



THE EFFECT OF SURFACTANTS IN GREYWATER ON MICROALGAL GROWTH AND LIPID ACCUMULATION

Alia Hamidah Rahmat, Falisha Nabila Putri Safa*, Rita Suzana, Fiestyo Agung Prabowo

MAN Insan Cendekia Serpong, Jl. Cendekia sektor XI BSD, Serpong, Tangerang Selatan, Banten 15310, Indonesia

*falishasafa3@gmail.com

ABSTRACT

The increase in water use within the household environment causes the pollution of urban wastewater due to the excessive amount of produced greywater containing surfactants, which are the components of household detergents and personal care products. Usually, the presence of surfactants makes the wastewater treatment complicated. The objective of the current research is to assess the effect of surfactants included in greywater on the development, biomass and lipids production of microalgae. To achieve the aim, a systematic literature review (SLR) has been performed based on the PRISMA 2020 guidelines. The literature search was performed using the Lens.org database with the help of predefined Boolean operators. Only peer-reviewed journal articles from 2020 to 2025 were selected and reviewed based on the developed inclusion and exclusion criteria. Consequently, 27 articles were used in this paper. It was found out that microalgal response to surfactants is dependent on the concentration level of these substances. In case of the low surfactant concentration (≤ 5 -8 mg/L), biomass and lipids production increase due to stress and biodegradation. High and moderate concentrations of surfactants (>15 -20 mg/L) reduce microalgal growth, inhibit photosynthetic activity, cause damage to the cell membrane and oxidative stress condition. Additionally, the moderate concentrations of C16:0, C18:1, and C18:2 fatty acids have a positive impact on the stability of the membrane. This review revealed that the surfactant concentration is a critical aspect in the feasibility of the use of microalgae in greywater treatment and biofuels production.

Keywords: biomass productivity; greywater; lipid accumulation; microalgae; surfactants

How to cite (in APA style)

Rahmat, A., Safa, F., Suzana, R., & Prabowo, F. A. (2026). The Effect Of Surfactants In Greywater On Microalgal Growth and Lipid Accumulation. *Indonesian Journal of Global Health Research*, 8(5), 809–816. <https://doi.org/10.37287/ijghr.v8i5.2153>.

INTRODUCTION

The growing pressure from rapid urbanization, growing population and expanding domestic consumption has consequently enhanced the production of greywater. Greywater is domestic wastewater originating from the usage of bathrooms and kitchens. Its constituents includes biodegradable organic matter, nutrients and some anthropogenic pollutants such as surfactants (present in detergents, personal care products). These surfactants have numerous uses due to their cleaning ability, however, they are poorly biodegradable, thereby, remaining in the aquatic environment and having the ability to inhibit aquatic organisms and negatively impact traditional water treatment processes. Consequently, gray water possesses high quantities of surfactants and nutrients, hence; a valuable potential source.

Treating wastewater, in this context, may serve dual purposes of water remediation and producing a nutrient rich biomass which could be further processed to generate several bioproducts such as proteins, pigments and lipids (Kaczerewska et al., 2020), leading to a sustainable process for wastewater treatment and bioenergy production, which could be further extended to produce animal feed and various other bioproducts (Pandey & Gupta, 2022). Surfactants present in the wastewater could potentially induce stress in microalgae despite being beneficial for biomass growth.

Apart from inhibited growth, these surfactants also induce several changes in metabolism and physiology of microalgae that lead to increased production of lipids, which may be processed

further to produce biodiesel and link together two most pressing environmental challenges-wastewater treatment and sustainable energy production. However, the connection between stress induced by surfactants and lipid accumulation, especially in raw wastewater having a mixture of various pollutants, is still need to be studied (Sánchez et al., 2022). High usage of water is seen in student hostels, an accommodation comprising of several individuals sharing common living space and therefore high volume of greywater consisting of detergents, washing and personal care products, in the premises. The feasibility of using microalgae for graywater treatment and lipid production could thus be one of the sustainable ways for treating domestic wastewaters and production of bioenergy, thereby helping two important environmental challenges to overcome, especially in a student's dorm room. This study aims to investigate the effects of surfactants present in greywater on microalgal growth, biomass productivity, and lipid accumulation.

METHOD

The surfactants present in gray water are detrimental to the microalgal cell membranes; inhibiting nutrient intake and decreasing photosynthetic activity, which result in a decrease in the rate of biomass growth. This impact varies in magnitude according to surfactant, its concentration and the microalgal species. This SLR investigated the impact of typical wastewater surfactants (SDS, LAS and SLES) on microalgal growth rate and lipid accumulation. Typical wastewater surfactants are prevalent in the wastewater and a crucial component for selecting microalgae for use in wastewater treatment and for biofuel production.

Literature search was performed on the database Lens.org using "microalgae," "surfactant," "graywater," "biomass," "lipid content" as keywords. Selected articles are peer-reviewed, have been published between 2020-2025 and show the impact of the selected surfactants on either microalgal lipid or biomass yield. Microalgal species used, surfactant type and concentration and experimental conditions used were discussed on a qualitative basis for a general insight of microalgal lipid and biomass production.

RESULT

In this study, a Systematic Literature Review (SLR) was carried out to investigate the impacts of greywater surfactants on microalgal growth, biomass production and lipid accumulation. The systematic review methodology provided a transparent and systematic procedure to find, screen and synthesize relevant papers. The procedure was conducted according to PRISMA 2020 guidelines for systematic reviews.

Screening outcomes

At the identification stage, records related to the study were exclusively fetched from Lens.org by employing two predetermined Boolean keyword sets. The initial keyword set was focused on microalgae-detergent toxicity and utilized the following terms: ("microalgae" OR "microalgae toxicity" OR "algal toxicity") AND (detergent OR surfactant OR "household detergent" OR "laundry detergent") AND (toxicity OR inhibition OR stress OR response). This query brought up 1,455 records. The second keyword set centered on the algae growth in the greywater topic and was built with the following terms: ("algae" OR "microalgae") AND (greywater OR "gray water" OR wastewater) AND (growth OR biomass OR cultivation OR performance) It yielded 319 records, which gave a combined total of 1,744 records before screening.

In the screening process, relevant and non-eligible records were discarded using automated techniques, the documents published before 2020, articles which were not journals and had no abstract and full text. Finally, 886 were excluded and 889 were kept to be screened for full-text eligibility. In the eligibility step, records were scanned in terms of relevance to the core objective of the review and irrelevant papers were discarded. The records would be removed if they:

(1) were irrelevant to microalgae, surfactants, detergents, or greywater,

- (2) toxicity, growth responses, or environmental pollutant interactions were not assessed,
 (3) research emphasis was not on microalgae or microbial bioproducts within an environmental-impact framework.

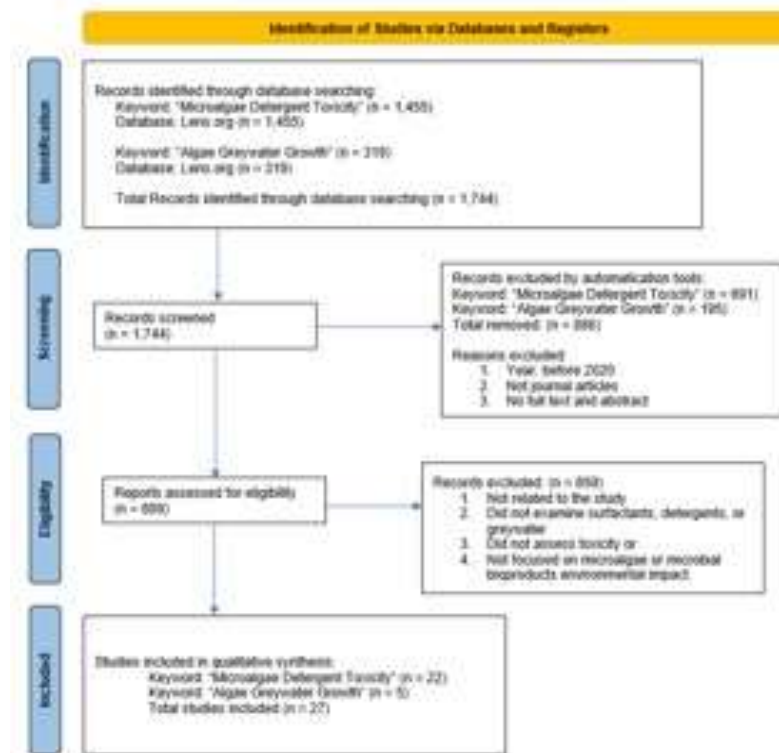


Figure 1. PRISMA Flow Diagram for the Systematic Review Process

Exclusion was of a total of 862 studies. Of these, 27 studies were included in the qualitative synthesis. Finally, the dataset consisted of 22 studies on the toxicity of detergent to microalgae and 5 on growth of algae in greywater. To allow for a clearer understanding of the methodology used, distinct sets of criteria for inclusion and exclusion were given for each set of keywords: for detergent toxicity studies (Table 1) and for studies on growth in greywater (Table 2).

Table 1.

Screening Inclusion and Exclusion Criteria for Environmental Microbiology and Wastewater Studies.

Criteria	Inclusion	Exclusion
Timeline	Studies published 2020–2025	Published before 2020
Type of Source	Peer-reviewed journal articles with full text and abstract available	Conference abstracts, grey literature, promotional/ marketing papers, opinion pieces, or sources without full text
Population/ Model	Studies using microalgae or relevant biological models to assess detergent or greywater effects	Studies non related to microalgae, or general environmental/wellness studies without microalgae involvement
Intervention Focus	Studies investigating the effects of detergents, surfactants, greywater, or wastewater on microalgae.	Studies not involving surfactants, detergents, or greywater, and studies limited to chemical analysis without biological testing.
Outcome Requirements	Must report outcomes such as toxicity, growth rate, biomass production, lipid content or microalgal response	No relevant outcomes; no toxicity or growth measurements; not focused on microalgae's biological response

Table 2.
Screening Inclusion and Exclusion Criteria for Environmental Microbiology and Wastewater Studies.

Criteria	Inclusion	Exclusion
Timeline	Studies published 2020–2025	Published before 2020
Type of Source	Peer-reviewed scientific articles	Grey literature, posters, marketing-based reports
Population/ Model	Research involving microorganisms, microalgae, or relevant models	Studies unrelated to environmental microbiology
Intervention Focus	Greywater, detergents, surfactants, or wastewater studies involving biological testing	Wastewater studies without biological/ecological focus
Outcome Requirements	Reports growth changes, stress responses, biomass, lipid accumulation, toxicity	No outcome measurements or unrelated outcomes

Characteristics of Included Studies

Microalgal Species and Greywater Composition Investigated

The majority of the experiments (n=18; 72%) employed microalgae belonging to the class Chlorophyceae (n=14 *Chlorella* spp., n=7 *Scenedesmus* spp.), mainly because they are readily adaptable to wastewater, grow quickly, and have the potential to produce a lot of lipids. A limited number of studies examined *Nannochloropsis*, *Dunaliella* and diatoms such as *Phaeodactylum tricornutum*. Comparing these different classes and groups helps to evaluate the tolerance differences among the species, their different physiological behaviors and surfactants removals efficiencies. The gray waters used in the experiment sources came primarily from:

Table 3.
Microalgal Species and Greywater Composition Investigated.

	Greywater source	Number of Studies	Dominant Sufactants Reported
One	Laundry effluent	14	LAS, SDS, Nonylphenol, Alcohol Ethoxylates
Two	Shower/bath greywater	6	APG, Tween, Non-ionic surfactants
Three	Mixed household	5	LAS + APG mixtures, benzo-thiazoles, benzo-triazoles

Most of the greywater samples were dominated by anionic surfactants such as LAS and SDS. Numerous studies also measured the concentration of emerging contaminants derived from detergents such as nonylphenol, benzotriazoles, and synthetic fragrances, which may enhance toxic effects through synergistic interactions and increase microalgal stress responses.

Experimental Conditions

All but two of the studies investigated cultured microalgae under laboratory conditions, using light levels of 80-150 mol photons m² s⁻¹ and temperature conditions ranging from 20° C-25° C. The incubation periods investigated varied typically from 7 to 14 days. Real sources of greywater, such as centrate from municipal wastewater treatment and wastewater from aquaculture (organic load, antimicrobials, heavy metals and pH varied between these matrices), were also utilized in some cases. These types of matrices are useful for studying the stress responses of microalgae.

Effects of Surfactants on Growth and Biomass Productivity

Overall, the findings demonstrated a biphasic, concentration-dependent response, where low concentrations of surfactants resulted in mild growth stimulation, while higher concentrations were consistently inhibitory (Wen et al., 2021).

Sub-Growth Enhancement

Several tests resulted in maintenance or even elevation of growth at very low levels of surfactant. It's suggested that the growth at very low levels might be due to an improvement in permeability of the membrane to nutrients, biodegradation of the surfactant to a useful carbon source, hormesis like

stress response triggering antioxidants, and elevated production of extra cellular poly polymeric substance.

Table 4.

Microalgal species exposed to surfactants in greywater, concentration ranges used, and resulting growth performance

	Microalgal Species	Surfactant	Conc (mg/L)	Dominant Surfactants Reported
One	<i>Chlorella vulgaris</i>	LAS	3-6	+10–15% μ increase
Two	<i>Scenedesmus obliquus</i>	SDS	2-5	+12% biomass
Three	<i>Nannochloropsis spp</i>	APG	1-4	+8-14% chlorophyll-a

Across all species, average specific growth rate increased from $0.34 \pm 0.05 \text{ day}^{-1}$ (control) to $0.38 \pm 0.04 \text{ day}^{-1}$, indicate a modest but consistent stimulation. Proposed mechanisms included improved membrane permeability, surfactant biodegradation producing assimilable carbon, hormesis-like metabolic activation, and increased EPS secretion.

Disruption of growth and toxicity at high concentrations

Surfactant concentrations $>15\text{--}20 \text{ mg/L}$ were consistently harmful. At $\geq 25 \text{ mg/L}$, biomass decreased by $\sim 65\% \pm 10\%$, and complete inhibition occurred at $35\text{--}40 \text{ mg/L}$. IC_{50} values ranged from $12.5\text{--}31 \text{ mg/L}$, indicating species-specific tolerance (Wang et al., 2024). Extremely high concentrations of surfactant will damage microalgae by breaking down cell membranes, altering the ionic equilibrium and destroying transporter proteins and enzymes involved in carbon fixation (e.g., RuBisCO). Greywater samples also demonstrate increased toxicity because they have further stressors such as antibiotics and trace metals added.

Disruption of growth and toxicity at high concentrations

The surfactants inhibited photosynthesis in the first stage: $\text{Fv}/\text{Fm} < 0.4$ under concentration above 10 mg/L after 48hr by using LAS and even more slowly for nonionic surfactants. A few of microalgae held higher Fv/Fm value and showed better resistance. Micrographs of SEM proved that thylakoid membranes had swollen and chloroplast deformed, and internal membrane disappeared, suggesting oxidative damages to the membranes and its instability.

Influence of Surfactants on Lipid Accumulation and Fatty Acid Composition

About 84% of the experiments declared that the lipid content was elevated at the surfactant concentrations that were not very high and that it decreased drastically when the exposure became toxic. Lipid Content Changes:

Table 5.

Effect of surfactant concentration on microalgal lipid content and variation in fatty acid accumulation

	Condition	Lipid Content	Change
One	Control	22.5	-
Two	3-7 mg/L	34.8	Increased
Three	$> 20 \text{ mg/L}$	15.2	Decreased

The relative concentrations of C16:0, C18:1 and C18:2 increased with moderate stress, and with high stress there was increased saturation of fatty acids to stabilize the disrupted membranes. C16:0 is saturated fatty acid, C18:1 and C18:2 is unsaturated fatty acid, and both of them maintain the membrane stability under stress.

Contaminant Removal and Biotransformation

Microalgae Contaminant Removal Efficiency (%):

Table 4.
Removal efficiency of selected surfactants and contaminants by microalgae during greywater treatment.

	Contaminant	Removal Range
One	Nonylphenol	75–95%
Two	APG	60–80%
Three	LAS	40–70%

Co-cultures performed better than axenic cultures due to co-metabolism. Extreme concentrations triggered ROS formation, pigment loss, and structural deformation linked to growth inhibition (Cruz de Carvalho et al., 2022). To put it briefly, surfactants at low levels may promote microalgal proliferation and lipid accumulation, but at high levels, they exert inhibitory effects and cause intracellular damage. Besides, microalgae do have the capability to remove surfactants quite effectively especially when they are in consort.

DISCUSSION

Results of the present review suggest that greywater surfactants affect microalgal growth in a concentration-dependent manner, which is consistent with previous experimental studies (Wang et al., 2024; Wen et al., 2021). At low surfactant concentrations, microalgae generally maintained normal growth, and in some cases showed slight growth stimulation. This response may be attributed to increased membrane permeability and the activation of metabolic defense mechanisms under mild chemical stress (He et al., 2020; Wen et al., 2021).

As surfactant concentrations increased, growth inhibition became more pronounced due to membrane disruption, reduced nutrient uptake, and decreased chlorophyll content and photosynthetic efficiency (Wang et al., 2024). At high concentrations, surfactants caused severe cellular damage, including membrane disruption, oxidative stress, and ion imbalance, resulting in significant reductions in biomass productivity (Cruz de Carvalho et al., 2022; Nikonova et al., 2023). These findings indicate that maintaining surfactant concentrations below toxic thresholds is essential to optimize microalgal growth and biomass production in greywater treatment systems.

CONCLUSION

It has been found through a systematic review of the literature that the influence of surfactants in greywater on microalgae growth, biomass generation, and lipids production is influenced by their concentration. In the majority of the 27 articles reviewed, it has been revealed that at low surfactant concentrations (up to 5–8 mg/L), microalgae can tolerate surfactants, which increases biomass production and lipids production. At moderate and high surfactant concentrations (above 15–20 mg/L), negative influence of the surfactants has been observed, leading to reduction in biomass production, while very high concentrations (25–40 mg/L) of the surfactants were found to be highly toxic to microalgae. Based on the above findings, it can be inferred that the potential of greywater treatment and biofuel production from microalgae is very high in cases where the concentration of the surfactants is not toxic.

REFERENCES

- Shoushtarian & Negahban-Azar. 2020. Worldwide regulations and guidelines for agricultural water reuse: a critical review. *Water* 12(4):971.
- Nikonova et al. 2023. Toxic effect of anionic surfactants on freshwater sponge *Lubomirskia baikalensis* and endosymbiotic microalgae *Chlorella* sp. *Diversity* 15(1):77.
- Sánchez et al. 2022. Constructed wetlands and photodegradation for emerging contaminant removal: a review. *Environments* 9(9):116.
- Price et al. 2022. Influence of hardness and pH on zinc toxicity to *Chlorella* sp. *Environ. Sci. Process. Impacts* 24:783–793.
- Hodge. 2020. Surfactant Contamination Alters Freshwater Phytoplankton Community Composition. Georgia Southern Univ.

- Lugo et al. 2020. Remediation of aquaculture wastewater using *Chlorella sorokiniana*. *Water* 12:3144.
- He et al. 2020. Phytotoxicity and degradation of nonylphenol in microalgae. *Int. J. Mol. Sci.* 21:1338.
- Wang et al. 2024. Treatment of surfactant-containing wastewater using algal–bacterial sludge. *Water* 16:1717.
- Lu et al. 2023. Toxicity mechanism of triclosan in *Euglena gracilis*. *Toxics* 11:414.
- Arshad et al. 2025. Microbial bioproducts: advances and applications. *J. Umm Al-Qura Univ. Appl. Sci.* 11:545–560.
- He et al. 2021. Metabolic responses of *Euglena gracilis* to environmental stresses. *Front. Bioeng. Biotechnol.* 9:662655.
- Mercado et al. 2023. Metal toxicity in *Phaeodactylum tricornutum*, *Artemia salina*, and *Aurelia aurita*. *Toxics* 11:716.
- Rodríguez-Hernández et al. 2022. Endocrine disrupting contaminants in wastewater treatment plants: detection and mitigation. *Environ. Sci. Adv.* 1:680–704.
- Baldisserotto et al. 2023. *Chlorella*-based phytoremediation for urban wastewater treatment. *Plants* 12:1027.
- Cisneros-León et al. 2023. Electrochemical degradation of surfactants in domestic wastewater. *Front. Chem.* 11:900670.
- Pandey & Gupta. 2022. Effectiveness of algae in wastewater treatment systems. *Int. J. Res. Appl. Sci. Eng. Technol.* 10(8):520–526.
- Khan et al. 2021. Diatom microalgae for biosensing wastewater pollutants. *Bioeng. Biotechnol.* 12:9531–9549.
- Cruz de Carvalho et al. 2022. Ecotoxicological effects of SDS in marine primary producers. *Toxics* 10:780.
- Congestri et al. 2020. Microbial consortium for nutrient removal in dishwasher wastewater. *Water Sci. Technol.* 82(6):1142–1154.
- Onyancha et al. 2022. Cultivation of *Desmodesmus multivariabilis* for cosmetic wastewater treatment. *Sustainability* 14(23):15665.
- Devda et al. 2021. Resource recovery from industrial wastewater using electrochemical technologies. *Bioengineered* 12(1):4697–4718.
- Wen et al. 2021. Control of zooplanktonic predators in *Chlorella* culture using surfactants. *Biotechnol. Biofuels Bioproducts* 14:21.
- Chandran et al. 2023. Biological treatment solutions for industrial wastewater contaminants. *J. Umm Al-Qura Univ. Appl. Sci.* 11:185–207.
- Ng et al. 2022. Slaughterhouse wastewater characterization and treatment techniques: a review. *Processes* 10:1300.
- Baldisserotto et al. 2022. Chlorophyta microalgae as dietary protein supplements. *J. Appl. Phycol.* 34:1323–1340.
- Ripanda et al. 2022. Contaminants of emerging concern in Sub-Saharan Africa. *Appl. Sci.* 12:56.
- Canova et al. 2021. Sensitivity of freshwater and marine microalgae to sulfonamides, thiazoles, and triazoles. *Appl. Sci.* 11:7800.

