Citation: Burgess, A.; Palmer, G.T.; Lowe, D.J.; Cooke, P.J. 2003. Progressing the science of effluent treatment using lasersizer diffraction analysis: a pilot study. *In:* Currie, L.D.; Hanly, J.A. (eds), "Tools for nutrient and pollutant management: applications to agriculture and environmental quality". *Fertilizer and Lime Research Centre, Massey University, Occasional Report* 17, 249-252.

PROGRESSING THE SCIENCE OF EFFLUENT TREATMENT USING LASERSIZER DIFFRACTION ANALYSIS: A PILOT STUDY

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Introduction

Disinfection of waste water with ultraviolet (UV) light is a common procedure in many sewage treatment plants because it is used to inactivate coliform bacteria in the effluent. The number of coliform bacteria in a given sample is used as a proxy to indicate the presence of targeted pathogenic organisms. Typically the coliform bacteria exist in a particle-associated state which results in their being shielded from the UV light (Darby et al., 1999). Such particles are documented in the size range 20 to 80 μm, and therefore measurement of the size distribution in a sample could be used to indicate the degree of shielding. UV treatment is less effective for particles larger than about 40 μm in size (Table 1).

Table 1. General comparison of mean particle size, bacteria concentration and UV effectiveness in treating effluent (after Darby et al., 1999; Cairns, 2003).

Particle size (μm)	UV effectiveness	Coliform bacteria concentration
<11	Increases	Decreases
11-40	⇑	⇓
>40	Decreases	Increases

Our pilot study used the laser diffraction technique to generate particle-size distributions of samples of effluent. By quantifying the amount of bacteria-shielding particles using this technique we were able to estimate the general efficacy of the UV sterilization process. The surface weighted mean diameter statistic was taken as a numerical measure of the bacteria-shielding particle size distribution.

Methods

The Malvern 'Mastersizer-S' lasersizer (long bed version) was used to generate particle-size distributions of effluent suspension samples. With a 300RF mm (Reverse Fourier) lens the Mastersizer-S is capable of measuring grains from 0.04 to 880 μm in diameter. It uses laser diffraction analysis which is based on the principle that particles of a given size diffract light through an angle that increases with decreasing particle size. When monochromatic light is passed through a suspension, the diffracted light is focussed on a multi-element ring detector that senses the angular distribution of scattered light. The scattered light distribution is

converted subsequently into a distribution of spherical particles that would provide the observed scattering intensity pattern (McCave and Syvitski, 1991; Hayton et al., 2001).

We obtained human effluent samples from the Pukete Waste Water Treatment Plant in Hamilton City. Four bulk 'grab' samples were collected at different stages of treatment as follows:

i after primary treatment

ii after secondary treatment

iii after UV treatment

iv prior to discharge (outlet to river).

Batches of liquid samples i–iv, each ~500 and 1000 ml in volume, were run through the lasersizer with no pre-treatment. Each sample was analysed three times, each analysis taking about 5 minutes.

Previous analysis of effluent had shown that such samples could sometimes generate a biofilm on the lasersizer lens, potentially compromising the integrity of the particle-size distributions. We therefore inspected the lens after each sample run both visually and using the live display facility associated with the computer monitoring software – biofilms show up as enhanced histograms on the detectors. We tried flushing the lasersizer system with both alcohol (ethanol) and detergent after each sample run to remove any biofilm build-up.

Results

Biofilms were visible around the edges of the lens, and evident as histograms on the live display detectors, if the lasersizer was not cleaned after processing each effluent sample batch. We found that flushing the lasersizer system with ethanol between sample batches removed the biofilms. Detergent flushing was less effective than the alcohol treatment, and necessitated further flushing with clean water to remove the detergent, and so was discontinued.

The mean diameters of particles from the primary-treated effluent (sample i) were ~7 μm, and those of particles from the secondary-treated, UV-treated, and outlet effluent (samples ii–iv) were ~27–29 μm (Fig. 1). The low errors associated with the triplicate analyses (Fig. 1) indicated that the lasersizer generates reproducible and reliable results. The Malvern software generates a report that shows size distributions as well as statistical parameters such as mean grain size for each sample (Fig. 2).

Discussion

On the basis of our limited number of analyses, it is evident that the Pukete plant effluent treatments are effective because the mean particle-sizes of the effluent samples all fall within the size range corresponding to efficacious UV sterilisation (Table 1). Because of the speed and simplicity of particle-size analysis using the lasersizer it may become feasible, with further research, for the plant to use this technique routinely to help monitor effluent properties to ensure that waste water is sufficiently sterilised when discharged back into the environment. The current cost of such analysis by lasersizer at the University of Waikato is <$60 per sample, with a turnaround time of around one week (depending on numbers of samples to be processed).

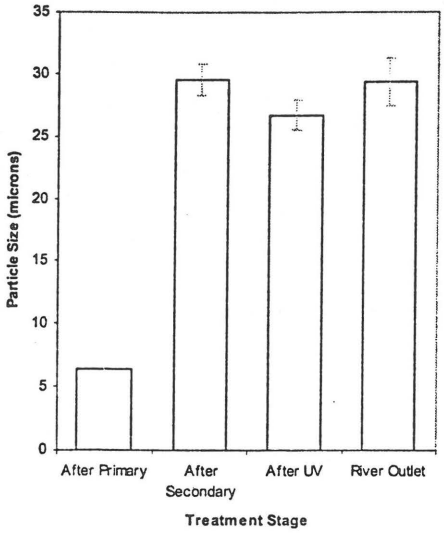


Fig. 1. Mean particle size of effluent samples from the four effluent treatment stages. Error bars are for instrument replication at 95% confidence intervals.

MALVERN INSTRUMENTS MASTERSIZER

Result: Histogram Report

User Name Alison Burgess — Security Level: 1

Sample Details

Sample ID: After UV Treatment
Sample File: RESEARCH
Sample Path: C:\SIZERS\DATA\ALI\
Sample Notes:

Run Number: 7
Record Number: 6

Measured: Wed Nov 12, 2003 4:37PM
Analysed: Wed Nov 12, 2003 4:37PM
Result Source: Analysed

System Details

Range Lens: 300RF mm
Presentation: 3OHD
Analysis Model: Polydisperse
Modifications: None

Beam Length: 2.40 mm
[Particle R.I. = (1.5295 0.1000), Dispersant R.I. = 1.3300]

Sampler: MS17

Obscuration: 2.0 %
Residual: 0.423 %

Result Statistics

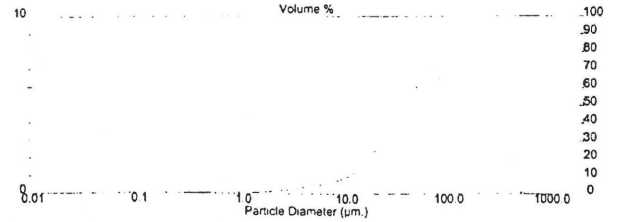
Distribution Type: Volume
Mean Diameters:
D [4, 3] = 94.14 um

Concentration = 0.0077 %Vol
D (v, 0.1) = 17.23 um
D [3, 2] = 25.73 um

Density = 2.560 g / cub. cm
D (v, 0.5) = 68.32 um
Span = 2.809E+00

Specific S.A. = 0.0911 sq. m / g
D (v, 0.9) = 209.14 um
Uniformity = 8.618E-01

Size (um)	Volume In %	Size (um)	Volume In %	Size (um)	Volume In %	Size (um)	Volume In %
0.050	0.00	0.813	0.07	13.23	1.00	215.2	2.20
0.056	0.00	0.909	0.07	14.79	1.18	240.6	1.90
0.063	0.00	1.02	0.07	16.54	1.40	269.0	1.62
0.070	0.00	1.14	0.07	18.49	1.65	300.7	1.32
0.078	0.00	1.27	0.08	20.67	1.94	336.2	1.02
0.087	0.00	1.42	0.08	23.11	2.26	375.9	0.76
0.098	0.00	1.59	0.08	25.84	2.59	420.2	0.45
0.109	0.00	1.78	0.09	28.89	2.94	469.8	0.10
0.122	0.00	1.99	0.10	32.29	3.30	525.3	0.02
0.137	0.00	2.22	0.12	36.11	3.64	587.3	0.00
0.153	0.00	2.48	0.14	40.37	3.96	656.6	0.00
0.171	0.00	2.77	0.17	45.13	4.25	734.1	0.00
0.191	0.00	3.10	0.19	50.46	4.49	820.7	0.00
0.213	0.00	3.47	0.23	56.41	4.66	917.6	0.00
0.238	0.00	3.88	0.26	63.07	4.76	1025.9	0.00
0.266	0.00	4.34	0.29	70.52	4.79	1147.0	0.00
0.298	0.01	4.85	0.33	78.84	4.75	1282.4	0.00
0.333	0.01	5.42	0.37	88.14	4.65	1433.7	0.00
0.373	0.02	6.06	0.41	98.55	4.54	1602.9	0.00
0.416	0.02	6.77	0.45	110.2	4.33	1792.1	0.00
0.466	0.03	7.57	0.50	123.2	3.98	2003.6	0.00
0.521	0.04	8.47	0.56	137.7	3.60	2240.1	0.00
0.582	0.05	9.47	0.64	154.0	3.23	2504.5	0.00
0.651	0.05	10.58	0.73	172.1	2.86	2800.1	0.00
0.727	0.06	11.83	0.85	192.5	2.52	3130.5	0.00
0.813	0.06	13.23		215.2		3500.0	



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Mastersizer S long bed Ver. 2.14
Serial Number 32913-57

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Fig. 2. Particle-size distribution and associated statistical data for a UV-treated effluent sample (mean diameter = 26 µm).

Conclusions

Our pilot study suggests that the analysis of particle-size distributions of effluent samples using laser diffraction techniques may provide a simple, fast, reproducible and cheap way of assessing the general effectiveness of the UV treatment of wastewater from sewage treatment plants. No special sample pre-treatment is required but flushing the lasersizer with ethanol between analyses prevents biofilm contamination. Further study would help to improve understanding of the relationships between particle size parameters, including mean grain size, and bacteria concentrations in effluent at various stages of treatment.

Acknowledgements

We thank David Hight, Operations Manager (Wastewater) of the Hamilton City Council, for providing samples and information. AB is particularly grateful to Dr Megan Balks for the opportunity to attend the ASPAC conference and for her help in preparing the poster paper. We also thank Lance Currie for allowing us extra time to prepare this paper and for his encouragement.

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