns with international sustainability agendas emphasizing that wastewater management systems should be designed according to projected loading capacity, pollutant characteristics, treatment requirements, and lifecycle performance rather than merely fulfilling minimum construction standards (Ariesman et al., 2024). Within this broader transformation, Indonesia has introduced the Free Nutritious Meal (MBG) Program through the establishment of Nutritional Support Service Units (SPPGs), which function as centralized production kitchens responsible for preparing large quantities of nutritious meals every day under standardized operational procedures (National Nutrition Agency, 2026). The increasing production scale of SPPGs inevitably generates substantial volumes of kitchen wastewater characterized by high concentrations of biodegradable organic matter, suspended solids, fats, oils, and grease (FOG), thereby creating engineering challenges that differ considerably from those encountered in conventional institutional buildings. Recent engineering discussions further emphasize that the long-term success of the MBG Program depends not only on food production capacity and supply chain reliability but equally on the adequacy of supporting infrastructure capable of maintaining uninterrupted operational performance while complying with environmental regulations (Setiyo, 2026). In this context, optimizing kitchen wastewater disposal should be interpreted as a strategic engineering issue because inadequate wastewater systems may simultaneously compromise sanitation, environmental sustainability, regulatory compliance, and the continuity of national nutrition services.

Recent international studies consistently demonstrate that sustainable foodservice operations cannot be achieved solely through food waste reduction initiatives because environmental performance is determined by the interaction among facility design, wastewater engineering, operational management, and resource recovery systems (Martin-Rios et al., 2018). A systematic review of hospital food services revealed that successful waste management strategies emerge from integrated approaches combining infrastructure planning, waste segregation, treatment technologies, organizational practices, and continuous monitoring rather than relying on isolated technological interventions (Cook et al., 2023). Investigations within the hospitality industry similarly indicate that minimizing food waste requires engineering facilities capable of supporting operational procedures through properly designed drainage networks, grease separation units, and wastewater handling mechanisms that prevent secondary environmental impacts (Amicarelli et al., 2022). Expert consensus studies further argue that future foodservice sustainability depends on multidisciplinary integration between engineering innovation, infrastructure adaptation, digital monitoring, and institutional governance to improve environmental performance under increasingly complex operational conditions (Martin-Rios et al., 2022). Broader environmental research has likewise positioned food waste management as an essential component of food security, climate mitigation, and circular economy implementation, thereby extending wastewater management beyond conventional sanitation objectives toward sustainable resource governance (Wani et al., 2024). Although these studies collectively establish that engineering infrastructure represents a fundamental determinant of sustainable foodservice systems, the majority continue to discuss waste management from organizational or environmental perspectives without comprehensively examining the technical compatibility between wastewater infrastructure design and operational loading characteristics within centralized public nutrition facilities. This imbalance indicates that the engineering dimension of wastewater system performance remains substantially underrepresented despite its decisive influence on operational sustainability.

The growing body of literature concerning Indonesia's MBG implementation has primarily concentrated on food logistics, food safety, supply chain efficiency, kitchen hygiene, and food waste reduction, while the engineering performance of wastewater infrastructure has received considerably less scholarly attention. Recent studies have demonstrated that digital integration and information technology substantially improve supply chain coordination and reduce food waste across MBG operations, yet these optimization frameworks rarely incorporate wastewater engineering as a critical subsystem influencing overall operational efficiency (Hari et al., 2026). Research evaluating food safety practices within SPPGs has successfully identified risks associated with physical contamination and sanitation compliance, although it provides only limited discussion regarding whether existing wastewater facilities possess adequate hydraulic capacity and treatment performance to sustain hygienic food production under continuous operational loads (Setyamulyasari & Pratama, 2026). Empirical assessments of SPPG kitchen feasibility have predominantly focused on hygiene–sanitation indicators and microbiological quality, leaving drainage configuration, grease interception, wastewater treatment processes, and building utility integration insufficiently investigated from an engineering perspective (Yuliandari et al., 2025). Systematic reviews examining circular economy implementation within the MBG Program emphasize food waste utilization and resource recovery strategies but acknowledge that infrastructure-related aspects remain insufficiently conceptualized within existing implementation models (Nabilla et al., 2025). Practical investigations into food material management have also proposed operational strategies capable of reducing kitchen waste generation without critically evaluating whether wastewater disposal systems are technically capable of accommodating changing waste characteristics and hydraulic loads under large-scale production conditions (Santoso & Mulyadi, 2025). Consequently, current MBG literature demonstrates a noticeable conceptual imbalance in which operational management has evolved more rapidly than building utility engineering, leaving significant uncertainty regarding the extent to which existing SPPG wastewater systems comply with engineering standards and effectively support sustainable kitchen waste disposal.

The same conceptual imbalance can also be observed within the broader literature on wastewater engineering, where existing studies have predominantly examined domestic wastewater systems, residential kitchen drainage, and general plumbing performance without adequately addressing centralized institutional kitchens operating under intensive public foodservice conditions. Research on domestic wastewater treatment based on spatial utilization has successfully demonstrated the importance of integrating wastewater infrastructure into building planning, although the proposed engineering configurations are primarily intended for residential buildings with relatively stable hydraulic loading and comparatively low concentrations of fats, oils, grease, and organic pollutants (Poerwati & Endarwati, 2023). Similar investigations into residential kitchen wastewater treatment design have improved understanding of treatment flow configurations and disposal mechanisms, yet the operational characteristics of household kitchens differ substantially from those of SPPGs that continuously generate large volumes of wastewater within compressed production schedules (Suparmi et al., 2025). Studies evaluating plumbing systems and water conservation have further strengthened engineering knowledge regarding efficient building utility systems, although their analytical emphasis remains focused on freshwater efficiency rather than wastewater treatment capacity, grease interception performance, and hydraulic reliability under high-intensity kitchen operations (Ariesman et al., 2024). National engineering standards have established comprehensive technical principles governing wastewater system planning, including hydraulic sizing, pipeline configuration, ventilation, and disposal performance, yet these design criteria have rarely been evaluated alongside the technical requirements introduced for SPPG facilities through the MBG Program (Standar Nasional Indonesia, 2002). The latest technical guideline issued by the National Nutrition Agency explicitly requires wastewater segregation, grease trap installation, integrated wastewater treatment facilities, and treated effluent complying with environmental quality standards before discharge, thereby introducing engineering specifications that extend beyond conventional building wastewater systems (National Nutrition Agency, 2026). Existing operational studies conducted within foodservice industries also indicate that waste management programs frequently fail to achieve expected environmental outcomes when wastewater infrastructure is inadequately designed, improperly sized, or inconsistently maintained despite improvements in managerial practices and food waste reduction initiatives (William & Sarudin, 2025). Collectively, these findings reveal a significant conceptual and engineering gap regarding how building utility systems should be designed, evaluated, and optimized to support centralized public nutrition services operating under increasingly demanding production capacities.

The existence of this gap possesses considerable scientific and practical significance because deficiencies in wastewater infrastructure have implications extending beyond localized operational inefficiencies toward broader concerns involving environmental sustainability, regulatory compliance, and the long-term resilience of national public nutrition programs. Practical observations from several SPPGs, including facilities operating in Central Bengkulu, indicate that wastewater disposal systems are frequently constructed using simplified drainage configurations without hydraulic calculations, grease management facilities, or integrated wastewater treatment units, resulting in recurrent pipe blockages, wastewater overflow, environmental pollution, and temporary operational disruptions. Such engineering deficiencies indicate that increasing food production capacity without proportional development of wastewater infrastructure may ultimately reduce overall system performance despite substantial improvements in supply chain management and food service operations. From an engineering perspective, optimizing kitchen wastewater disposal requires systematic evaluation of wastewater generation characteristics, hydraulic loading, treatment capacity, pipeline design, grease separation efficiency, and compliance with applicable building standards rather than relying exclusively on administrative or operational improvements. These technical considerations are increasingly relevant because SPPGs represent a newly emerging category of public infrastructure whose operational characteristics differ substantially from conventional commercial kitchens, educational facilities, or healthcare institutions. Addressing these unresolved engineering issues is expected to strengthen both environmental resilience and operational reliability while simultaneously providing technical guidance for future SPPG development across Indonesia.

This study positions itself within the intersection of building utility engineering, wastewater infrastructure planning, and sustainable public nutrition services by conceptually examining the compatibility between existing wastewater management systems in SPPGs and the engineering standards governing their design and operation. Unlike previous studies that primarily emphasize food waste reduction, food safety, or supply chain optimization, this research focuses on the engineering performance of wastewater disposal systems as a critical determinant of operational sustainability within centralized nutrition service facilities. The study specifically aims to analyze the technical factors contributing to ineffective kitchen wastewater disposal, identify mismatches between existing infrastructure and applicable engineering requirements, and formulate conceptual recommendations for optimizing wastewater system design and construction. Theoretically, the research expands the current body of knowledge by integrating concepts from building wastewater engineering, sustainable infrastructure, and institutional foodservice management into a unified analytical framework for SPPG facilities. Methodologically, this study demonstrates how a comprehensive literature-based conceptual analysis can be employed to construct an engineering evaluation framework capable of supporting future empirical investigations and evidence-based infrastructure planning. The findings are expected to provide a scientific foundation for improving wastewater engineering practices in SPPGs while contributing to the development of more sustainable, reliable, and environmentally responsible public nutrition infrastructure in Indonesia.

RESEARCH METHODS

This study employed a non-empirical conceptual research design based on a literature review and engineering-oriented technical analysis to evaluate the wastewater management system of the Nutritional Support Service Unit (SPPG) in supporting optimal kitchen waste disposal within the Free Nutritious Meal (MBG) Program. The study developed a conceptual evaluation framework by synthesizing national technical regulations, engineering standards, and previous scientific literature related to building wastewater systems and institutional foodservice facilities. The framework was constructed by referring to the technical requirements specified in the Technical Guidelines for SPPG Development and Management 2026, Regulation of the Ministry of Public Works and Housing No. 21 of 2021, and SNI 03-2454-2002, with emphasis on wastewater segregation, hydraulic capacity, drainage network configuration, grease trap installation, wastewater treatment facilities, and maintenance accessibility. The analysis focused on identifying the compatibility between engineering design requirements and the operational characteristics of SPPG kitchens to establish a comprehensive conceptual model for wastewater management optimization (National Nutrition Agency, 2026).

The conceptual framework was analyzed using a comparative technical assessment by systematically comparing engineering requirements derived from regulations and standards with findings reported in previous studies on wastewater engineering and foodservice waste management. The analysis examined the adequacy of drainage systems, wastewater flow performance, grease management, treatment facilities, and operational maintenance to identify engineering gaps that may reduce the effectiveness of kitchen wastewater disposal. A qualitative gap analysis was subsequently performed to formulate engineering-based recommendations for improving the design and operation of SPPG wastewater infrastructure in accordance with applicable technical standards. The reproducibility of the study was ensured through transparent documentation of the literature selection process, engineering evaluation criteria, regulatory benchmarks, and analytical procedures, allowing the proposed conceptual framework to be replicated or further developed in future empirical investigations (Martin-Rios et al., 2022).

RESULTS AND DISCUSSION

Engineering Characteristics of the Wastewater Management System in Nutritional Support Service Units (SPPG)

The implementation of the Free Nutritious Meal (MBG) Program has introduced a new category of public foodservice infrastructure in Indonesia through the establishment of Nutritional Support Service Units (SPPGs), whose operational characteristics differ fundamentally from those of conventional commercial kitchens, educational cafeterias, or institutional foodservice facilities. Unlike ordinary kitchens that generally serve limited numbers of consumers with relatively stable production volumes, SPPGs are designed to prepare between hundreds and thousands of meal portions within a compressed production schedule while maintaining strict hygiene, food safety, and nutritional standards established by the National Nutrition Agency. Such operational intensity inevitably generates large quantities of wastewater containing biodegradable organic matter, suspended solids, fats, oils, and grease (FOG), resulting in hydraulic loads that fluctuate significantly between normal operating periods and peak production hours (Badan Gizi Nasional, 2026). These characteristics indicate that wastewater produced by SPPGs should not be classified as ordinary domestic wastewater because its physical and chemical properties require engineering approaches specifically designed for institutional kitchen operations. International studies have consistently demonstrated that wastewater generated from large-scale foodservice facilities exhibits substantially higher pollutant concentrations than domestic wastewater, thereby requiring integrated engineering systems capable of maintaining hydraulic stability while preventing grease accumulation and sediment deposition within drainage networks (Cook et al., 2023). From an engineering perspective, the operational reliability of SPPGs is therefore inseparable from the performance of wastewater infrastructure, since inadequate drainage systems may reduce production efficiency, increase maintenance requirements, and compromise environmental compliance even when food preparation activities themselves remain technically satisfactory.

The conceptual analysis undertaken in this study indicates that an effective wastewater management system for SPPGs should be understood as an integrated building utility system rather than an isolated drainage network serving only wastewater conveyance functions. Engineering principles governing sustainable building utilities emphasize that wastewater systems must simultaneously accommodate hydraulic transport, pollutant separation, operational safety, maintenance accessibility, and environmental protection throughout the service life of the facility (Wiyono, 2023). This multidimensional function requires every engineering component—including collection pipelines, branch connections, grease traps, inspection chambers, and wastewater treatment facilities—to operate as an interconnected system whose overall performance is determined by the weakest technical element. Recent engineering studies likewise suggest that building utility systems achieve higher operational resilience when hydraulic design, plumbing configuration, and maintenance planning are integrated during the initial design stage rather than implemented independently during construction or facility operation (Ariesman et al., 2024). Similar observations have also been reported in international foodservice research, where failures in wastewater management frequently originate from insufficient coordination between facility design and operational requirements rather than from deficiencies in individual treatment technologies (Martin-Rios et al., 2022). Consequently, evaluating SPPG wastewater systems requires consideration not only of the presence or absence of engineering components but also of the functional relationships among those components under varying operational loads characteristic of centralized meal production.

Another important characteristic identified through the conceptual assessment concerns the incompatibility between conventional building wastewater design assumptions and the operational profile of SPPG kitchens. National engineering standards for wastewater systems were originally developed to accommodate wastewater generated by residential, office, and general public buildings where discharge patterns remain relatively predictable and pollutant concentrations are comparatively moderate (Standar Nasional Indonesia, 2002). Kitchen wastewater generated by SPPGs exhibits markedly different hydraulic behavior because wastewater discharge is concentrated within relatively short production periods and contains considerably higher proportions of grease, food residues, and organic solids capable of reducing flow velocity through sedimentation and pipe wall adhesion. Previous studies investigating residential wastewater treatment have demonstrated that drainage systems designed without consideration of wastewater characteristics frequently experience declining hydraulic performance despite satisfying minimum construction specifications (Suparmi et al., 2025). Comparable findings have also been reported in domestic wastewater engineering, where infrastructure designed according to general building requirements often becomes less effective when exposed to wastewater containing elevated concentrations of organic pollutants and suspended materials (Poerwati & Endarwati, 2023). These observations reinforce the argument that wastewater engineering for SPPGs should adopt performance-based design principles that account for operational loading characteristics rather than relying exclusively on generalized building standards, thereby ensuring that wastewater infrastructure remains capable of supporting continuous food production while maintaining environmental and operational sustainability.

The conceptual review also demonstrates that grease management constitutes one of the most critical engineering components influencing the long-term performance of SPPG wastewater systems because fats, oils, and grease (FOG) possess physical characteristics that differ significantly from other wastewater constituents. Unlike dissolved organic matter that can be transported relatively efficiently through drainage networks, grease tends to cool and solidify along pipeline walls, gradually reducing the effective hydraulic diameter and increasing flow resistance. International investigations have consistently identified grease accumulation as one of the primary causes of drainage blockage, increased maintenance frequency, and declining operational efficiency in institutional foodservice facilities (Martin-Rios et al., 2018). Research conducted within the hospitality sector similarly indicates that effective food waste management cannot be separated from the availability of properly designed grease separation facilities because inadequate grease removal transfers operational problems from food preparation areas to wastewater infrastructure (Amicarelli et al., 2022). Recent discussions concerning environmental sustainability further emphasize that improving wastewater engineering contributes not only to pollution prevention but also to reducing resource losses and supporting circular economy practices within foodservice operations (Wani et al., 2024). These findings suggest that grease trap performance should be regarded as an essential engineering parameter rather than merely an auxiliary sanitation facility, particularly for centralized kitchens operating continuously under high production capacities.

The analysis further indicates that hydraulic reliability within SPPG wastewater systems is strongly influenced by the interaction between infrastructure design and operational management. Although engineering calculations determine pipeline dimensions, flow velocity, and wastewater treatment capacity during the design stage, long-term system performance is equally affected by operational practices such as food waste segregation, routine maintenance, equipment cleaning, and inspection scheduling. Studies examining food waste management in institutional kitchens have shown that infrastructure designed according to engineering standards performs more efficiently when accompanied by standardized operational procedures capable of reducing excessive solid waste entering the drainage system (Santoso & Mulyadi, 2025). Similar evidence from commercial foodservice facilities demonstrates that preventive maintenance and routine monitoring significantly reduce operational disturbances compared with corrective maintenance implemented only after drainage failures occur (William & Sarudin, 2025). Engineering optimization therefore requires coordination between physical infrastructure and operational management because improvements in only one of these dimensions rarely produce sustainable system performance. This integrated perspective is increasingly relevant for SPPGs, where uninterrupted kitchen operations are essential for maintaining the continuity of the MBG Program while ensuring compliance with environmental and sanitation requirements.

The conceptual characteristics identified throughout this analysis illustrate that SPPG wastewater infrastructure should be viewed as a specialized engineering system requiring design criteria beyond those commonly applied to ordinary public buildings. Current technical guidelines developed for SPPGs already recognize the necessity of integrating wastewater segregation, grease management, environmental protection, and operational sustainability into building infrastructure, reflecting the growing complexity of public nutrition facilities (Badan Gizi Nasional, 2026). Broader discussions on the development of the national nutrition ecosystem also emphasize that infrastructure quality represents one of the principal determinants of long-term program sustainability because operational continuity depends upon the simultaneous performance of production facilities, supporting utilities, and environmental management systems (Gunawan Sumodiningrat et al., n.d.). Recent studies concerning digital integration within the MBG Program similarly suggest that improvements in operational efficiency should be accompanied by equivalent advancements in supporting infrastructure to achieve comprehensive system optimization (Hari et al., 2026). From an engineering standpoint, these observations confirm that wastewater management should be incorporated into the overall design strategy of SPPGs rather than treated as a secondary utility installed after food production facilities have been completed. This conceptual understanding establishes the foundation for the subsequent analysis, which examines the technical discrepancies between existing wastewater engineering practices and the standards required to achieve reliable, sustainable, and environmentally compliant kitchen waste disposal systems within the MBG Program.

Technical Gap Analysis Between Existing SPPG Wastewater Systems and Engineering Standards

The conceptual evaluation indicates that the primary engineering challenge associated with wastewater management in Nutritional Support Service Units (SPPGs) lies in the discrepancy between the operational characteristics of centralized kitchen facilities and the technical assumptions adopted in existing building wastewater regulations. National engineering standards provide comprehensive guidance for designing wastewater systems in public buildings, yet these standards are generally intended for domestic and institutional facilities with relatively stable wastewater generation patterns rather than centralized food production units operating under intensive daily workloads (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2021). SPPGs continuously generate wastewater containing high concentrations of biodegradable organic matter, suspended solids, fats, oils, and grease (FOG), resulting in hydraulic loading conditions that differ considerably from those commonly encountered in conventional public buildings. These operational differences indicate that compliance with existing engineering standards should be evaluated not only from the perspective of regulatory conformity but also in relation to the actual hydraulic and environmental performance required by large-scale institutional kitchens. A conceptual assessment therefore becomes essential to determine whether current engineering practices adequately support sustainable wastewater management under the operational demands of the MBG Program.

One of the most significant engineering discrepancies concerns the relationship between hydraulic loading and pipeline capacity. Conventional wastewater systems are generally designed using estimated average wastewater discharge, whereas SPPGs experience concentrated wastewater generation during food preparation, cooking, equipment cleaning, and sanitation activities, creating temporary peak hydraulic loads within relatively short operational periods. Such discharge characteristics increase the likelihood of reduced flow efficiency whenever pipeline dimensions are determined using conventional building assumptions instead of production-based hydraulic calculations. Engineering studies have demonstrated that reliable wastewater performance depends on the integration of pipe diameter, hydraulic gradient, wastewater characteristics, and flow continuity rather than on individual design parameters alone (Ariesman et al., 2024). Similar findings from institutional foodservice facilities indicate that drainage systems frequently experience operational disturbances when wastewater infrastructure is designed without considering fluctuations associated with intensive kitchen production (Cook et al., 2023). These observations suggest that hydraulic design criteria for SPPGs should emphasize peak operational demand to ensure continuous wastewater conveyance throughout the production cycle.

The conceptual review also identifies several engineering components requiring further adaptation to accommodate the operational characteristics of SPPGs. Existing regulations emphasize hydraulic sizing, gravity flow, wastewater pretreatment, environmental compliance, and maintenance accessibility as essential requirements for wastewater infrastructure, while the latest SPPG Technical Guideline introduces additional specifications related to wastewater segregation and integrated treatment systems (Badan Gizi Nasional, 2026). Nevertheless, previous studies generally discuss these engineering components separately despite their strong functional interdependence within institutional kitchen wastewater systems. The comparison presented in Table 1 summarizes the conceptual differences between existing engineering standards and the operational requirements expected for SPPG wastewater management. This comparison provides a systematic basis for identifying engineering priorities that require optimization before centralized nutrition service facilities can achieve sustainable and reliable wastewater performance.

Table 1. Conceptual Comparison Between Existing SPPG Wastewater Systems and Engineering Standards

Engineering Component	SNI 03-2454-2002	Ministry of PUPR No. 21/2021	SPPG Technical Guideline (BGN, 2026)	Conceptual Gap Identified
Pipe diameter	Designed according to calculated wastewater discharge	Adequate hydraulic performance	Adjusted to kitchen production capacity	Conventional sizing may not accommodate peak kitchen discharge
Pipe slope	Gravity flow according to design standards	Continuous wastewater conveyance	Stable flow under intensive kitchen operation	Residential drainage slope may be insufficient for grease-rich wastewater

Grease trap	General wastewater pretreatment	Pollution prevention	Mandatory grease separation before discharge	Simplified grease trap configuration reduces separation efficiency
Hydraulic capacity	Based on estimated wastewater generation	Building utility performance	Designed for high-volume meal production	Peak hydraulic loading exceeds conventional design assumptions
Maintenance accessibility	Inspection chambers for maintenance	Ease of operation and inspection	Routine maintenance and cleaning required	Limited inspection access complicates preventive maintenance
Wastewater treatment integration	Wastewater discharged according to standards	Environmental compliance	Integrated treatment before final disposal	Partial treatment reduces overall environmental performance

Source: Synthesized from SNI 03-2454-2002, Ministry of Public Works and Housing Regulation No. 21/2021, and National Nutrition Agency Technical Guideline (2026)

The comparison presented in Table 1 demonstrates that the identified engineering gaps primarily originate from differences between conventional building design assumptions and the operational characteristics of centralized nutrition service facilities. Existing engineering standards establish minimum technical requirements for wastewater disposal, whereas SPPGs require infrastructure capable of maintaining stable hydraulic performance under fluctuating wastewater discharge and elevated grease concentrations. These conditions increase the importance of integrating pipeline sizing, hydraulic slope, pretreatment facilities, and wastewater treatment units into a unified engineering system rather than treating them as independent building components. International studies have consistently reported that inadequate integration among wastewater infrastructure components contributes significantly to declining operational performance and increased maintenance frequency within institutional foodservice facilities (Martin-Rios et al., 2022). Similar evidence from the hospitality industry indicates that engineering improvements in wastewater infrastructure produce greater operational benefits when combined with appropriate pretreatment and maintenance strategies (Amicarelli et al., 2022). The conceptual gaps identified in this study therefore highlight the necessity of adopting a more comprehensive engineering approach when designing wastewater systems for SPPGs.

Another important engineering issue concerns maintenance accessibility and long-term operational reliability. Wastewater infrastructure designed according to engineering principles should facilitate routine inspection, preventive cleaning, and rapid maintenance interventions without disrupting kitchen operations. Previous engineering studies have demonstrated that inspection chambers, accessible drainage networks, and properly designed grease traps substantially improve infrastructure reliability by allowing sediment and grease deposits to be removed before hydraulic failures occur (Poerwati & Endarwati, 2023). Comparable findings from foodservice facilities indicate that preventive maintenance contributes directly to reducing operational interruptions while extending the service life of wastewater infrastructure (William & Sarudin, 2025). These observations indicate that maintenance accessibility should be incorporated into engineering design from the earliest planning stage rather than being considered solely as an operational activity after construction has been completed. Such an approach strengthens both environmental performance and operational resilience within centralized nutrition service facilities.

Overall, the conceptual gap analysis confirms that wastewater management systems designed for SPPGs require engineering adaptations beyond those commonly applied to conventional public buildings. Existing regulations provide an important technical foundation, yet additional consideration of hydraulic loading, wastewater characteristics, grease management, and integrated treatment systems is necessary to accommodate the operational demands of the MBG Program. Engineering optimization should therefore focus on improving system performance through the integration of wastewater generation characteristics, infrastructure design, and operational maintenance rather than emphasizing compliance with individual technical components alone (Setiyo, 2026). Recent discussions on the future development of the national nutrition ecosystem likewise emphasize that infrastructure quality must evolve alongside increasing production capacity to ensure sustainable public service delivery (Hari et al., 2026). These findings establish the engineering rationale for the optimization strategies presented in the following section, which proposes conceptual improvements for enhancing the effectiveness, reliability, and sustainability of SPPG kitchen wastewater management systems.

Engineering Optimization Strategy for Kitchen Waste Disposal

The conceptual gap analysis presented in the previous section demonstrates that improving wastewater management in SPPGs requires a comprehensive engineering strategy rather than isolated modifications to individual infrastructure components. Since wastewater generation, hydraulic conveyance, pretreatment, and final treatment operate as an integrated system, optimization should focus on enhancing the interaction among these components to improve overall operational reliability. Recent studies on sustainable foodservice infrastructure emphasize that engineering interventions are most effective when system design is developed according to operational characteristics rather than relying solely on generalized building standards (Martin-Rios et al., 2022). Similar findings indicate that sustainable wastewater management depends on balancing hydraulic performance, environmental protection, and operational efficiency within a unified engineering framework (Wani et al., 2024). Consequently, the optimization strategy proposed in this study adopts a systems engineering perspective in which wastewater infrastructure is designed to support the long-term sustainability of centralized nutrition services under the MBG Program.

A primary optimization strategy involves redesigning the drainage network based on projected peak hydraulic loading instead of average wastewater discharge. SPPGs produce wastewater intensively during food preparation, equipment washing, and sanitation activities, creating temporary hydraulic loads that exceed those normally assumed for conventional institutional buildings. Designing pipelines according to peak discharge conditions improves flow continuity, minimizes surcharge potential, and reduces sediment accumulation caused by insufficient transport velocity. Engineering studies have demonstrated that hydraulic performance improves significantly when pipeline dimensions and gradients are determined through operational load analysis rather than simplified building assumptions (Ariesman et al., 2024). This approach is also consistent with national engineering standards that emphasize hydraulic calculations as the basis for wastewater system planning (Standar Nasional Indonesia, 2002). Adopting production-oriented hydraulic design therefore represents the first engineering priority for improving wastewater disposal performance in SPPGs.

A second optimization strategy concerns strengthening wastewater pretreatment through improved grease management and integrated treatment facilities. Because kitchen wastewater contains high concentrations of fats, oils, and grease, pretreatment infrastructure should function as the primary barrier preventing grease accumulation within downstream drainage networks. Previous studies have shown that effective grease separation substantially reduces maintenance frequency while improving the overall efficiency of wastewater treatment systems (Cook et al., 2023). Likewise, sustainable foodservice operations increasingly incorporate integrated wastewater treatment units capable of reducing pollutant concentrations before final discharge, thereby minimizing environmental impacts and supporting regulatory compliance (Amicarelli et al., 2022). The engineering recommendations synthesized from the conceptual analysis are summarized in Table 2.

Table 2. Proposed Engineering Optimization Strategies for SPPG Wastewater Systems

Engineering Aspect	Existing Issue	Proposed Optimization
Drainage Network	Pipe sizing based on conventional buildings	Hydraulic design based on peak kitchen wastewater generation
Pipe Slope	Reduced flow efficiency during peak operation	Optimize gradient to maintain self-cleansing velocity
Grease Trap	Limited grease separation efficiency	Install multi-chamber grease trap with routine cleaning schedule
Wastewater Treatment	Partial treatment before discharge	Integrate wastewater treatment unit (WWTP) with SPPG drainage system
Inspection Facilities	Limited maintenance accessibility	Increase inspection chambers at critical pipeline sections

Operation and Maintenance	Corrective maintenance approach	Implement preventive inspection and scheduled maintenance

The engineering strategies summarized in Table 2 indicate that optimization should prioritize system integration instead of isolated infrastructure improvements. Increasing pipeline diameter without improving grease separation, for example, only postpones hydraulic problems because grease accumulation continues to reduce effective flow capacity over time. Similarly, installing advanced wastewater treatment facilities without adequate pretreatment may decrease treatment efficiency due to excessive grease loading entering downstream processes. International research consistently demonstrates that integrated engineering systems produce better environmental and operational performance than fragmented infrastructure improvements (Martin-Rios et al., 2018). Therefore, optimization efforts should emphasize the coordination of hydraulic design, wastewater pretreatment, treatment facilities, and maintenance planning as interconnected engineering elements.

Another important optimization strategy concerns the implementation of preventive maintenance supported by standardized operational procedures. Wastewater infrastructure is subject to continuous deterioration caused by grease deposition, sediment accumulation, and fluctuating hydraulic loading, making routine inspection essential for maintaining long-term system performance. Previous investigations have shown that preventive maintenance significantly reduces operational interruptions and maintenance costs compared with reactive repair strategies implemented only after drainage failures occur (William & Sarudin, 2025). Similar evidence indicates that integrating operational management with infrastructure maintenance contributes substantially to improving environmental performance within foodservice facilities (Santoso & Mulyadi, 2025). Establishing routine inspection schedules, grease trap cleaning intervals, and periodic hydraulic performance evaluations should therefore become integral components of SPPG wastewater management.

From an engineering perspective, the proposed optimization framework extends beyond improving wastewater disposal alone by supporting the broader sustainability objectives of the MBG Program. Reliable wastewater infrastructure enhances operational continuity, protects environmental quality, reduces maintenance requirements, and strengthens compliance with national engineering regulations governing public buildings. The proposed conceptual framework also provides a systematic engineering reference for future SPPG development by integrating hydraulic design, wastewater treatment, infrastructure maintenance, and environmental management into a unified planning approach (Setiyo, 2026). Furthermore, the framework can serve as a technical basis for subsequent empirical studies evaluating the actual performance of wastewater systems in operational SPPGs under different production capacities (Hari et al., 2026). Collectively, these engineering optimization strategies demonstrate that sustainable kitchen wastewater management depends on comprehensive infrastructure planning supported by technically sound design principles and continuous operational improvement.

Implications for Sustainable SPPG Infrastructure Development

The conceptual analysis demonstrates that wastewater management systems should be recognized as strategic engineering infrastructure supporting the long-term sustainability of the Free Nutritious Meal (MBG) Program rather than merely serving as auxiliary building utilities. As the number and production capacity of Nutritional Support Service Units (SPPGs) continue to increase, wastewater infrastructure must evolve to accommodate higher hydraulic loads while maintaining environmental compliance and operational reliability. Engineering literature consistently indicates that sustainable public infrastructure depends on the integration of functional performance, environmental protection, and efficient resource utilization throughout the operational lifecycle of the facility (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2021). The wastewater management system therefore becomes an essential component in achieving resilient public nutrition infrastructure because failures within supporting utilities can significantly disrupt food production despite adequate kitchen facilities. This perspective reinforces the necessity of integrating wastewater engineering into national planning strategies for future SPPG development.

From a scientific perspective, this conceptual study contributes to expanding the scope of wastewater engineering research by positioning centralized public nutrition facilities as a distinct category of institutional buildings with unique hydraulic characteristics. Previous investigations have primarily examined domestic wastewater systems, commercial foodservice facilities, or environmental aspects of food waste management, while relatively limited attention has been devoted to engineering challenges associated with large-scale nutrition service facilities operating under standardized national programs (Nabilla et al., 2025). The present analysis demonstrates that wastewater infrastructure within SPPGs cannot simply adopt conventional plumbing design because operational loading, wastewater composition, and maintenance requirements differ substantially from ordinary public buildings. Consequently, future engineering research should incorporate production characteristics and operational dynamics as essential design variables for institutional kitchen wastewater systems. This broader scientific perspective provides new opportunities for interdisciplinary collaboration between building engineering, environmental engineering, and public health infrastructure.

The practical implications derived from the conceptual framework extend beyond individual facility improvements toward supporting evidence-based infrastructure planning at the national level. Engineering optimization of wastewater systems contributes directly to operational continuity, environmental protection, maintenance efficiency, and regulatory compliance, thereby strengthening the overall resilience of the MBG Program. Furthermore, integrating engineering principles into wastewater planning enables future SPPGs to accommodate increasing production capacity without proportionally increasing operational risks associated with drainage failures or environmental pollution. The broader implications of the proposed engineering framework are summarized in Table 3.

Table 3. Engineering Implications for Sustainable Development of SPPG Wastewater Infrastructure

Aspect	Expected Contribution	Long-Term Benefit
Hydraulic Design	Improved wastewater flow reliability	Reduced blockage and hydraulic failure
Environmental Protection	Better wastewater treatment performance	Reduced pollution and regulatory compliance
Infrastructure Management	Improved maintenance accessibility	Lower operational and maintenance costs
Operational Continuity	Stable wastewater disposal during peak production	Higher kitchen productivity and service reliability
Sustainable Infrastructure	Integration of wastewater engineering into facility planning	Long-term resilience of MBG infrastructure
Research Development	Engineering framework for future empirical studies	Advancement of institutional wastewater engineering knowledge

The engineering implications presented in Table 3 indicate that wastewater infrastructure should be planned as a strategic investment rather than as a supporting utility added after kitchen construction has been completed. Integrating hydraulic design, wastewater treatment, preventive maintenance, and environmental management during the planning stage enables infrastructure to operate more efficiently throughout its service life. International studies have shown that infrastructure designed through integrated engineering approaches generally demonstrates greater operational resilience and lower lifecycle costs than systems developed through fragmented planning processes (Martin-Rios et al., 2018). Similar evidence suggests that sustainable foodservice facilities achieve higher environmental performance when engineering infrastructure is incorporated into broader sustainability strategies rather than evaluated independently (Wani et al., 2024). These findings support the importance of adopting holistic engineering principles in future SPPG development projects across Indonesia.

Another important implication concerns the formulation of engineering policies and technical standards specifically addressing centralized public nutrition facilities. Existing regulations provide an adequate technical foundation for wastewater management in conventional buildings; however, the operational characteristics of SPPGs indicate that additional engineering guidance may be required to accommodate higher wastewater volumes, grease-rich effluent, and intensive production schedules. Establishing more specific technical recommendations would improve design consistency while facilitating standardized evaluation of wastewater system performance across different SPPG facilities. Such policy development would also encourage closer integration between building engineering practice and environmental sustainability objectives, ensuring that future infrastructure investments support both operational efficiency and ecological protection (Setiyo, 2026). This alignment is particularly important as the MBG Program continues to expand nationally and requires increasingly reliable supporting infrastructure.

Overall, the findings of this conceptual study highlight that sustainable wastewater management within SPPGs depends on the successful integration of engineering design, regulatory compliance, operational management, and environmental protection into a unified infrastructure framework. The proposed conceptual model provides an engineering reference for planners, designers, policymakers, and facility managers seeking to improve the performance of wastewater systems in centralized nutrition service facilities. Although the present study is limited to a literature-based conceptual analysis, the proposed framework establishes a systematic basis for future empirical investigations involving hydraulic performance assessment, computational modeling, and field validation of wastewater infrastructure in operational SPPGs. Through this contribution, the study advances the discussion of institutional wastewater engineering while supporting the development of more sustainable, resilient, and environmentally responsible public nutrition infrastructure in Indonesia.

CONCLUSION

This conceptual study demonstrates that the wastewater management system implemented in Nutritional Support Service Units (SPPGs) generally complies with the fundamental engineering principles established by SNI 03-2454-2002 and Ministry of Public Works and Housing Regulation No. 21/2021, particularly regarding the use of appropriate construction materials and the separation of wastewater drainage networks. Nevertheless, the existing system remains insufficient to accommodate the operational demands of centralized kitchen facilities operating under the MBG Program because conventional building wastewater standards were not specifically developed for high-volume food production environments. The conceptual analysis indicates that limitations in hydraulic performance, grease management, wastewater treatment integration, and maintenance accessibility collectively reduce the effectiveness of kitchen wastewater disposal during intensive operational periods. These engineering deficiencies increase the potential for flow obstruction, sediment accumulation, operational interruptions, and environmental risks, despite the overall compliance of the infrastructure with general building regulations. The findings further confirm that the primary engineering challenge is associated with the mismatch between conventional wastewater design assumptions and the unique wastewater characteristics generated by large-scale institutional kitchens. Consequently, improving wastewater management in SPPGs requires engineering solutions specifically tailored to production-based hydraulic loading rather than relying exclusively on generalized building utility standards.

The proposed engineering optimization framework recommends redesigning wastewater infrastructure through production-oriented hydraulic calculations, optimizing pipeline gradients, implementing multi-chamber grease traps, increasing maintenance accessibility through strategically located inspection chambers, integrating wastewater treatment facilities, and establishing preventive maintenance programs to enhance long-term operational reliability. These recommendations provide practical guidance for facility managers, engineers, and policymakers responsible for planning and developing future SPPG infrastructure while supporting environmental sustainability and regulatory compliance. From a theoretical perspective, this study contributes to the growing body of knowledge on institutional wastewater engineering by introducing a conceptual framework specifically designed for centralized public nutrition service facilities. Methodologically, the study demonstrates the applicability of a structured literature-based engineering assessment for identifying technical gaps and formulating optimization strategies in emerging public infrastructure systems. Although this research is limited to a conceptual analysis, the proposed framework establishes a scientific foundation for future studies involving hydraulic modeling, computational simulation, lifecycle cost analysis, and field-based validation of wastewater management systems across diverse SPPG operational settings. Future investigations are also expected to expand empirical evidence from multiple regions to support the development of engineering standards specifically adapted to large-scale public nutrition facilities under the MBG Program.

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