Appendices

Appendix 1: Questionnaire

March 17, 2014.

QUESTIONNAIRE

This survey is a pilot study as part of an on-going research on the measures for mitigation of foaming in anaerobic digesters. The research is aimed at developing a predictive model of foam formation in anaerobic digesters by identifying important design and operating variables that favour foaming. These variables will be used to calibrate and test the predictive model which will then form the basis of operating anaerobic digesters in a mode that reduces excessive foaming.

However, this particular survey is for the clarification of some vital issues that conflict each other as has been discovered during a review of the literature. It will also assist in making a useful decision on the factors to consider for the methodology.

It would be appreciated if you could spare 30 minutes of your time to respond to this questionnaire. Be assured that your participation is highly valued and absolutely necessary, while precautions have been put in place to protect your privacy.

Historical data within a period of six months or more on most of the survey questions (refer to 1.2, 1.3, 3.2 & 4.5) that relate to measured data will be invaluable.

Your contribution will be highly appreciated.

Name of Wastewater Treatment Plant:

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Location:

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1.0 Background of wastewater treatment works

1.1 What is the population equivalent contributing to the works?

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1.2 The influent characteristics in terms of:

S/n	Flow Characteristics	Values		
		Date 1	Date 2	Average
1	Flow rate to the works (m^3/d)			
2	Chemical oxygen demand (mg/l)			
3	Total suspended solid (mg/l)			
4	Ammonia-nitrogen (mg/l)			
5	Biological oxygen demand (mg/l)			
6	Iron (mg/l)			
7	Phosphorus (mg/l)			

Comments (If any):

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1.3 What are the consent conditions for the works?

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1.4 What is the secondary biological treatment process employed at the works (Activated sludge process (ASP), trickling filter, rotating biological contactor, sequencing batch reactor, etc.)?

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1.5 The operating parameter in terms of:

S/n	Operating Parameters	Values		
		Date 1	Date 2	Average
1	Sludge age (per day)			
2	Food to mass ratio			
3	Volumetric loading rate ($kgBOD/m^3$)			
4	Mixed liquor suspended solid (mg/l)			
5	Recycle ratio			
6	Sludge volumetric index			

Comments (If any)

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1.6 Is there any microbial organism selector zone? Yes or No

If yes, how effective is it?

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What is/are the identified microbial organisms selected?

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1.7 Are there any biological nutrient removal processes done as part of the tertiary treatment process? Yes or No

If yes, what are they?

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Procedure used?

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1.8 Has bulking sludge been experienced in the secondary clarifier? Yes or No

If yes, to what extent and how was it treated?

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2.0 Anaerobic digester design

2.1 A brief description of the AD highlighting the following:

a. Shape and size

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b. Age of the digester

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c. Point of loading and withdrawal of the sludge

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d. The presence of scum remover

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e. Slope of the gas pipe

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f. Monitoring and measuring instrument

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Further comments (If any):

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3.0 Anaerobic digester (AD) process

3.1. What are the constituents and proportion of waste in the AD?
(Primary sludge, surplus activated sludge, humus, codigestates such as feedstocks and septic waste, etc)

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3.2 What are the operating parameters? These may include factors such as:

S/n	Operating Parameters	Values
1	Frequency of feeding	
2	Solid retention time	
3	Temperature	
4	pH	
5	Alkalinity	
6	Organic loading rate	

Comments (If any)

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3.3 How is mixing of sludge achieved in AD? Gas or Mechanical

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3.4 How is the temperature in the AD maintained?

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3.5 Is there analysis of the content such as surfactants, biosurfactants, volatile fatty acid (VFA), FOG, detergents, proteins? Yes or No

If yes, please comment:

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4.0 Foaming history

4.1. Has there been any evidence of foaming? Yes or No

If yes, was it during the start up or any other time? Please specify.

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4.2 How is foaming identified? (Monitoring gadgets or Physical observation, etc)

Comments (If any):

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4.3 How is foaming measured? (Height, volume, diameter, e.t.c)

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4.4 Do you have data on the foam measurements? Yes or No

If yes, for how long have these been collected?

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4.5 If data are available will you be able to make it available for the current research? Yes or No

4.6 Is foaming seasonal? Yes or No

4.7 What adverse conditions could be related to the foaming incidence?

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4.8 Is there any pre-treatment of sludge on site to reduce foaming? Yes or No

If yes, what method of pre-treatment was used?

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How effective is the control measure?

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5 Gas production

5.1 What is the volume of biogas produced?

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5.2 What is the average volume of methane, carbondioxide, water vapour and hydrogen sulphide in the biogas?

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5.3 How long does the biogas stay in the AD before it is transferred to the storage tank?

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5.4 How is the biogas transferred to the storage tank?

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5.3.1 Any other Issues considered relevant to this study but not dealt with in this survey:

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Thank you for taking your valuable time to complete this questionnaire.

Appendix 2: Summary of response to Questionnaire

	AF	Hatton	NB	SF
PE	124,450	250,433	76,000	806,883
Influent quality				
Flow rate to the works (m3/d)	26831	112994	9819	335226
Chemical oxygen demand (mg/l)	427	233	404	297
Total suspended solid (mg/l)	204	135	180	168
Ammonia-nitrogen (mg/l)	25	13.2	25	17
Biological oxygen demand (mg/l)	167	85	162	116
Iron (mg/l)	n/a	n/a		
Phosphorus (mg/l)	n/a	n/a	5	
Biological treataboility	0.391100703	0.364806867	0.400990099	0.390572391
Consent				
BOD	<25 mg/l	<25 mg/l	15 to 50	25 to 50
TSS	<35 mg/l	<35 mg/l		150 to 375
COD	≤125 mg/l	≤125 mg/l	125 to 250	125 to 250
Faecal Coliform (UV)	<2000 cfu/100ml			
Transmissivity (UV)	>40%			
Pellets		<90		
Phosphorus			0.5	
Aluminium			1 to 2	
Ammonia			7 to 27	
Zinc andChromium				1000 to 2000
Turbidity				25 to 50
Copper				300 to 600
ASP operation conditions				
Sludge age (per day)	5 days	5 days	2.7 days	3.3 days
Food to mass ratio	0.23	0.18	0.08	0.34
Volumetric loading rate (kgBOD/m3)	0.69	0.052	0.117	0.073
Mixed liquor suspended solid (mg/l)	2984	2170	2972	2030
Recycle ratio	0.56	0.31	0.8	0.83
Sludge volumetric index	95.62	45.2	76 (SSVI)	83

ASP operation conditions contd.				
	AF	**Hatton**	**NB**	**SF**
Bulking sludge	No response	No response	Few events with bulking sludge, treated with hypo	No response
Digester configuration				
No of cylinders	1	2	2	6
Diameter (m)	14.489	14	12.6	15
Height (m)	12	14	12.5	13.84
Volume (m^3)	1979			
Proportion of feed to Digester				
	88% of digester feed is centrifuge thickened mixed sludge at 8.1 %DS:	GBT thickened sludge at 7.19 DS:		
	55% SAS	48% secondary	15% Thickened secondary sludge at 5.74 DS	36% thickened at 5.72% DS secondary sludge + import (Gravity belt thickener)
	33% Primary	44% primary sludge	33% Thickened primary sludge at 4.48% DS	64% thickened at 4.28% DS primary sludge (Picked fence thickener)
	12% is diluted imported cake at 9.30% DS	8% mixed import	52% Import mixed secondary primary at 3.2% DS (assumption, DS may largely vary)	

Operating conditions in the AD	**AF**	**Hatton**	**NB**	**SF**

Frequency of feeding	10 min / 30 min	10 min / 30 min	10 min / 30 min	20 min / 2 hours
Solid retention time	37.1 days	16 d	19 days	14.6 d
Temperature	33.2	36	Dig 1: 40 / Dig 2: 39.7	35
pH	7.61	7.1	Dig 1: 7.28 / Dig 2: 7.3	7.2, (5.7 feed)
Alkalinity	9535 mgCaCO3/l(outlet)	3221 mgCaCO3/l	Dig 1: 4215 mgCACO3/l ; Dig 2: 3901 mgCACO3/l	5700 (ideally in the range of 2000 to 4000mg CaCO3/L)
Organic loading rate	1.37 kgVS/m3.d	2.9 kgVS/m3.d	1.5 kgVS/m3.d	2.8 kgVS/m3.d
Mixing	Gas	Gas	Mechanical impeller	Sludge recycling
VFA	250mg/L (ideal 50-300mg/L)	N	13 / 15.8 mg/ L	N
Foaming	Yes; 2008 - 2012	Yes, 2 foaming events ever	No	Frequent foaming
Adverse conditions	Intermittent loading	Load increased in digesters	No	SAS/primary sludge ratio (more foaming when high SAS ratio, >50%)
	possible foaming in the ASP			Foam in ASP
	bad temperature regulation			Outlet pipe causing headlosses (might be too small)
	Changing levels			
Biogas (Nm^3/d)	2837	5863	1975	23255
Biogas (methane)%	59.77	61	64.5	63

Responses that were common to the various wastewater treatment works
1. Monitoring and measuring instrument Common flow meter for both digesters (Hatton) Pressure sensor Hydrostatic sensor for level Charis probe (Hatton only) Pressure relief valve
2. How is heating achieved? Sludge Recirculation with a water/sludge heat exchanger
3. How is foaming identified? (Monitoring gadgets or Physical observation, etc) Going through the gas line and trhough the pressure relief valve. In Hatton through Charis probe + coming out of Pressure relief valve
4. How is foaming measured? (Height, volume, diameter, e.t.c) Not measured, level of foam sporadically checked visually (sight glass on top of digesters)
5. Use of foaming control measures In AF and Hatton, Antifoaming (BURST) is dosed in the heating recirculation circuit in Seafield, Continuous anti foaming dosing (combination of BURST in the recirculation heating circuit and SNF in the digester feed tank)
6. How effective is the control measure? Situation improved but uncertain if it is due to better operation or antifoaming
7. How long does the biogas stay in the AD before it is transferred to the storage tank? Directly stored in gas holding tank
8. How is the biogas transferred to the storage tank? Pipes, no pumping. Pressure is controlled by the gas holder itself

Appendix 3: List of putative metabolites used in metabolomics analysis

Mass	RT	FORMULA	Isomers	Putative metabolite	Confidence	TvsCTRL	Pvalue
132.0535442	13.38909084	C4H8N2O3	6	L-Asparagine	10	25.65	0.069
342.1165568	13.69937306	C12H22O11	42	Sucrose	8	19.02	0.157
132.0898762	18.18791964	C5H12N2O2	6	L-Ornithine	8	13.92	0.19
146.0690093	13.21489134	C5H10N2O3	6	L-Glutamine	10	6.81	0.164
105.0425692	13.74248152	C3H7NO3	3	L-Serine	10	4.58	0.132
155.0695018	14.32411857	C6H9N3O2	5	L-Histidine	10	3.49	0.286
133.0375772	12.91654068	C4H7NO4	4	L-Aspartate	8	2.99	0.056
257.1025247	12.81192399	C8H20NO6P	1	sn-glycero-3-Phosphocholine	10	2.93	0.139
189.0639417	11.97781999	C7H11NO5	4	N-Acetyl-L-glutamate	8	2.47	0.373
196.0583925	12.441623	C6H12O7	11	D-Gluconic acid	10	2.36	0.352
208.0849945	10.81704125	C10H12N2O3	2	L-Kynurenine	10	2.33	0.421
117.0790327	10.97642223	C5H11NO2	16	Betaine	10	1.81	0.002
219.1105736	8.654877112	C9H17NO5	1	Pantothenate	10	1.71	0.057
147.053012	12.69078463	C5H9NO4	14	L-Glutamate	10	1.65	0.234
115.0634211	12.04739994	C5H9NO2	4	L-Proline	10	1.63	0.499
89.04772391	13.22720002	C3H7NO2	9	L-Alanine	8	1.54	0.368
113.0589747	9.905976585	C4H7N3O	1	Creatinine	10	1.51	0.204
134.0215662	13.34366674	C4H6O5	4	(S)-Malate	10	1.47	0.566
104.047323	9.209706813	C4H8O3	13	(R)-3-Hydroxybutanoate	10	1.41	0.289
119.0582821	12.96571482	C4H9NO3	11	L-Threonine	10	1.4	0.399
149.0510217	11.17225541	C5H11NO2S	5	L-Methionine	10	1.39	0.56
152.033395	10.87878394	C5H4N4O2	3	Xanthine	10	1.38	0.344
125.0146505	13.15593171	C2H7NO3S	1	Taurine	10	1.37	0.59
175.095684	13.76013208	C6H13N3O3	3	L-Citrulline	10	1.36	0.625
169.0739449	8.323078452	C8H11NO3	4	Pyridoxine	8	1.26	0.104
148.0371902	12.71443353	C5H8O5	18	(R)-2-Hydroxyglutarate	8	1.23	0.667
75.03190248	13.76894072	C2H5NO2	3	Glycine	10	1.22	0.658
307.0833575	12.42547377	C10H17N3O6S	3	Glutathione	10	1.19	0.608
244.069367	9.989072333	C9H12N2O6	3	Uridine	10	1.17	0.582
136.038615	10.2675916	C5H4N4O	3	Hypoxanthine	8	1.16	0.222
165.0789906	10.27291475	C9H11NO2	7	L-Phenylalanine	10	1.15	0.453
123.0320387	7.688774655	C6H5NO2	4	Nicotinate	8	1.12	0.559
203.1158599	10.77060004	C9H17NO4	1	O-Acetylcarnitine	8	1.07	0.595
156.0170899	9.840512004	C5H4N2O4	2	Orotate	8	1.01	0.925
131.0946815	10.74676672	C6H13NO2	12	L-Leucine	10	1.01	0.958

174.1116858	20.73201234	C6H14N4O2	2	L-Arginine	10	1	0.998
204.0899024	11.45627085	C11H12N2O2	6	L-Tryptophan	10	0.91	0.819
103.0997285	17.63666676	C5H13NO	1	Choline	10	0.89	0.779
240.0239765	13.57962918	C6H12N2O4S2	2	L-Cystine	10	0.87	0.778
268.0806768	10.72385503	C10H12N4O5	3	Inosine	8	0.85	0.572
267.0965355	9.385093821	C10H13N5O4	3	Adenosine	10	0.85	0.494
111.0433621	11.14931482	C4H5N3O	1	Cytosine	10	0.8	0.548
166.0267514	12.09269624	C8H6O4	7	Phthalate	9	0.68	0.426
118.0266832	12.74178527	C4H6O4	7	Succinate	10	0.58	0.118
151.0494386	11.99110421	C5H5N5O	3	Guanine	10	0.56	0.215
135.0545471	9.855144472	C5H5N5	1	Adenine	10	0.49	0.031
183.0660987	13.06502701	C5H14NO4P	1	Choline phosphate	10	0.41	0.131
88.01603341	7.767032049	C3H4O3	3	Pyruvate	10	0.37	0.118
163.0303349	7.74185134	C5H9NO3S	1	Acetylcysteine	7	0.35	0.022
130.0266976	12.08011486	C5H6O4	7	Itaconate	10	0.34	0.321
103.0633654	13.55872219	C4H9NO2	14	4-Aminobutanoate	10	0.32	0.266
192.0271425	14.31354215	C6H8O7	12	Citrate	10	0.03	0.405

Appendix 4: Link to IDEOM_Ify_Kanu_results.xlsb

https://heriotwatt-my.sharepoint.com/personal/irk1_hw_ac_uk/_layouts/15/guestaccess.aspx?docid=16551eb7f0e194a2ab869ddbf6466e7ef&authkey=Ac3cp9S33mWZ2UbNadyoc9k&e=d2385b37e88341afb13698cdd4f4a252