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Comparative Effects of Car Wash Detergents and Biosurfactants (Rhamnolipids) on the Soil Environment: In Search of a Greener Alternative

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study investigates the comparative effects of synthetic car wash and a bio-based surfactant detergent, biotensidon, on the soil environment.
Study Design: Evaluation studies.
Place and Duration of Study: Geology and Woodland laboratory at William Smith Building, University of Keele, in 2018.
Methodology: 1000 g of Topsoil purchased from a local store was dried in the oven at 110^{0}C for 24 hours and its moisture content was determined. 100 g of the soil was irrigated with diluted

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detergents and cleaning solutions for 5 days. The leachates were then collected and analyzed for pH and Electrical Conductivity (EC) and further analyzed with Infrared Spectroscopy (IR) while the soil sample pellets were with X-Ray Fluorescence (XRF) machine.

Results: The colour of soil leachate when physically observed was consistently almost clear for tap water, light yellow for the biotensidon detergent and dark brown for the car wash detergent. For the pH for the same period, the soil leachates were between neutral and mildly alkaline among the different samples. However, for EC, the maximum EC recorded was in soil irrigated with Car Wash Detergent (1157, 1181, 1242, 1390 and 1876 µS/cm) for all of the 5 days. This is followed by soil irrigated with BioTensidon (732, 757, 796, 799 and 836 µS/cm) for the same period while the minimum EC was recorded in soil irrigated with tap water (456, 487, 500, 505 and 553 µS/cm) for the 5 days. The IR analysis of soil leachates showed peak values that did not differ with all the three leachates collected each day, while the XRF analysis showed the major elements SiO_2, Al_2O_3 and Fe_2O_3 to be the most dominant for analyzed samples.

Conclusion: Both detergents examined had similar compositions of ingredients for making detergents. Some of these ingredients are well known to be harmful to humans, soil, water and plants, and these compositions vary between the detergents. Both detergents also have similar compositions of microelements that are essential for plant growth and some that are toxic to plants. However, the car wash detergents showed no amount of the element Lead (Pb). The car wash detergents significantly bleached organic fractions of the topsoil when examined physically. An 8% soil pH increase and 43% soil EC increase were recorded after 5 days of testing by car wash detergents when compared to the biosurfactants. Also, biosurfactants were shown to contain some toxic concentrations that may be unsafe.

Keywords: Carwash; detergents; soil; biosurfactants.

1. INTRODUCTION

Sources of environmental pollution vary with their origin and increase daily. According to [1], anthropogenic pollution- from Stationary Sources such as industry, power plants and sewage treatment facilities, have been the major contributor amongst the other sources; mobile, area and natural. The solid and liquid effluents released by these sources contaminate the environment while the gaseous emissions increase the level of CO_2 and other noxious gases in the atmosphere that contributes to greenhouse gases and global warming in addition to the acid rain phenomenon it causes. Furthermore, [1] noted that Area Sources which are made up of lots of smaller pollution from sources such as restaurant wastes and car wash detergents generated by cities are not a big deal by themselves but when considered as a group can be a rapidly increasing and important source of urban pollution.

As cities expand due to population increase, small and medium enterprises will continue to grow to create jobs opportunities and to boost the local economy. The car wash industry is regarded as one of such rising businesses. According to a report released in 2017 by the United States Census Bureau, there are over 100,000 car wash facilities in the United States with Americans spending approximately $5.8 billion annually at car wash facilities. Additionally, the International Carwash Association predicts that as the number of cars on the road continues to increase the need for car wash businesses should also increase. The carwash services offer customers convenience and emotional reward; these factors it is reported to have continuously driven consumer trends and growth as observed by [2] and as a population becomes more affluent and busier, these trends are predicted to keep rising [3].

There are concerns about the impact of car wash industries on the environment. Quite rightly because wastewater released from car wash can contain a wide range of toxic contaminants which ostensibly find their way into the environment and pollutes natural habitats of the ecosystem (terrestrial and aquatic). The Australian Car wash Association reported that cleaning agents (detergents) used for car washing can have harmful effects on plants and animal life despite being branded as biodegradable and eco-friendly. These detergents can be toxic to aquatic organisms thereby creating an imbalance in rivers and streams [4]. Petroleum hydrocarbons and polyaromatic hydrocarbons are typical ingredients of car wash detergents [5]. These components are also carcinogenic to humans and they inhibit plant and animal growth. Furthermore, when these accumulated contaminants are ingested by aquatic animals and move up the food chain, they are eaten by humans and the cycle becomes continuous [5,6]. Some of these toxic contaminants include oil, nitrate, nitrite, chemical oxygen demand, grease, heavy metals, phosphates and surfactants contained in the detergents that are difficult to degrade by natural means if introduced into the environment [7]. The wastewater usually flows into gutters and storm water channels polluting surface water (rivers, streams and lakes) [8], water table (aquifer and groundwater) as they leach into the subsurface [9] and even portable water sources [10].

Another challenge faced in the car wash industry that is of environmental concern (both commercial and personal car washing), is the huge dependence and consumption of freshwater resources especially in rinsing the soap during washing. For example, a commercial car wash company based in Pennsylvania, United States of America, Ridekleen estimates that up to 40 gallons of water are used for a single car wash. And these wastewaters are directly released into the environment which in addition to the pollution menace, constitute public health concerns. And with the advent of technology to reduce human labor, mechanical car wash has become more prominent, easier and effective leaving in their wake huge contaminants that enter our environment [11] Although, efforts are being put in place especially by governments to minimize both industrial emissions and these area source pollutions.

For example, citizens of Switzerland and The Netherlands are not allowed to wash their cars at home, while those in countries like Poland, Italy and Portugal only have such strict rules for their professional facilities [12]. In these countries, the effluents from the professional car washing services are, by law, required to drain into an oil-water separator or clarifier for pre-treatment before they are safely discharged into municipal wastewater flow channels [13]. However, this strategy seems to be ineffective, at least in some countries as an investigation conducted in Malaysia by [14] revealed. The study reported that only a handful of car wash facilities treat their effluent before discharging. These irregularities of effluent treatment by-pass had earlier been reported by [15] as “commonplace in most countries”.

This development has led to an increased research interest in car wash detergents to find environmentally-friendly alternatives. This concern is apt because detergents primarily contain synthetic surfactants, bleaching agents and additives [16] and other dominant sources of xenobiotic origin (XOCs) find their way into municipal wastewater and are often difficult and expensive to treat [17]. If there is continuous exposure to such detergent-wastewater, especially in soil, it can lead to the accumulation of surfactants that will in turn lead to water repellent soils which will hugely affect agricultural productivity and environmental sustainability [18].

2. MATERIALS AND METHODS

The evaluation of potential environmental effects of the synthetic and bio-based detergents on soil was conducted in the Geology and Woodland laboratory at William Smith Building, University of Keele. The soil sample- topsoil, was purchased from a local store in Stoke-on-Trent. The sealed topsoil was immediately transported to the laboratory for further analysis. The bag of topsoil was opened under the aseptic conditions to avoid any form of contamination. With a clean plastic trowel, 1000 g of soil was weighed in a pre-weighed container and air-dried in the oven at 110^{0}C for 24 hours. The dried soil was weighed to determine its moisture content of the soil. Dried soil was sieved using a 2 mm sieve to obtain an even-sized soil. 100g of the soil was placed in a burette and each burette was irrigated with diluted detergents. Cleaning solutions were prepared daily for 5 days and used to irrigate the soil. The leachates were then collected and analyzed for pH and Electrical Conductivity (EC). The experimental setup is shown in Fig. 2. The soil in Tube A was leached with tap water (control), Tube C with car wash detergent (surfactant) and Tube B with biotensidon (biosurfactant). The leachates were then further analyzed with Infrared Spectroscopy (IR) (described in sections 2.4 & 2.5) while the soil sample pellets were with X-Ray Fluorescence (XRF) machine (sections 2.5 & 2.6).

2.1 Effect of Detergents on Soil Quality

The following soil properties were analyzed to determine the effect of the detergents on soil quality.

2.1.1 Soil pH

Soil pH was determined by mixing, 20 g of dried soil sample with 50 ml distilled water in a beaker and stirring continuously for about 2 minutes. The mixture was then allowed to settle for about 1 hour. Whatman's filter paper was used infiltration to remove the solids. The pH of the

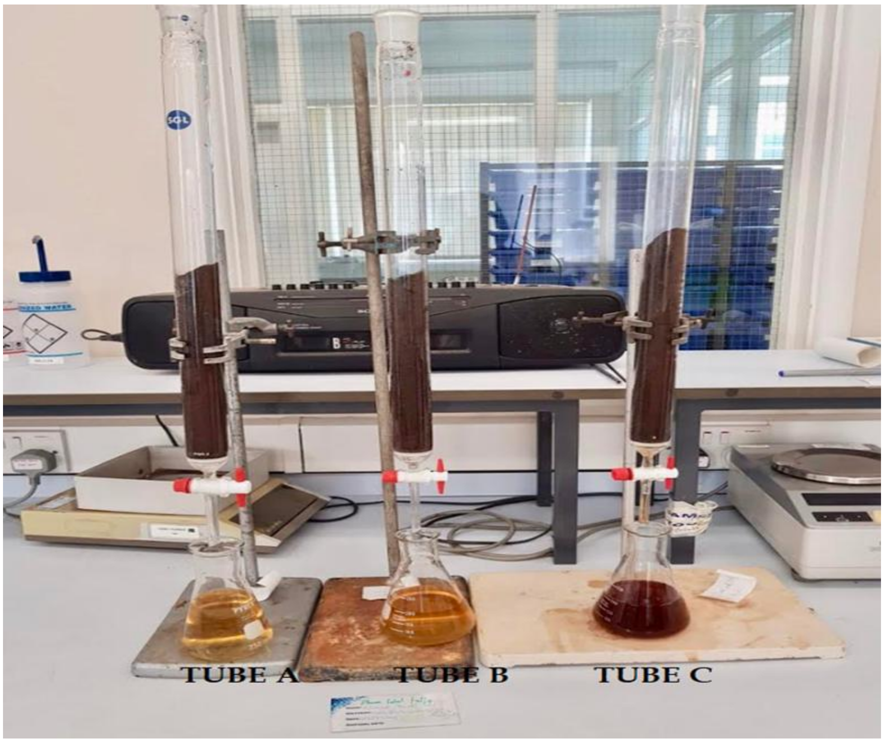


Fig. 1. Experimental set-up employed in the study

filtrates was determined using a digital pH meter available in the laboratory. Likewise, the pH of each soil leachate was measured using a calibrated pH meter.

2.1.2 Soil moisture content

The moisture lost in soil was measured using a known amount of soil sample and was air-dried for 24 hours in an oven at a temperature of 105^0C. Soil samples were then weighed before and after drying and the percentage were calculated as below [19].

The moisture content of the soil (conventional oven method) used for the study was thus calculated as described above;

$Mw = Mcws - Mcs$
$Mw = 300 - 166 = 134$ g
$Ms = Mcs - Mc$
$Ms = 166 - 14.6 = 151.4$ g

To determine the moisture content in percentage (%)

$w = Mw / Ms \times 100$
$w = 134 / 151.4 \times 100$
$w = 88.51\%$

2.2 Cleaning Solution (Detergent) Preparation

Two detergents were used in the experiment for comparative analysis. First, car wash detergent- a chemically synthesized surfactant (combination of TFR, glass cleaner, hi-foam shampoo, tyre shine, wheel cleaner) and Biotensidon, a biosurfactant. The car wash detergents were gotten from a hand car wash in Newcastle under Lyme, Stoke-on-Trent while the biotensidon was obtained from the manufacturers in Germany. The detergents were prepared according to the manufacturer's dilution instructions. The car wash detergent was diluted a ratio of 100:1 and the biotensidon was diluted at a ratio of 250:1. 200 ml of each detergent was collected and used to irrigate the examined soil samples already placed in the buret to leach the soil.

2.3 Soil Leachate Analysis

All parameters were measured by the Standard Method of water and wastewater analysis. The pH and EC of the soil solution (leachate) were determined after each experiment. pH and EC were measured using calibrated pH and EC meters. The leachate was also run on the IR machine to determine the composition of the compounds present in the leachate and possible percentage match.

2.4 IR Machine Operations

The IR machine was used to analyze the leachate of the soil. After the leachate was collected, about 1 ml of leachate was run on the machine via a host of selected libraries which include;

- Aldrich vapour phase sample library
- Arson
- Chem 202
- HR Aldrich alcohols and phenols
- HR Aldrich aldehydes and ketones
- HR Aldrich dyes, indicators, nitro and azo compounds
- HR Aldrich esters, lactones and anhydrides
- HR Aldrich hydrocarbons
- HR Aldrich organometallic, inorganic, silanes, boranes and deuterated compounds
- HR Aldrich phosphorus and sulfur compounds
- HR Aldrich solvents
- Hummel polymer sample library
- Organics by RAMAN sample library

After the samples were run, possible matches of the library with the sample were collected and recorded.

2.5 Soil Pellet Preparation for XRF Analysis

A significant amount of leached soil samples and unleached soil samples were air-dried at 105^0C for 24 hours. Air-dried soil samples were finely grounded using mortar and pestle and then sieved using a 63-micron sized sieve to get an even fine powder. 10 grams of the soil powder was then mixed with 1 ml polyvinylpyrrolidone methylcellulose (binding agent or glue for XRF pellets) and allowed to sit for 1 min. The mixed soil was then compressed using a maximum pressure of 10 tons for 30 seconds to form a soil pellet. The pellets were then transferred to the oven to bake and dried for 24 hours. Pellets were run on the XRF machine for the detection of possible contaminants and metals.

2.6 XRF Analysis

The soil pellets being prepared were run on the XRF machine to check for the presence of major elements (in wt. %) and trace elements (in ppm). All data were corrected against the standard, NIST 2709a San Joaquin Soil.

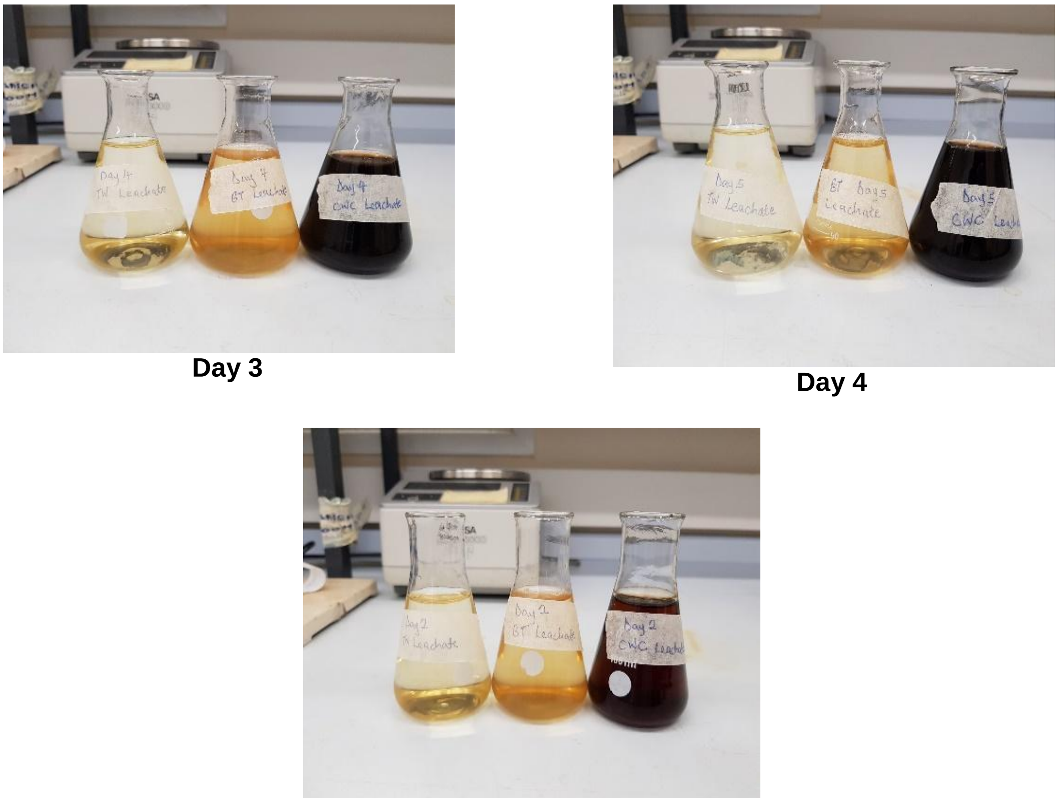
3. RESULTS AND DISCUSSION

3.1 Color Analysis of Soil Leachates and Pellets

The physical appearance (color) of the leachates showed clear colour differences between the leachates each day for the five (5) days tested, as shown in Fig. 2. The three conical flasks in each picture, from left to right: the flask on the left is Tap Water leachate used as control, the flask in the middle represents the BioTensidon leachate (biosurfactant) and the flask on the right side represents the Car Wash detergent leachate (surfactant). The colour of soil leachate when physically observed was consistently almost clear for tap water, light yellow for the biotensidon detergent and dark brown for the car wash detergent.

Day 1

Day 2



Day 3 **Day 4**

Day 5

Fig. 2. Soil leachates and colour analysis result for both synthetic surfactants and biosurfactants, and control (From left to right; Tubes; A (Control), B (biosurfactants) and C (synthetic surfactants)

3.2 Chemical Analysis of Soil Quality

The results of soil quality namely pH and EC are shown in Table 1 and Table 2. For the pH for the same period, the soil leachates were between neutral and mildly alkaline among the different samples. However, for EC, the maximum EC recorded was in soil irrigated with Car Wash Detergent (1157, 1181, 1242, 1390 and 1876 µS/cm) for all the 5 days. This is followed by soil irrigated with BioTensidon (732, 757, 796, 799 and 836 µS/cm) for the same period while the minimum EC was recorded in soil irrigated with tap water (456, 487, 500, 505 and 553 µS/cm) for the 5 days. This is illustrated in Table 2.

3.3 Analysis of Concentration of Different Analytes

The IR analysis of soil leachates for synthetic surfactants, biosurfactants and control is shown in Table 3, Figs. 3, 4 and 5. Table 3 shows a summary of the peak values of the analytes, which did not differ with all the three leachates collected each day while Figs. 3, 4 and 5 show the infrared graph analysis of biotensidon, car wash cleaning agents and tap water (control) respectively.

Table 1. 5-day pH analysis of soil leachates for synthetic surfactants (CWC), biosurfactants (BT) and control (TW)

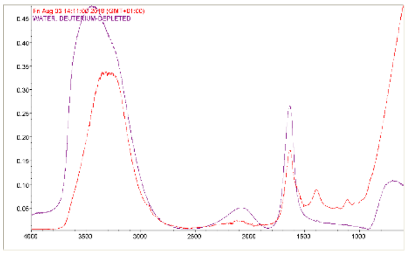
pH	TW	BT	CWC
Day 1	7.15	7.13	7.74
Day 2	7.19	7.24	7.89
Day 3	7.25	7.29	7.91
Day 4	7.30	7.33	7.95
Day 5	7.34	7.38	8.12

3.4 Soil Pellet Analysis using XRF Machine

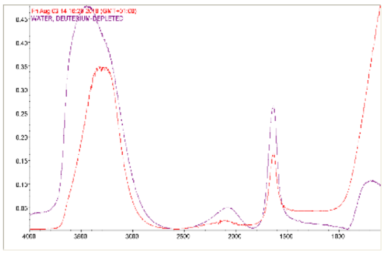
The XRF results for the major and minor elements respectively found in all three (3) leachates employed in this study, are shown in Tables 3 and 4. In the major element category, the trio of SiO_2, Al_2O_3 and Fe_2O_3 were the most dominant for analyzed samples.

Table 2. 5-day EC analysis of soil leachates for synthetic surfactants (CWC), biosurfactants (BT) and control (TW)

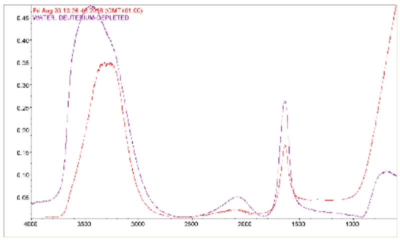
Electrical conductivity (µS/cm)	TW	BT	CWC
Day 1	456	732	1157
Day 2	487	757	1181
Day 3	500	796	1242
Day 4	505	799	1390
Day 5	553	836	1876



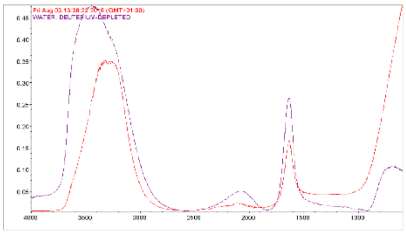
Concentrated



Diluted



Day 1



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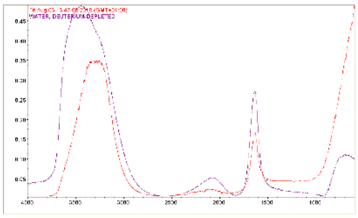
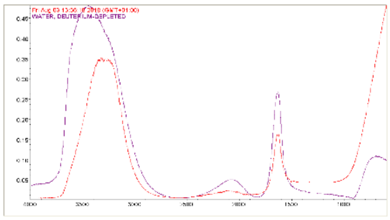
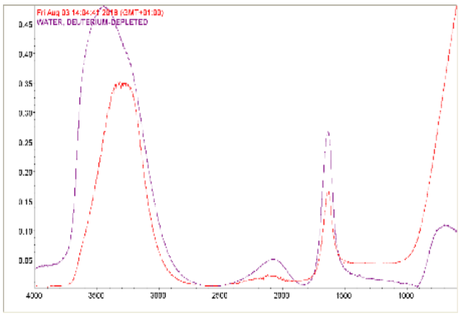


Day 3

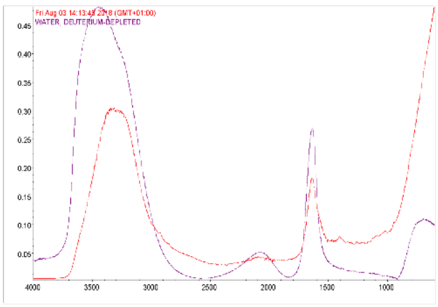


Day 4

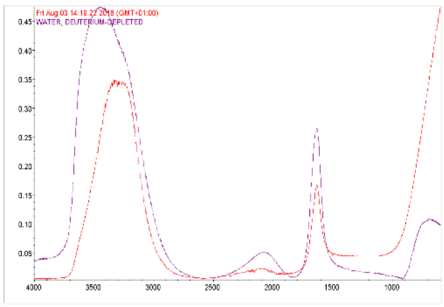


Day 5

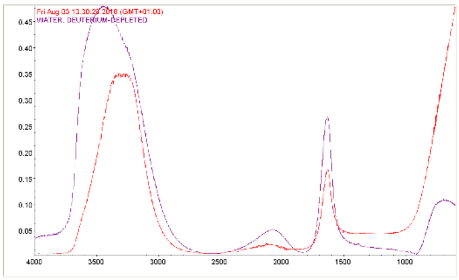
Fig. 3. Infrared (IR) graphs for biotensidon analysis comprising concentrated, diluted and daily results



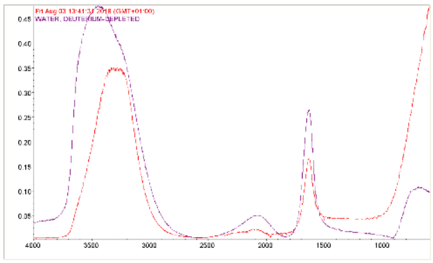
Concentrated



Diluted



Day 1



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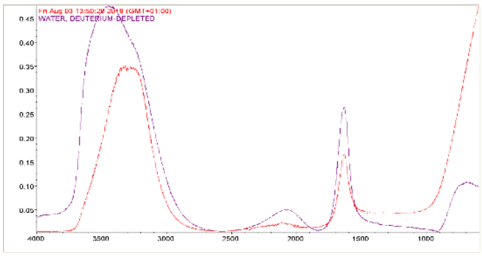
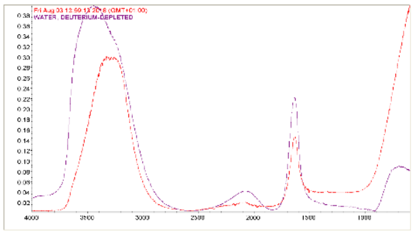
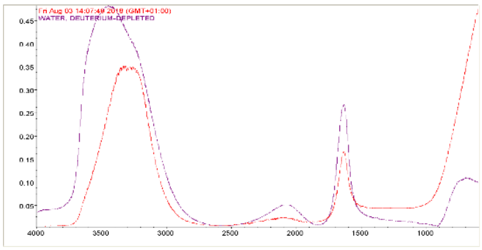


Day 3

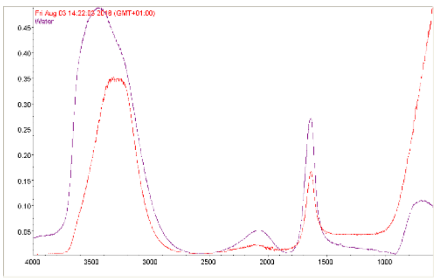


Day 4

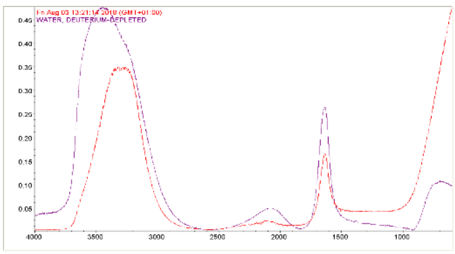


Day 5

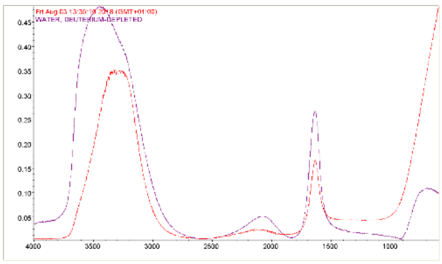
Fig. 4. Infrared (IR) graphs for car wash cleaning agent analysis comprising concentrated, diluted and daily results



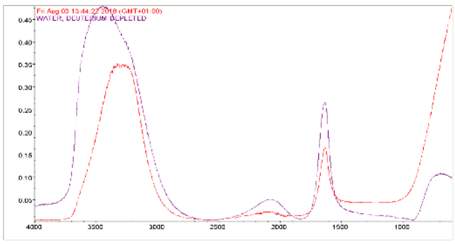
Water



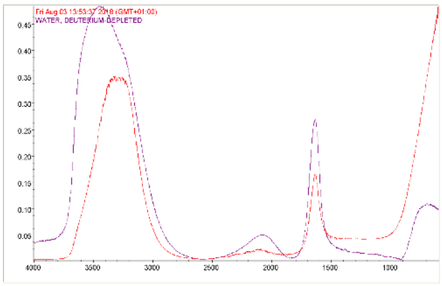
Day 1



Day 2



Day 3



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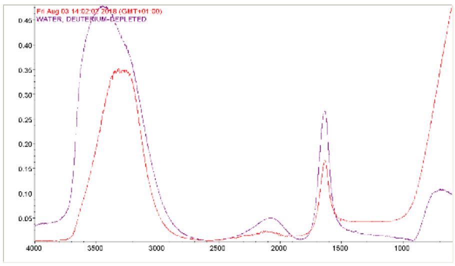

Day 5

Fig. 5. Infrared (IR) graphs for tap water analysis comprising concentrated, diluted and daily results

From this study, the colour difference of soil leachates exposed to detergents was obvious, suggesting a reduced soil quality due to the washing out of soil organic nutrients. The colour of the leachate from the biotensidon is closer to that of water which might suggest it does not wash off the soil nutrients as compared to the car wash detergents. Also, the IR data in Table 3 and the graphs presented in Figs. 3, 4 and 5 don't provide sufficient evidence to support the assumption. However, further empirical analysis using other investigative tools is needed to ascertain this claim. [20] reported that the presence of high organic substances in the soil will result in a high concentration of leachate colour. This was further substantiated in a study by [21] that revealed a low biodegradability of leachate is classified as stabilized leachate and usually contains a high number of organic substances indicated by colour change in leachate such as indicated by the biotensidon. This result might suggest that the car wash chemical leaches off a significant number of organic compounds from the soil and reduces the soil quality when exposed to the soil thus the leachates become darker every 24 hours. It can also be observed based on this study that the car wash detergent has a low degradability as compared to the biotensidon detergent.

Based on data in this study, it was observed that the pH values of both the biosurfactant detergents and control (tap water) were around neutral. This observation can be compared to a similar study carried out in Canada by [22] where most of the soil leachate analyzed was around the neutral value. Biosurfactants usually have maximum effect, high critical micelle concentration and separation of the carboxyl group at a neutral pH [23, 24] which suggests that its optimal function is at around neutral pH as suggested by the result in Table 1. However, the findings for the car wash detergent revealed a rather remarkable difference. An average pH value of 7.9 was recorded against 7.3 for both the control and biosurfactants for the 5 days period tested; which is approximately an 8% increase in pH. It can also be observed that the pH value of the car wash detergent leachate on Day 1 of the analysis was 8% higher than that of the biosurfactant. In addition, compared to Day 5 for the same analyte (car wash detergent), the pH rose to 8.12 (the highest value throughout the study period); representing a 5% increase from Day 1. Although data from this study cannot conclusively predict that the pH of the car wash detergent will continue to rise based on the experimental set-up. But studies such as [25] have shown that car wash effluent when exposed to the soil can have pH values of up to 10.

In addition, the pH level greater than 7.5 is sub-optimal for soil quality or health [26] and minimizes the availability of major and minor soil nutrients required for optimal plant growth [27] by introducing toxic and heavy metals into the soil as seen in Tables 4 and 5. This effluent contains high carbonate/alkali content that would affect pH in both wastewater and receiving soil as seen in the study. The result thus suggests that disposing of car wash effluent ~~to~~ in soil can result in elevated pH levels due to sodium salts levels contained in the wastewater and has been found to have a negative impact on plant biomass, soil enzymes and worm avoidance when used for irrigation [28] due to its low sodium adsorption ratio levels in the soil [29].

The result of EC (in micron Siemens per centimeter µS/cm) conducted on the soil leachates is presented in Table 5 indicates on a scale from the highest to lowest EC readings, CWC- BT- TW. Comparing the EC results of the biosurfactants and car wash detergent samples,

Table 3. 5-day tabular IR analysis of soil leachates for synthetic surfactants (CWC), biosurfactants (BT) and control (TW)

Compounds	**Day 1**			**Day 2**			**Day 3**			**Day 4**			**Day 5**							
	TW	**BT**	**CWC**	**TW**	**BT**	**CWC**	**TW**	**BT**	**CWC**	**TW**	**BT**	**CWC**	**TW**	**BT**	**CWC**	**BT conc**	**CWC conc**	**BT dil.**	**CWC dil.**	**TW**
Water, deuterium depleted	66.1	66.6	64.4	66.2	66.4	65.3	66	65.3	65.1	65.4	66.1	67	66.1	65.8	66.1	64.6	65.7	66.3	66.1	61.3
Water	66.0	66.5	64.3	66.1	66.3	65.2	65.9	65.2	65	65.2	66	66.9	65.9	65.8	66	64.5	65.6	66.2	66	61.3
2-Hydroxy Hexanedial, 25 WT % solution	56.9	57.2	55.4	56.7	57.1	56.6	56.6	56.2	56.2	56.3	56.7	57.5	56.7	56.6	57.1	56.5	57	56.8	56.8	53.3
Glyoxal, 40 WT % solution in water	44	44.4	42.7	44.1	44.2	43	43.6	43.8	43.5	43.6	44.1	44.2	44	43.8	44	42.1	44.2	44.1	43.8	40.8
Glutaric dialdehyde 25 WT % solution	42.6	42.7	41.2	42.2	42.6	40.2	42.4	42.3	42.1	42.1	42.4	42.7	42.6	42.2	42.6	41.6	41.3	42.7	42.2	40.6
Formaldehyde, 37 WT % solution in water	40.3	40.6	39.1	40.3	40.3	39.4	40.3	40	39.8	39.8	40.1	40.5	40.2	40.1	40.4	40.4	41	40.3	40.3	37.7
Butyramide	38.7	38.9	39.3	38.8	39.3	38.7	39.2	38.8	38.8	38.6	39.3	38.9	39.4	38.9	39.2	39.5	41.8	39.7	39.7	38.7
Titanium (IV) Bis (Ammonium lactato) dihydrate	35.2	35.7	34.6	35.4	35.6	33.2	35.4	34.6	35	34.8	35.3	35.7	35.3	35.2	35.3	39.4	41.2	35.7	35.4	33.5
succinic dialdehyde 40 WT solution	35.1	35.2	33.7	35	35.1	34.5	34.7	34.7	34.4	34.7	35	35	35	34.8	35	32.4	32.3	35.1	34.9	35.6
D-erythrose. Tech. Approx 60%	29.9	30.1	29.2	29.1	30	29.9	29.8	29.3	29.7	29.7	30	-	29.9	29.9	29.8	-	-	29.9	29.9	27.9

Key:
TW= Tap water, BT= Biotensidon, CWC= Car wash chemicals

Table 4. XRF analysis of major elements for analyzed detergents, control and unleached soil

Analysis	**Major Elements (wt. %)**								
Sample name	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**	**K_2O**	**P_2O_5**
Control	58.70 ± 0.18	0.56 ± 0.01	8.52 ± 0.07	3.39 ± 0.04	0.03 ± 0.01	1.56 ± 0.08	2.29 ± 0.06	2.14 ± 0.05	0.13 ± 0.01
Unleached soil	49.12 ± 0.16	0.60 ± 0.01	7.63 ± 0.07	3.60 ± 0.04	0.04 ± 0.01	1.46 ± 0.08	2.63 ± 0.07	2.11 ± 0.05	0.13 ± 0.01
Biotensidon	57. 83 ± 0.18	0.49 ± 0.01	7.40 ± 0.07	2.98 ± 0.03	0.01 ± 0.01	1.32 ± 0.08	2.54 ± 0.06	1.93 ± 0.04	0.35 ± 0.01
Car wash chemicals	63.44 ± 0.19	0.53 ± 0.01	7.86 ± 0.07	3.19 ± 0.03	0.02 ± 0.01	1.50 ± 0.08	2.65 ± 0.06	1.97 ± 0.04	0.10 ± 0.01

Table 5. XRF analysis of minor elements for analyzed detergents, control and unleached soil

Analysis	**Trace Elements (ppt.)**									
Sample name	**As**	**Ba**	**Cr**	**Cu**	**Pb**	**Rb**	**Sr**	**V**	**Zn**	**Zr**
Control	5 ± 2	496 ± 34	71 ± 10	89 ± 12	12 ± 6	57 ± 2	111 ± 2	70 ± 17	55 ± 7	301± 4
Unleached soil	6 ± 2	457 ± 33	71 ± 10	0 ± 14	29 ± 6	57 ± 2	105 ± 2	69 ± 17	34 ± 6	333 ± 4
Biotensidon	4 ± 2	395 ± 32	66 ± 9	77 ± 11	9 ± 6	50 ± 2	107 ± 2	67 ± 15	33 ± 6	315 ± 4
Car wash chemicals	5 ± 2	363 ± 31	92 ± 10	92 ± 11	0 ± 11	53 ± 2	113 ± 2	63 ± 16	45 ± 6	309 ± 4

high EC levels of up to 43% increase in CWC to BT were found. Also, a sharp increase of 30% was detected in the CWC soil leachate between Day 1 and Day 5. An increased presence of salts in the soil increases the level of pH and EC. Thus, this is in tandem with the pH result contained in Table 1. In sum, EC levels were lower for tap water and biotensidon as compared to the car wash detergents.

A study by [30] observed an increase in the level of EC and temporary accumulation of salts and metals in wastewater from detergents as compared to tap water after constant exposure. This shows soil salinity and sodicity may have been affected due to long-term exposure to detergents. Based on the scope of this study, the high EC level implies a high concentration of synthetic detergent. This position supported by [31] showed that the presence of detergent in the soil is indicative of an increased level of EC in soil.

The IR spectrometry results obtained did not provide any significant difference to conclude that there is any distinguishable level of pollutants contained in the leachates analyzed. Additionally, the peaks did not differ with all the three leachates collected each day, as shown in Figs. 4, 5 and 6. This could be either as a result that statistical analysis was not conducted for this study or other analytical techniques are required to substantiate this result.

The x-ray fluorescence analysis shows the various components of major and minor (trace) soil elements when exposed to both car wash detergents and biosurfactant. In the major element category, the trio of SiO_2, Al_2O_3 and Fe_2O_3 were the most dominant for both analyzed samples. And all of these chemical compounds are ingredients for making detergents and soap. Also, the high weight percentage of SiO_2 in the unleached soil is not surprising as silicon dioxide is commonly found in nature as quartz, a major constituent of sand.

4. CONCLUSION

The findings in this study suggest that both detergents examined have similar composition of ingredients for making detergents. Some of these ingredients are well known to be harmful to humans, soil, water and plants, and these compositions vary between the detergents. Both detergents also have similar compositions of microelements that are essential for plant growth and some that are toxic to plants. However, the car wash detergents showed no amount of the element Lead (Pb). The car wash detergents significantly bleached organic fractions of the topsoil when examined physically. An 8% soil pH increase and 43% soil EC increase were recorded after 5 days of testing by car wash detergents when compared to the biosurfactants. Also, biosurfactants were shown to contain some toxic concentrations that may be unsafe.

DISCLAIMER

The products used for this research are commonly and predominantly used products in our area of research and country. There is no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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