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Conceptual Design of a 60 kL/d Effluent Treatment and Water-Reuse System for an Integrated Edible-Oil and Home-Care Manufacturing Facility

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Abstract: This design case presents a conceptual effluent treatment plant (ETP) for a facility that combines edible-oil refining, soap and detergent manufacture, margarine or shortening production, and personal-care formulation. A nominal wastewater flow of 60 kL/d is used as the project basis. The proposed configuration is source segregation; screening and oil separation; equalization and pH control; coagulation-flocculation and dissolved-air flotation (DAF); biological treatment; clarification and filtration; and, where a validated reuse case exists, membrane polishing or reverse osmosis (RO). The design is deliberately presented as conceptual. The values in this document are assumptions for feasibility assessment, not guaranteed performance values or construction dimensions. Final design requires site sampling, treatability trials, hydraulic profiling, civil design, equipment-vendor data and approval by the relevant regulatory authority.

Keywords: *Biological Treatment; Dissolved Air Flotation; Effluent Treatment Plant; Industrial Wastewater; Reverse Osmosis; Water Reuse.*

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I. INTRODUCTION

The facility is assumed to discharge wastewater from refining, batch formulation, washdown and utility operations. These sources may contain free and emulsified oil, fatty acids, suspended matter, surfactants, salts and variable pH. CPCB identifies free and emulsified oil, suspended oilcake particles, dissolved fatty acids and dissolved solids as characteristic contributors in edible-oil wastewater [1]. The project objective is to provide a stable treatment system capable of meeting the applicable discharge consent or supporting internal non-potable reuse, subject to final confirmation of water quality and regulatory requirements.

II. METHODOLOGY AND DESIGN BASIS

Table 1. Conceptual Design Basis and its Limitations.

Item	Conceptual design basis	Status
Nominal flow	60 kL/d; average reference flow = 2.5 m3/h over 24 h.	Assumption. Peak hourly flow must be measured.
Waste streams	Edible-oil refining, soap/detergent manufacture, margarine/shortening, personal care and washdown.	To be confirmed by source mapping.
Treatment objective	Comply with site-specific discharge consent; assess non-potable reuse after tertiary treatment.	Regulatory and reuse requirements to be confirmed.
Sludge route	DAF and biological sludge to dewatering, characterization and authorized disposal or recovery route.	Requires waste classification and local approval.
Reuse option	Tertiary treated water for appropriate non-potable duty; RO only after a membrane-feed assessment.	Conditional option, not a base guarantee.

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The nominal flow must not be used to infer tank volume without a measured operating profile. Cleaning cycles may concentrate most of the daily discharge into a small number of hours. The design sampling plan should therefore include flow-proportional composite sampling across normal production, product changeovers and cleaning events, as well as grabs from high-strength streams. Required parameters include pH, conductivity, COD, BOD, oil and grease, suspended solids, surfactants, nutrients, chlorides, sulphates, alkalinity and formulation-specific constituents. The planned reuse duty should additionally define microbiological and aesthetic criteria where people may contact the water.

III. PROPOSED TREATMENT SYSTEM

A. Source Segregation and Preliminary Controls

High-strength or hazardous side streams should be assessed before they enter the common drain. The design case assumes separate management of soapstock, concentrated cleaning residues, solvent-bearing water and off-specification product. Product recovery, dry clean-up and controlled release of batch waste reduce both treatment load and chemical consumption. Coarse screening protects pumps and mixing equipment. A free-oil separator is included ahead of equalization, but it should not be expected to resolve stable emulsions created by soaps or surfactants.

B. Equalization and pH Control

Equalization is the control point for variable flow, pH and concentration. Continuous mixing or aeration should prevent settling and maintain a representative feed to downstream treatment. Acid or alkali dosing must be controlled by on-line pH measurement with manual verification. The final set point will be established by jar tests and biological-treatability work; it should not be fixed solely from a generic design manual. Adequate freeboard, foam-control provision, chemical containment and access for cleaning are required.

C. Coagulation-Flocculation and DAF

The case adopts coagulation-flocculation followed by DAF as the primary removal step for oil, colloids and a portion of suspended matter. Coagulant and polymer selection should be based on a test matrix that evaluates pH, dose, mixing intensity, settling or flotation behaviour, clarified-water quality and sludge yield. DAF offers an advantage over gravity clarification when floc is buoyant or when oil and surfactant-related emulsions persist. The skimmer discharge should be routed to a covered sludge-holding system; direct disposal of floated scum is not acceptable without characterization.

D. Biological Treatment and Clarification

The post-DAF stream is assumed to be treated biologically after confirmation that residual surfactant and formulation chemicals do not inhibit the selected biomass. An MBBR, SBR or another aerobic configuration may be selected during detailed design. Anaerobic treatment can be investigated for a stable, high-strength biodegradable fraction, but should not be specified without a biodegradability and gas-management assessment. Surfactants can contribute to foam and treatment difficulty, especially when loading changes abruptly [2, 3]. Final biomass separation may use a secondary clarifier or a configuration intrinsic to the selected biological process.

E. Tertiary Treatment and Water Reuse

The conceptual polishing stage includes media filtration and, where justified by residual dissolved organics or reuse criteria, activated carbon or ultrafiltration. Treated water may be considered for non-potable duties only after verifying the relevant water-quality targets. RO is treated as a conditional extension, not an assumed final step. ISO 23070 notes that RO system design for reuse depends on feed-water quality and technical requirements [4]. The owner must define the intended water use, required recovery, concentrate-management route and membrane chemical-compatibility plan before procurement.

IV. CONCEPTUAL PROCESS FLOW

Source-segregated wastewater -> bar screen -> free-oil separator -> equalization with controlled pH adjustment -> flash mixing and flocculation -> DAF -> biological reactor -> secondary solids separation -> media filtration -> treated-water tank -> discharge or qualified reuse. Optional membrane treatment may follow tertiary filtration only where feed quality and concentrate management have been demonstrated. Sludge from DAF and biological treatment is thickened or conditioned as appropriate, dewatered, characterized and transferred through an authorized route.

V. RESULTS AND DISCUSSION

The compliance target must be derived from the site consent and receiving environment. CPCB lists sector standards for edible-oil and vanaspati industry wastewater, including pH 6.5-8.5, suspended solids 150 mg/L, oil and grease 20 mg/L, BOD 100 mg/L (three days at 27 C) and COD 200 mg/L; a more stringent BOD criterion may apply in specified receiving-water conditions [5]. These are not automatically the correct targets for a mixed facility, public-sewer discharge or internal reuse. The project team should obtain the applicable consent-to-establish and consent-to-operate conditions before issuing the final process guarantee.

Table 2. Water-Reuse Applications Require Separate Fitness-For-Purpose Assessment.

Potential water use	Design condition before approval	Indicative treatment barrier
Floor washing / flushing	Confirm hygiene, colour, odour and storage requirements.	Tertiary filtration plus disinfection as required.

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Gardening / irrigation	Confirm salinity, residual chemicals and soil suitability.	Application-specific treatment and monitoring.
Cooling-tower make-up	Confirm cycles of concentration, scaling, corrosion and microbiological programme.	Polishing; membrane treatment if required by water chemistry.
Boiler feed	Confirm boiler pressure and manufacturer feed-water specification.	Typically requires purpose-designed demineralization and conditioning.

VI. IMPLEMENTATION CONSIDERATIONS

The civil layout should allow gravity transfer where practical, chemical containment, crane or lifting access, safe maintenance space, ventilation and segregation of clean and contaminated drainage. Tank structural design must account for groundwater uplift, soil conditions, hydrostatic load, earthquake requirements where relevant, chemical resistance and freeboard. Coating or lining selection should be supported by the expected pH range, temperature and exposure to oils, fatty acids and chemical doses. No universal wall thickness, concrete grade or tank geometry is asserted in this case.

Major mechanical packages include influent and transfer pumps with duty/standby philosophy, equalization mixing equipment, chemical-storage and dosing systems, a DAF recycle and skimming system, aeration equipment, solids-handling equipment, filter backwash facilities and a control panel with alarms. The final connected load, blower capacity and pump head depend on actual tank geometry, pipe routing and measured treatment demand. Instruments should include flow, pH, level and, for aerobic systems, dissolved oxygen. Routine laboratory monitoring should trend COD, oil and grease, solids and site-relevant surfactant parameters.

VII. LIMITATIONS AND NEXT-STAGE WORK

Table 3. Key Project Risks and Actions Before Detailed Design.

Risk	Potential consequence	Required next action
High variation in batch discharge	pH shock, foam, unstable DAF and biological upset.	Complete source map and peak-flow study; enforce controlled release.
Unverified chemistry	High chemical use or poor oil/surfactant removal.	Run jar tests and pilot DAF trials.
Biological inhibition	Failure to meet organic-removal target.	Conduct biodegradability and inhibition tests on representative mixed wastewater.
Premature RO selection	Membrane fouling and unmanaged concentrate.	Prepare feed-water assessment, membrane pilot and concentrate plan.
Unapproved sludge route	Compliance and cost exposure.	Characterize sludge and secure authorized management route.

The next project stage should deliver: (1) a wastewater-source and mass-balance study; (2) a 7- to 14-day composite sampling programme covering operating modes; (3) treatability tests for pH adjustment, coagulation-flocculation, DAF and biological treatment; (4) a discharge-consent and reuse-requirement register; (5) preliminary PFDs and P&IDs; (6) civil, electrical and safety design inputs; (7) a sludge and concentrate management plan; and (8) a capital and operating-cost estimate with sensitivity to chemical, power and disposal costs.

VIII. CONCLUSION

This 60 kL/d case provides a practical starting point for an integrated ETP project. Its central design principle is to control variability before it reaches sensitive treatment stages. Segregation, equalization, chemical treatment and DAF address oil-rich and surfactant-containing wastewater; biological and tertiary stages should then be selected from test results and required end use. The case is suitable for feasibility discussion and publication as a conceptual project design case once author details, site context and actual performance data are added. It is not a construction drawing, vendor guarantee or regulatory approval document.

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