Data Visualization in Engineering Pedagogy through Determination of Colour Variance in Contaminated Grass Samples

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Conor White, James Uhomoibhi(✉)
Ulster University, Northern Ireland, UK
j.uhomoibhi@ulster.ac.uk

Abstract—Big Data and Data Analytics have in recent times become important areas of focus in academia, business, and society. The use of such tools allow for the in-depth analysis of more complex or nuanced issues that in turn allow the results to be examined and understood by a less specialised user base. In the case of environmental engineering there are a number of strategies for determining pollution levels of contaminated areas, however many of these rely on an existing knowledge of that field in order to be fully understood. By applying an analytical framework to the complex issue of environmental engineering, it is hoped that the results yielded could better serve the understanding of those outside this specialist industry. This paper utilizes experiments involving data visualisation of oil pollution studies and their effects on environment for enhanced learning in engineering education. Tracking and analysis of images and the use of accessible applications for the analysis of acquired data revealed the level of impact of the different types of oil pollution on grass vegetation. In accounting for these changes, the primary Red, Green, and Blue (RGB) colours and corresponding values are used. The use of spectral analysis applications available in spectroscopy and comparison of results would in future prove useful in assessing some aspects of these changes in relation to wavelength and colours changes. The results of these studies would contribute in no small measure to the determination of best cleaning strategies for oil spills.

Keywords—Data visualisation, enhanced learning, engineering education, data analysis, visual analysis, oil pollution, Environmental Engineering

1 Introduction

In engineering education and practice, there is a professional and ethical responsibility to assess and understand the problems facing the world today. Not only for our own development and understanding, but also to aid in the understanding of those affected in meaningful and intuitive ways. One such problem that has long existed in the public eye is that of environmental pollution and its impacts, more specifically that of oil pollution. When developing an understanding of these impacts, it is important to realise that they can be analysed from more than one viewpoint, either professionally or from that of the public. As the world moves to becoming more dependent on digital media, it is vital that our methods of teaching and learning evolve to benefit and be supported by this transition. Local learning on environment has effect on awareness in learners [1-4]. This has potential to exert changes in individuals and society. Most notable and easily identifiable of these is the ecological impact. In the aftermath of any large scale accident or oil spill, this is the impact that attracts the largest public outcry. Despite this, however, our means of analysis is focused around the understanding of the scientific community. While not inherently negative, this creates a limitation when highlighting concerns or addressing the public.

The current research study, through experiments, sought to find a means of intuitive analysis for the ecological impacts that result from oil contamination of terrestrial plant life, as well as a means of tracking and understanding the changes undergone by the plant life post-contamination and how they can be used in the determination of cleaning strategies. The paper also reports on impact assessment of such level of pollution on environment through examining the effect of depth of penetration problem.

3.1 Background, oil pollution studies and environment

The goal of this project is to categorise the associated impacts of oil pollution and assess them in ways that are best supported by modern technology and its expansive outreach. A large part of this lies in making the assessments and their results more intuitively accessible to the public or a layperson. Often times it is a large public outcry that affects changes or highlights issues; as engineers and educators it is important that our means of teaching does not hamper the ability of those without academic or professional knowledge to learn and understand these issues. The determined impacts have been broken down into the following categories: social, political, economic, technological and ecological. The following sections detail the ecological effects as a result of a small scale oil spill.

2 Methodology and approach

The experimentation undergone involves the controlled contamination of plant life, more specifically it deals with the changes undergone by the plant life throughout the testing period. As will become evident throughout the following section, there are a number of changes undergone by the contaminated samples.

This includes their shape, size, texture, and perhaps most obvious of all changes, their colour. This aspect has been selected as the focal point of the observation, in that the colour variance of each contaminated sample will be assessed, both visually as well as through analytical means. This is by means of macro image sampling and determination of colour variance.

The means of analysis for the colour variation is through the Adobe RGB Colour Space. This method of colour space uses the 3 colours, Red, Green, Blue on a scale of 0 - 255 parts, in order to create and display any other colour. The closer the colour value is to 0, the darker and richer that colour will be, while the closer to 255, the lighter and more faded it will be. This has been utilised as means of first identifying the dominant colour present throughout the following results, secondly it will be used as a means of detailing the exact components of that colour as per its Red, Green, and Blue parts.

When plotted across the timeline, the results from this can be used as means of better identifying the exact colour variance undergone by the samples. It will better showcase what samples have undergone the most extreme changes as well as their rate of doing so.

The effects of noxious contaminants such as oil on plant life are well documented [5], so it is expected that the findings follow these trends. Rather than simply assess and document the changes undergone by the plant life, the aim of this report is to instead catalogue the specific changes per contaminant. This means that were the experimentation repeated on a wider scale, the findings could potentially be utilised throughout different sectors as a visual aid to be used when initially assessing smaller scale oil spills. This could potentially help certain sectors or laypeople to have a benchmark when determining the type of contaminant as well as the timeline of contamination.

The following experimentation was originally taken as part of a university dissertation carried out and supervised by the respective authors of this paper [6]. This research sought to follow the same aims of this paper, to assess colour variance through a means that would prove intuitive to those outside of the scientific community. As such the following research was conducted independently from previous research in the field.

Five identical grass samples dug from a sown lawn and potted in containers measuring approximately 350mm x 210mm were contaminated with approximately 50ml each of the chosen oil types highlighted below:

- Kerosene
- Petrol
- Diesel
- Engine Oil
- Control (Uncontaminated)

Macro images were then taken at daily intervals when time permitted using an x24 macro lens on a 16MP camera. The images were catalogued together for the chosen sample and are documented in the following pages under the section of the specific contaminant. Below each image is the dominant colour in that cell which has been determined through obtaining the colour value using the Adobe RGB Colour Space. The analysis for each sample has been carried out using 24 macro photographs of each sample taken across a period of 37 days following the contamination of the specified oil.

The effects of heavy oils such as kerosene and diesel on plant life are well established and upon experimentation, they are expected to cause the most negative effect on the plant colour. Due to petrol's lighter atomic mass, it is expected to evaporate more quickly than the others and therefore cause less damage overall to the grass. As well as the colour changes, there are a number of other outcomes expected in that the size, shape, and texture of the grass leaf will also change across the testing period.

It is expected that the colour variance of each sample, over a long enough period of time, will eventually reach the same final result. The difference will be however in the rate at which these changes occur, the negative effects of kerosene and diesel being thought to peak before that of petrol and engine oil.

3 Results and discussion

This section documents the results gathered from the detailed experiment and analysis through the methods previously indicated. In each section there are a total of 24 macro images of the associated sample arranged in 3 rows of 8 images along with the specified day on which that image was taken. Below each image is the dominant colour in that cell that has been identified through the use of the aforementioned Adobe RGB Colour Space utilised in the Adobe editing software suite; in this case it has been done through Adobe InDesign although any other package would give identical results.

These colour cells have served the basis for the results to be analysed. By identifying the dominant colour in each image it has been possible to track and chart its changes throughout the specified timeline. Following each set of images for the sample is the corresponding graph. This has been plotted using the colour values obtained for that image in each of the Red, Green, and Blue bands based on a scale of 0 – 255 parts per colour. This was plotted as a function of time through which the testing occurred. In this case it was over the course of 37 days, where Day 0 is the image taken before contamination occurred.

Following each graph there will be a discussion of the observed results in the form of both visual analysis, through the discussion of the changes from image to image, as well as analytical analysis as obtained from the colour cells and the plotted graph. Following this section is Table 1 through which the graphs where derived from; it has been filled in with the red, green, and blue colour values for each image across each of the following 5 samples [7]: Kerosene, Petrol, Diesel, Engine Oil and Control.

Kerosene is thin oil obtained from the fractional distillation of crude oil. It is unrefined petroleum; a highly refined form of kerosene is used in jet aircraft fuel. Kerosene is a mixture of hydrocarbons of the alkane series, consisting mainly of hydrocarbons with 11 or 12 carbon atoms. Boiling points of kerosene range from 160°C/320°F to 250°C/480°F. It is important to note that crude oil contains approximately 10-15% kerosene.

Petrol is mixture of hydrocarbons derived from petroleum, mainly used as a fuel for internal-combustion engines. It is colourless and highly volatile. Leaded petrol contains antiknock (a mixture of tetra ethyl lead and dibromoethane), which improves the combustion of petrol and the performance of a car engine. The lead from the exhaust fumes enters the atmosphere, mostly as simple lead compounds. There is strong evidence that it can act as a nerve poison on young children and cause mental impairment. This prompted a gradual switch to the use of unleaded petrol in the UK. Unleaded petrol contains a different mixture of hydrocarbons from leaded petrol. Leaded petrol cannot be used in cars fitted with a catalytic converter.

Diesel oil, also known as derv (diesel-engine road vehicle), is a lightweight fuel oil used in diesel engines. Like petrol, it is a petroleum product.

Engine oil is a blend using base oils composed of petroleum-based hydrocarbons enhanced with additives, particularly anti-wear additive plus detergents, dispersants and, for multi-grade oils, viscosity index improvers.

The Control Sample is uncontaminated and represents the benchmark for the other samples to be compared to.

RGB Values for the three primary colours red, green and blue (RGB) were analysed using the Adobe image analysis program. The RGB colour values for the grass sample obtained for the period of study are shown in Table 1.

Table 1. RGB Colour Values per Oil Type (Kerosene, Petrol, Diesel)

	Kerosene			**Petrol**			**Diesel**			**Engine Oil**			**Control**		
Day	***R***	***G***	***B***	***R***	***G***	***B***	***R***	***G***	***B***	***R***	***G***	***B***	***R***	***G***	***B***
0	35	65	0	81	109	58	16	41	0	81	109	58	16	41	0
1	36	81	0	38	93	2	42	86	0	38	93	2	42	86	0
2	50	67	31	35	85	14	40	96	7	35	85	14	40	96	7
3	47	80	37	58	106	22	69	101	0	58	106	22	69	101	0
6	117	111	75	77	102	1	119	141	77	77	102	1	119	141	77
7	193	172	109	101	153	9	200	177	101	101	153	9	200	177	101
10	211	170	152	59	94	4	164	109	88	59	94	4	164	109	88
11	245	210	182	53	104	25	208	171	145	53	104	25	208	171	145
12	202	180	131	219	187	114	146	117	85	219	187	114	146	117	85
13	154	138	86	219	187	126	173	130	88	219	187	126	173	130	88
14	180	133	81	219	177	119	146	109	64	219	177	119	146	109	64
15	165	139	114	146	138	63	177	139	116	146	138	63	177	139	116
16	178	147	129	140	107	90	168	127	99	140	107	90	168	127	99
17	205	151	104	153	113	87	172	152	66	153	113	87	172	152	66
18	216	176	127	189	148	82	149	111	90	189	148	82	149	111	90
19	188	137	80	135	92	57	177	138	105	135	92	57	177	138	105
24	202	166	130	144	92	55	106	73	58	144	92	55	106	73	58
28	201	160	98	176	132	71	95	65	41	176	132	71	95	65	41
30	194	161	128	204	151	97	139	99	91	204	151	97	139	99	91
32	159	120	103	167	116	89	177	135	110	167	116	89	177	135	110
33	199	160	127	177	124	84	143	102	84	177	124	84	143	102	84
35	187	149	113	164	118	84	128	94	67	164	118	84	128	94	67
36	200	172	148	149	108	88	149	113	81	149	108	88	149	113	81
37	160	112	76	133	98	70	166	121	88	133	98	70	166	121	88

3.1 Kerosene results analysis and discussion

Kerosene by virtue of its properties was deemed to be one of the more damaging oils to be used, with the initial assumption being that it would see the most negative results across the smallest time frame. From the images, the degradation of the grass leaves starts around Day 6: this is noted in both the immediate colour change from a dark rich green, to a much paler, almost brownish-green, as well as the change in size of the leaves. In the days immediately before this image there has been no discernible change in the quality of the leaves themselves, the size and shape has been maintained throughout until this initial degradation on Day 6, where the leaves have first started to wither and die. This degradation continues on throughout the following images where the obvious drying out and withering of the leaves has occurred. This is noted both in their size and shape, as well as the colour as it continues to fade out of the green spectrum.

This continues to develop until Day 14 (see Fig. 1) or so where it can be seen that afterwards, there is no discernible difference in the leaf colour throughout the rest of the testing period. Following on from this point the colour variation is less extreme and follows a similar trend of more muted browns with slight yellow tones. The low quality of the leaf is simply maintained from that point onwards until the end of the testing period. It could be said that from about Day 15 or Day 16 onwards, is where the grass in that sample has died and will exhibit no further growth.

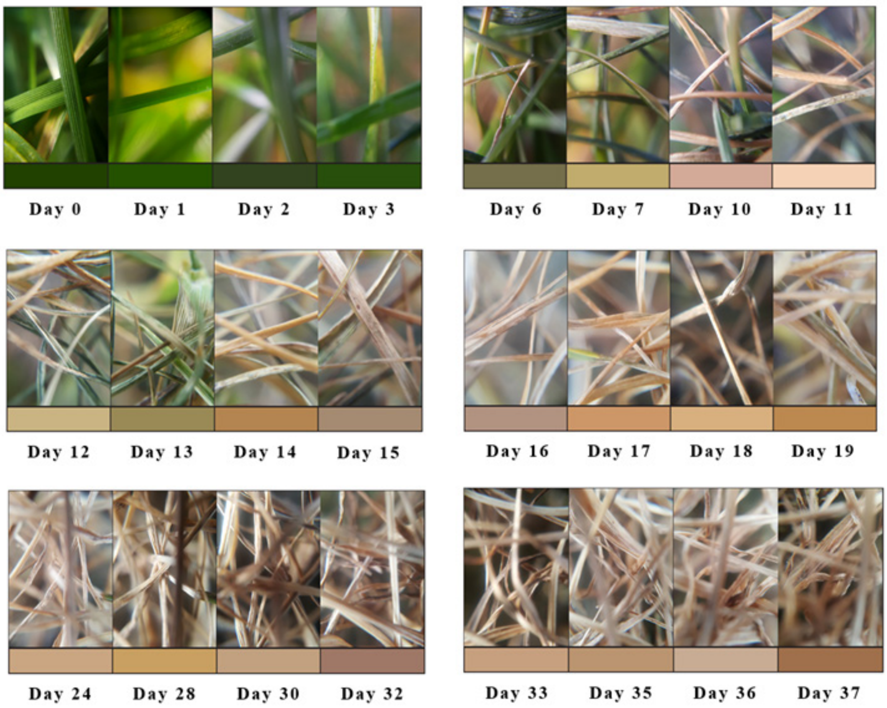

Fig. 1. Images of grass growth on soil contaminated with kerosene oil

These observations are further evident in the associated graph of Fig. 2, where between Day 3 and Day 6, there is an immediate spike in the colour variation as the leaves begin to wither. This variation continues over the next 5 days until Day 11, where the graph peaks indicating that this colour variation is towards the lighter end of the spectrum and shows one of the paler colours obtained from the analysis. Immediately following this peak there is a decline on Day 12, as indicated by the darker colour the leaves start to exhibit. As previously visually observed, there is little colour variation beyond this point as around Day 14 the colour moves back towards the lighter end of the spectrum and begins to balance out, exhibiting little or no change as the testing period continues. This as previously discussed is the observable moment at which the leaves have died and will exhibit no further growth throughout the rest of the testing period.

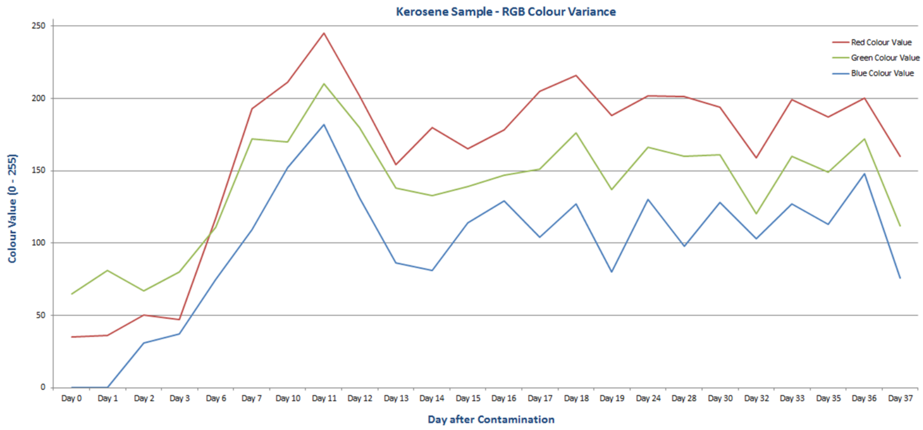

Fig. 2. RGB colour values plotted as a function of time after contamination with kerosene oil

3.1 Petrol results analysis and discussion

Petrol is a much lighter oil than the other samples used and is expected to evaporate faster therefore minimising the negative effects on the grass sample. The initial degradation occurs much later in this sample; in fact this is the sample with the longest timeframe in which there is little to no variance in the observed colour. The variance here begins subtly throughout the first 2 weeks but doesn't shift until Day 12, where the colour moves from the continuing rich, dark green tones to a much paler yellow tone (see Fig. 3). This change continues over the next few days until Day 15 and Day 16 where the colour becomes much darker as it moves towards shades of brown and the decline of the leaves health becomes more evident.

From Day 16 onwards, the degradation is seemingly maintained as there is little to no colour variance occurring between images. The quality of the leaf can be seen in the following week however, as from Day 24 onwards, the leaves have begun to wither and die. From this point onwards there is little to no shift in colour or leaf quality meaning at this point it could be observed that the leaves have begun to die and will exhibit no further growth.

The graph (see Fig. 4) indicates similar findings in that for the initial week there is no discernible variation in the leaf colour.

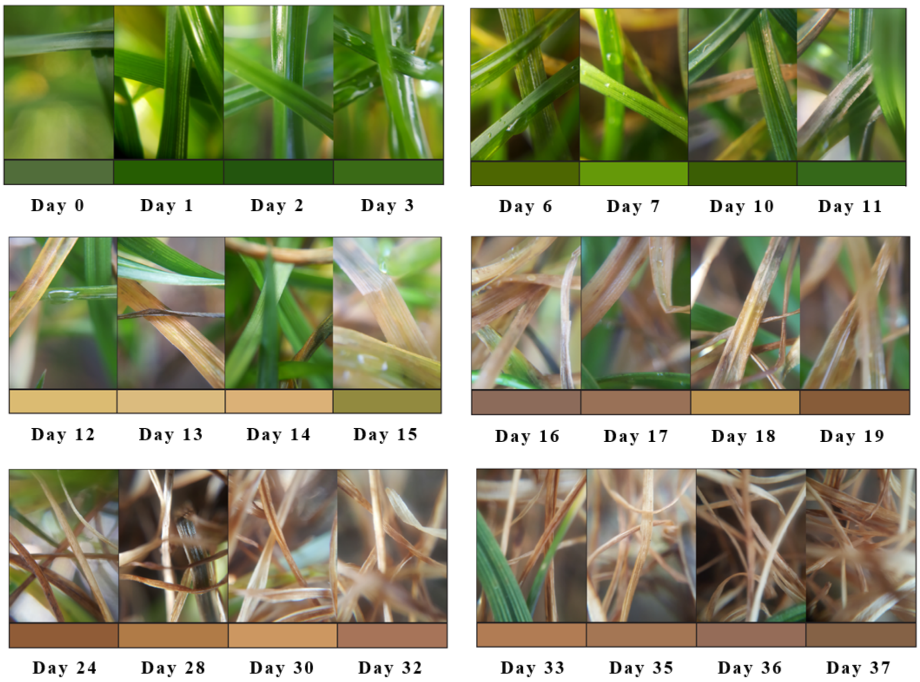

Fig. 3. Images of grass growth on soil contaminated with petrol

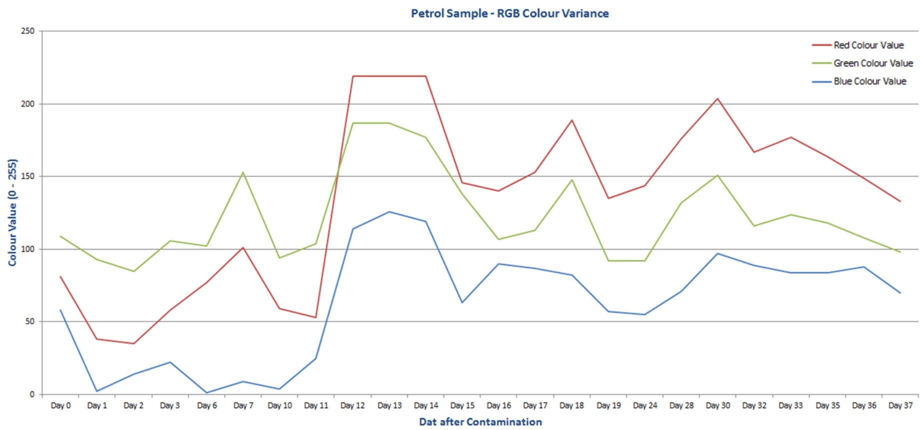

Fig. 4. RGB colour values plotted as a function of time after contamination with petrol

Until that of Day 12, where there is an immediate shift from the darker, richer colours to the lighter end of the spectrum, indicating that the effects of the oil have only just begun. This variation towards the lighter end of the spectrum continues through the following days as little shift occurs in the colour. This paler colour is maintained until the immediate drop off occurring on Day 15. As previously discussed above, from this point onwards the leaves start to exhibit much more negative changes as the colour shifts lower on the spectrum again to that of more reddish tones away from the previous greener colours. As indicated on the graph, this colour variance is maintained throughout the rest of the testing period as the leaves begin to wither and die. This signifies that while the effects took longer to notice, the observable time in which the grass was undergoing a variance in colour, was a lot more abrupt than for the other samples.

3.2 Diesel results analysis and discussion

Diesel was believed to exhibit some of the harsher changes that would occur between samples. It was expected that the changes in this sample would be over a much shorter timeframe and the colour variance and degradation of the leaves exhibited would be much more severe than that of petrol. Just as previously observed with kerosene, the initial variation in the colour occurs on Day 6 after the steady maintenance of the colour over the previous days (Fig. 5).

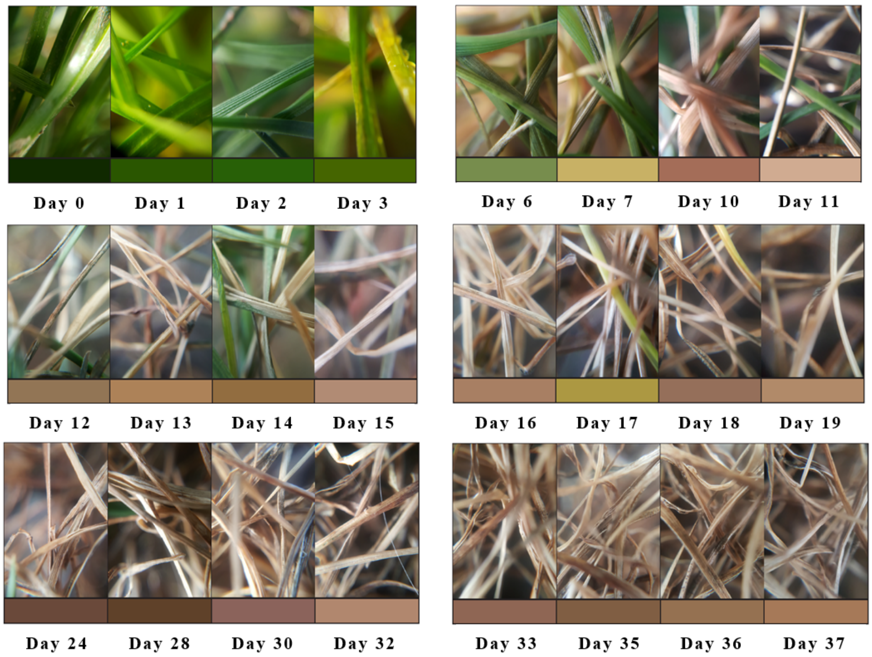

Fig. 5. Images of grass growth on soil contaminated with diesel

This variation is slight at first as it moves from the initial dark green towards a much paler shade of green and then on Day 7 it moves closer to a yellow tone. This loss of green tones continues throughout the next few days, where it becomes obvious on Day 11 that the leaves have already begun to wither and lose their colour. This is evident on Day 12 where the colour has become a much more muted brown tone which continues developing throughout the remainder of the testing process.

Over the course of the week immediately following Day 12, there is little to no change in the colour variation until that of Day 24, where the tone drops to a much darker brown as the leaves maintain their withered state. There is a somewhat noticeable change in the size of the leaves between Day 19 and Day 24 as they continue to wither until their lowest point on Day 24. At this point it could be said that the death of the leaves has occurred and they will exhibit no further growth or changes. These darker tones are then maintained throughout the rest of the testing process, showing no discernible changes over this period.

As shown in the graph the colours remain dark and rich through the initial days and then on Day 6 they immediately shift towards the lighter end of the spectrum where they remain over the next few days (see Fig. 6). This is evident in the much lighter shades of green the samples exhibit over these days. As discussed above, the degradation continues on Day 12, where the colour shifts down again on the spectrum and is more or less maintained as slight and subtle variations occur throughout the remainder of the testing period.

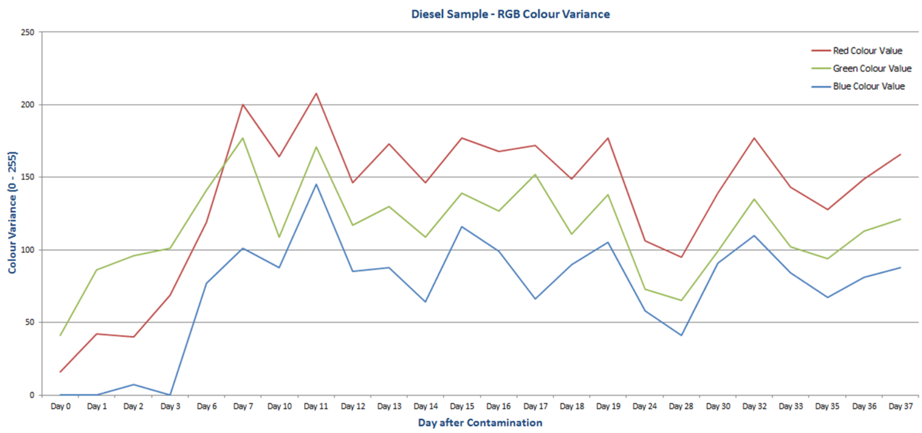

Fig. 6. RGB colour values plotted as a function of time after contamination with diesel

The much richer, dark brown tones are evident here as on Day 24 the colour shifts lower on the graph again towards the darker end of the spectrum,.where it once again slightly adjusts and is maintained until the conclusion of the testing period. The use of easily accessible applications for analysis and interpretation of these results has proved helpful in visualizing and understanding changes that occur in common vegetation.

3.3 Engine oil results analysis and discussion

A quick observation across the entirety of the images of Fig. 7 shows that while colour variance has occurred, it is much less significant than that of the other samples. The initial variance in colour occurs early on at the Day 3 mark, where the colour has faded from that of a dark, rich green, to that of a much more muted yellow tone. This colour still exists within the green spectrum however and doesn't exhibit any sort of discernible change in the quality of the leaves themselves. This variance continues on, subtly developing until Day 15 where it reaches a darker brown colour; from this point onwards it can be observed that there is no more colour variance occurring on each individual leaf. This can be seen quite clearly on Day 12, where the leaf colour varies throughout its length, reaching a darker, richer green the closer it is to its root.

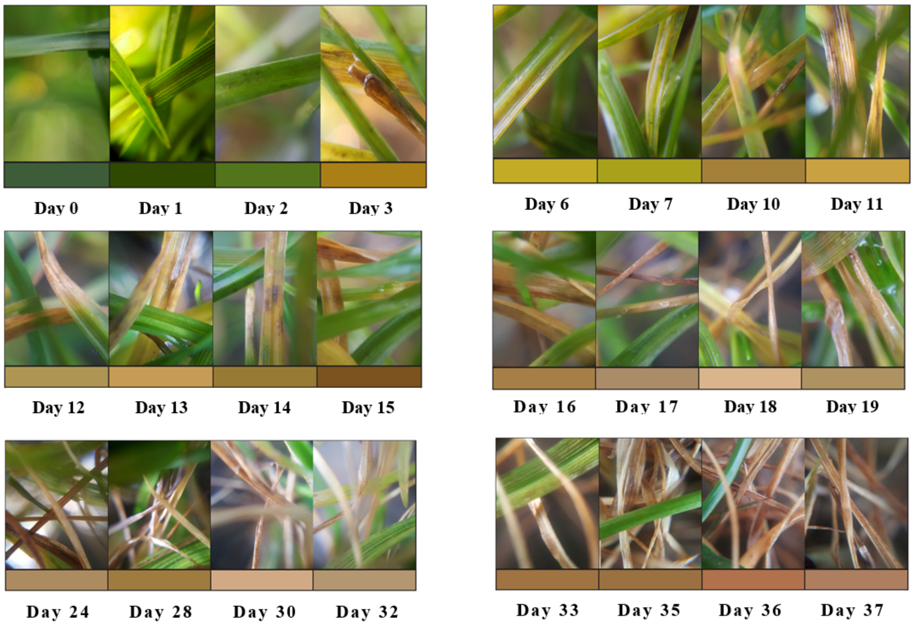

Fig. 7. Images of grass growth on soil contaminated with engine oil

This variance in individual leaves begins to peter off following this point, where it can be noted that the quality of the leaves themselves begins to fall. From Day 17 onwards, the leaves are noticeably thinner and paler, where, from this point, the colour variance seems to have stabilised as the leaf health and quality declines further until the end of the testing period. The point at which the leaves have begun to wither and die is a lot less obvious than in the previous sample as hints of colour can still be seen intertwined throughout the sample. The end of the testing period at Day 37 is the closest point at which the death of the leaves could be said to have occurred.

Once again from the graph (see Fig. 8), the initial colour variance is immediately observable in that on Day 3, there is an immediate shift towards the opposite end of the spectrum where the colour has become much lighter than the initial images. This variance begins to stabilise throughout the following images as discussed previously where the shift is much more subtle until Day 15, where it immediately drops off again towards the darker end of the spectrum. This moves back up over the next few days until Day 18 or so, where the variance in colour becomes much more maintained as the testing period progresses.

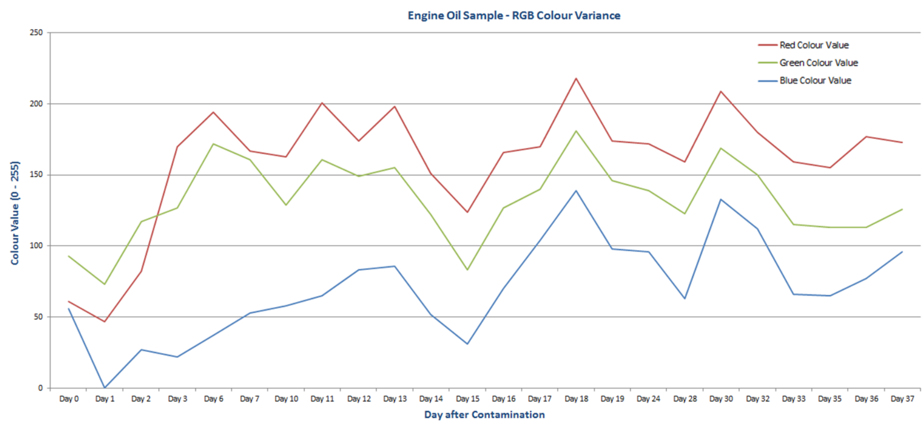

Fig. 8. RGB colour values plotted as a function of time after contamination with engine oil

3.4 Control results analysis and discussion

This sample exists to represent the benchmark to which all other samples should be compared to.

As can be seen from the images in Fig. 9 there is no degradation what so ever in the quality of the leaves with only slight variations in similar tones of the colour. These variations can simply be attributed to the different lighting conditions under which the samples were taken. The quality and dark, rich green colour of the sample remains throughout the testing process and is evident in the associated graph.

The lines on the graph (see Fig. 10) indicate that little to no colour variance occurred in the sample, as discussed above. Despite this, however, it serves as an important benchmark to which the other samples can be compared.

As the colour is maintained throughout, it can be seen that there is very little vertical shift on the lines indicating that they stayed within a very narrow field on the colour spectrum. Each of the graphs exists on the same axis in order to make these shifts in colour more obvious.

This graph serves as an indicator that the process used has effectively been able to track and display the associated colour variance undergone by the grass samples when contaminated. As the lines on this graph remain under 150 for all 3 colour bands throughout, it serves as an indicator to what the standards should be.

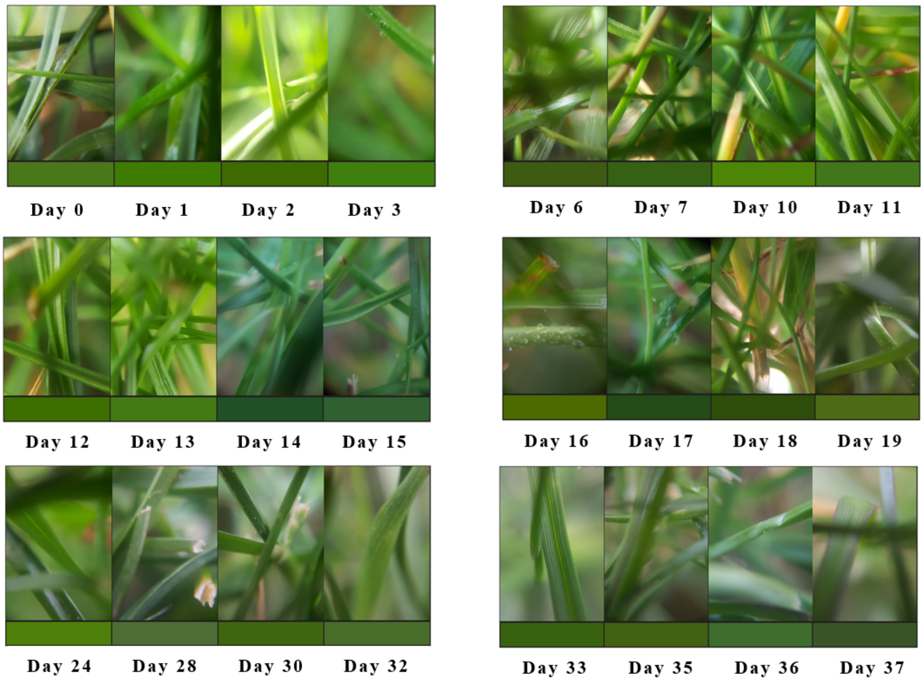

Fig. 9. Images of grass growth on uncontaminated soil

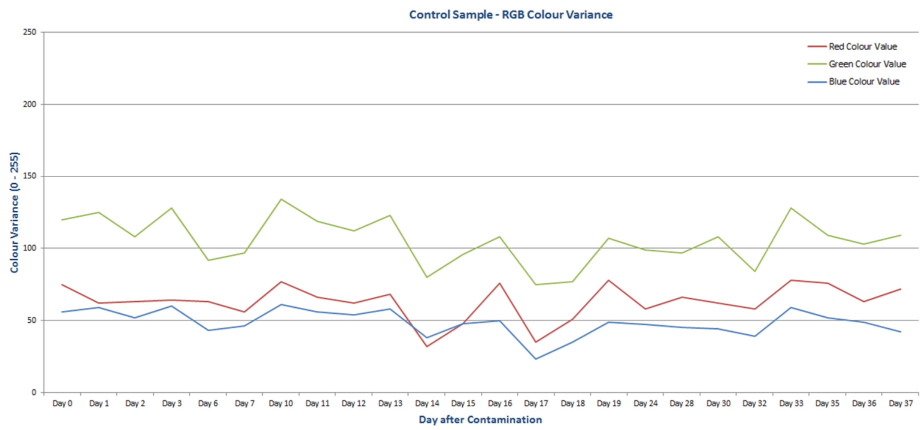

Fig. 10.RGB colour values plotted as a function of time

4 Conclusion

Results of the current research seem to confirm some of the assumptions made at the beginning of the study. While the effects of oil on grass are well known and have previously been documented, these results stand to not only confirm them, but also to serve as a benchmark to which other samples could be compared. Each of the samples were subjected to the same environmental conditions, meaning that the only variable was the type of oil used to contaminate that sample. This goes to show little variance from the anticipated results, thus confirming that the methods used for the process to be in accord with standard.

Environmental issues are complicated as most of them are open-ended. They oftentimes involve social, economic, cultural political and scientific factors, which are interwoven. The solution to these issues require a myriad of possibilities [8-11] and a process which involves understanding the practical implications of proposed solutions, evaluating scientific evidence and assessing proposals which could be loaded with environmental and economic consequences. Research into big data and visualization improves understanding and hence helps and should contribute to the making of informed decisions.

Were these experiments to be repeated on a larger scale, it is hoped that the results obtained would not only match up with the expected results, but that they also could serve as a basic guide, as a means of visually assessing the type of contaminant and severity of contaminated plant life across a number of different industries and sectors, including civil, urban, agricultural, marine, as well as learning tools in schools or colleges. As these environments and/or workplaces may not necessarily be made up of only specialists in this field, it is important that the original aim is adhered to in order to best serve as a teaching tool. The measuring and tracking of the colour variance between each sample was chosen as it was the most obvious and easily monitored change that occurred in the samples. This meant that the obtained results could potentially serve as a simple, intuitive indicator of the change that has taken place across a specified timeline of contaminated plant life that could be better understood by those outside of the engineering profession. We conclude that data visualization of diverse easily observable phenomena such as oil pollution has the potential to enhance learning in engineering education, aid assessment process and provide deeper understanding of the effect of such pollution on the environment.

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6 Authors

Conor White is a mechanical engineering graduate student in the School of Engineering, Faculty of Computing, Engineering and the Built Environment, Ulster University, Northern Ireland, UK.

James Uhomoibhi is an engineering educator, a computer scientist, a Chartered Physicist, a Chartered IT Professional and a Fellow of the British Computer Society (BCS). He served as Faculty coordinator of e-Learning from 2004-2015. He lectures in engineering and researches in Artificial Intelligence and Applications at Ulster University, Northern Ireland, UK. He is African Laser Centre (ALC) Representative in Europe and he is visiting Professor in Benin and Lagos (Nigeria) and Dar es Salaam (Tanzania). He is a member of Editorial Boards of several journals including iJEP, IJILT, JME.

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