Department of
Primary Industries and
Regional Development
GOVERNMENT OF
WESTERN AUSTRALIA

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Factsheet:
Fats, Oils and Grease (FOG) Limits for Wastewater Irrigation

Overview

Fats, oils and grease (FOG) in wastewater have the potential to pose risk to plant life when applied to land. In an agribusiness context, FOG is of concern in abattoir, dairy, food processing and rendering waste streams, as well as any agribusiness which utilizes high levels of synthetic oils and grease or hydrocarbons etc. within their processes.

FOG binds to the soil and repels water, reducing uptake by plants which can result in wilting. This is estimated to occur when soil FOG concentrations reach 200 mg/kg of soil. To avoid accumulation in the soil, the FOG input should equal or be less than the rate at which it degrades in the soil – any greater than this can be considered as a trigger for concern. An initial estimation of this trigger value is no more than 100 kg/ha/month; however, rates likely vary depending on the microbial content, temperature, and soil type. The following equation can be used to convert the mass loading trigger value to a FOG concentration, if the monthly irrigation rate is known:

$$FOG\ concentration\ trigger\ value\ \frac{mg}{L} = \frac{10{,}000}{irrigation\ rate\ \frac{mm}{month}}$$

As these are merely estimations, they cannot be recommended as a hard limit but should serve as an **indicative trigger value** for concern when applying FOG wastewater to land. When the proposed FOG loading to land exceeds 100 kg/ha/month, ongoing soil testing is recommended. Irrigation can lead to gradual build-up over an extended period; therefore trend-based monitoring is required to monitor accumulation. Management strategies should be employed when soil FOG concentration exceeds 200 mg/kg (at 0-10cm). Management can include reducing FOG loading through water treatment, land amelioration (such as through clay addition), or otherwise demonstrating that the concentration is not impacting plant growth.

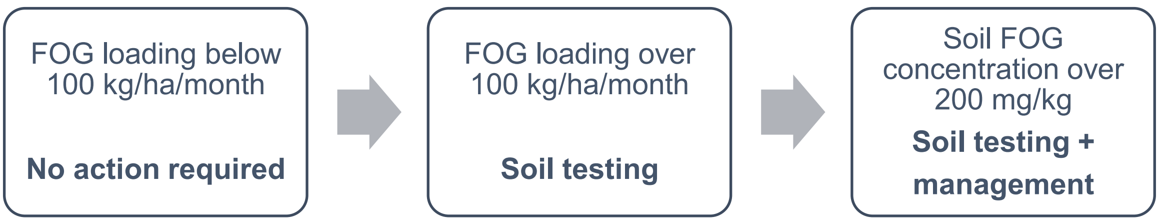

Figure 1: FOG decision flowchart

Abbreviations

Table 1: List of abbreviations

Abbreviation	Definition
CA	Capillary Action
DAF	Department of Agriculture and Food
DPIRD	Department of Primary Industries and Regional Development
FOG	Fats, Oils and Grease
GRDC	Grains Research and Development Corporation

Calculations

Maximum FOG Estimation

There are few studies that describe the negative effects of FOG on soils. Initial research found one paper, Travis et al. 2008, which describes the impacts of artificial greywater, containing various concentrations of FOG (in the form of vegetable oil), when applied to sands sourced from the Negev Desert, in Israel. In the Travis paper, FOG concentrations in the sand were associated with a linear decrease in capillary action, up to a maximum of 250 mg/kg with 60% capillary action loss. Further increasing of the FOG concentration did not result in further CA loss (but may increase its durability).

This reduction in capillary action occurs through FOG coating the soil matrix, reducing wetting and pore connectivity. This impairs the soil's capacity to retain and redistribute water via capillary forces, thereby reducing the fraction of soil water that is accessible to plant roots. Sand has been used as a conservative approach as coarse-texted soils have low inherent water-holding capacity and are particularly susceptible to water repellency. The field capacity of WA sands is typically 9 to 12% (DAF, 2009), while the wilting point for these sands is approximately 3% (DAF, 2009). In soils with such limited water-holding capacity, substantial impairment of capillary-driven water retention and redistribution is expected to markedly reduce plant-accessible water, potentially resulting in plant water stress functionally comparable to wilting, even where total soil water content remains above the wilting point.

In the absence of soil-specific data, a soil FOG concentration of approximately 250 mg/kg is considered as an indicative threshold at which adverse impacts on plant-availability water may become likely in sandy soils. A lower trigger value of 200 mg/kg is therefore adopted to account for uncertainty and variability in soil properties, environmental conditions and management practices. Exceedance of this trigger does not constitute evidence of unacceptable impact but signals the need for further assessment or implementation of management measures to protect soil function and plant health.

FOG Degradation Estimation

An additional follow-up paper by the same authors, Travis 2010, describes the short-term irrigation of artificial greywater containing 22 mg/L FOG to 3.9 kg of sand with an application rate of 0.5 L/day over 40 days. This paper can be used to estimate an application rate for FOG which avoids accumulation in the soil.

$$\frac{22\ mg/L * 0.5\ L/day}{3.9\ kg} = 2.8\ mg/kg/day$$

This is the amount the soil FOG concentration should increase per day – after 40 days it is expected that the FOG concentration within the soil to be equal to 112 mg/kg.

$$2.8\ mg/kg/day\ * 40\ days = 112\ mg/kg$$

However, after the 40 days, the concentration was found to be 65 mg/kg. This is due to oil-degrading bacteria, naturally present in the soil, removing a proportion of FOG - therefore the average removal rate of FOG from the soil is calculated below.

$$(2.8\ mg/kg/day - x\ mg/kg/day) * 40\ days = 65\ mg/kg$$

Where x = the average daily removal rate. Rearranging to solve for x:

$$x\ mg/kg/day = 2.8\ mg/kg/day\ - \frac{65}{40}\ mg/kg\ = 1.2\ mg/kg/day$$

FOG input must equal output to avoid accumulation in the soil, therefore the maximum allowable FOG application rate should not exceed 1.2 mg/kg/day.

For use with current DPIRD irrigation guidelines, this limit should be expressed in units of kg/ha/month.

$$kg/ha = mg/kg * bulk\ density\ g/cm^3\ * \frac{soil\ depth\ cm}{10}$$

WA sands have topsoil bulk density of 1.3 g/cm^3 (DAF, 2009). In Travis 2010, the maximum soil depth tested was 21 cm as accumulation did not exceed background FOG levels beyond this.

$$1.2\ mg/kg/day * 1.3\ g/cm^3\ * \frac{21\ cm}{10} = 3.3\ kg/ha/day$$

$$3.3\ kg/ha/day\ * 30\ days\ = 100\ kg/ha/month$$

This is the estimated maximum application rate for FOG.

Limitations

It is important to note the limitations of these calculations, which are principally based on a single series of studies done by the same author.

The single soil type used in these studies are sands from Israel, which may vary significantly both physically and microbially from West Australian sands. In addition, the impacts of FOG on other soil types were not studied – however it is likely that additional clay content is associated with higher FOG tolerance (due to a higher field capacity).

The estimated removal rate of approximately 1.2 mg/kg/day reflects an apparent average net removal observed over a 40-day laboratory experiment under near-optimal conditions and therefore likely represents an *upper-bound* (best-case) degradation rate, not what would reliably occur in the field, and should not be interpreted as a sustained long-term degradation capacity under field conditions. Biodegradation of hydrophobic organics in soils is often non-linear and may decline with time due to reduced bioavailability, ageing, oxygen transfer limitations, and changes in microbial activity.

A further limitation is the short duration of the experiment (40 days). While the observed average net removal rate suggests that sandy soil may process a portion of applied FOG over the short term, it does not demonstrate long-term steady-state behaviour. In particular, the time required for the soil system to reach a longer-term equilibrium (or for persistent fractions of FOG to accumulate) is unknown. Therefore, the calculated rate is best regarded as a screening-level, upper-bound estimate to inform indicative trigger values, rather than a definitive allowable application rate in a short time.

Although Travis et al. (2010) observed FOG above background to ~21 cm, this does not demonstrate uniform concentration or degradation capacity across the profile. FOG is likely to be concentrated in the surface soil where it is applied, and degradation processes may be depth dependent. Consequently, profile-average mass-balance calculations (e.g., based on a 0–20 cm or 0–21 cm mixing depth) may underestimate surface-layer exposure and the potential for hydraulic impairment. Soil trigger concentrations should be assessed primarily in the 0–10 cm layer, supported by secondary monitoring at 10–20 cm to confirm whether migration or accumulation below the surface is occurring.

Hence, these FOG calculations are conservative estimates of the maximum FOG loading before damage to plants occurs in a laboratory scenario and should be used as a trigger value only. To create a hard limit for FOG in wastewater or loading to land in future, further research is needed on degradation rates of FOG and water repellency in characteristic WA soils.

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