‘SolarMix’ - Innovation in Drying Technology

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Abstract

The dramatic population increase in South East Queensland has seen a significant increase in the load placed upon our Sewage Treatment Plants (STPs) and a dramatic increase in the amount of biosolids produced at these STPs. Dewatered biosolids produced by most Water Authorities consists of 85 % water and only 15% solids and it is difficult to achieve a higher solids content with conventional equipment without sacrificing machine efficiency. At present Water Authorities in South East Queensland spend between $40 and $50 per wet tonne for removal and disposal of biosolids which generally represents the highest expenditure component of the total operational budget of an STP. Achieving a significantly higher solid content in the biosolids would obviously represent a major operational cost saving for the Water Authority. A secondary problem faced by these STPs is difficulty consistently meeting Stabilisation Grade B as the biosolids produced have not received the required digestion/treatment times to reach the Stabilisation Grade B requirements. As a result, Stabilisation Grade C biosolids is produced and is always a management problem to both biosolids producers and beneficial reuse end-users in high population growth areas. A simple, economical, and environmentally friendly method of volume/mass reduction and further biosolids stabilisation is air-drying, however, traditional air drying has a reputation for being labour intensive, sometimes odorous, and particularly susceptible to rainfall in coastal areas.

Cabwater recently commissioned the ‘SolarMix’ process at the Burpengary East STP where solar energy & air drying is used to enhance the solids content and the stability of the biosolids in a manner that is protected from rainfall. The ‘SolarMix’ technology has taken the traditional method of bed air-drying and used modern technology to remove the traditional problems. This process has not only had a positive impact on the operational budget by reducing the amount of biosolids removed from the STP but has also significantly increased the stability of the biosolids which presents Cabwater with a number of other options for beneficial reuse.

The results collected to date confirm that the process is capable of continually producing biosolids with a solid content in excess of 65% (during both summer and winter) as well as reducing the levels of bacteria and pathogens to the point that it meets stabilisation grade A. The end result is dependant on the initial solid content, the biosolids type (STP treatment process), and climatic conditions.

Introduction

The Caboolture Shire is located approximately thirty minutes north of Brisbane and is currently one of the fastest growing areas in South East Queensland. Cabwater is a business unit of Caboolture Shire Council that is responsible for the operation and maintenance of water and sewerage units. Cabwater currently generates approximately 14,000 tonnes of dewatered biosolids from four STPs. The cost involved in removal & disposal of biosolids is expected to increase significantly in future as there are not many options available in the market for biosolids of this quality at present.

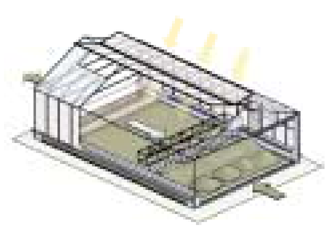
In 2000, Mixwell Pty. Ltd. submitted a proposal to install a “SolarMix” facility that utilises solar radiation in a controlled climate hothouse to increase the solid content of the biosolids as well as enhance the stabilisation of the biosolids. Although this facility was the first of its kind in Australia, the technology was being successfully utilised throughout Germany and several other European countries. After Cabwater conducted a detailed investigation that included several field trials and a visit to several solar drying facilities in Europe, it was strongly believed that the technology could deliver positive results in Queensland where the climatic conditions are far better suited to the solar drying process than in Europe.

2. Objectives of the Project

The primary objectives of this project were to assess the solar drying facility with respect to:

A. Rate of mass reduction of biosolids produced at four STPs conditions.
B. Rate of reduction in SOUR and pathogens (stabilisation)
C. Operational problems including odour & nuisance
D. Economic feasibility of process under prevailing conditions in Queensland.

3. Principles of Solar Drying Process



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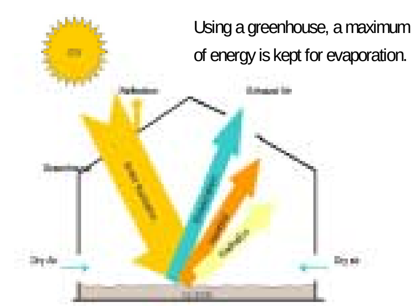

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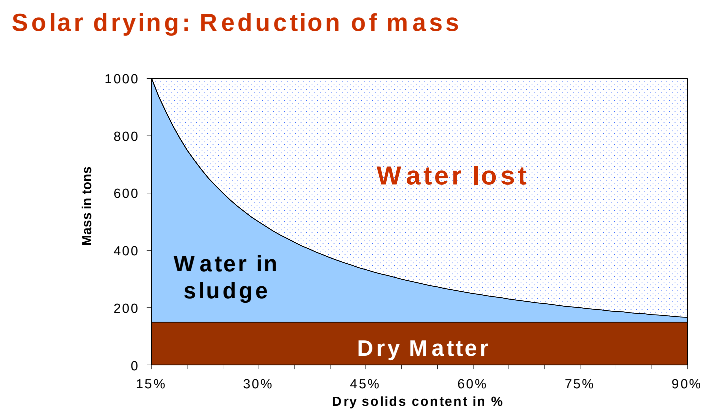
The principle adopted by this process is very simple - “air drying using solar radiation”. The radiation of the sun is used to heat the surface of the wet sludge spread evenly in the hot house and subsequently the warm sludge surface heats up the air in contact with the sludge which is always cooler than biosolids surface. This activity creates a positive differential vapour pressure between wet biosolids and the air layer in contact with the biosolids and subsequently water molecules from biosolids layer escape into open environment. The driving force for the drying process is the amount of radiation that reaches the biosolids surface and the amount of differential vapour pressure created. The performance of the process will be optimised when the environment has the driest possible air (lowest atmospheric humidity). Ventilation is an important factor to continually remove moisture laden air from the surface of the biosolids and replace it with fresh dry air.

3.1 Mass Reduction.



[3]

% of Solids	Dry Solids	Water	Total Weight	% of Reduction in Total Weight
15	150	850	1000	0
20	150	600	750	25
25	150	450	600	40
30	150	350	500	50
35	150	279	429	57
40	150	225	375	63
45	150	183	333	67
50	150	150	300	70
55	150	123	273	73
60	150	100	250	75
65	150	81	231	77
70	150	64	214	79

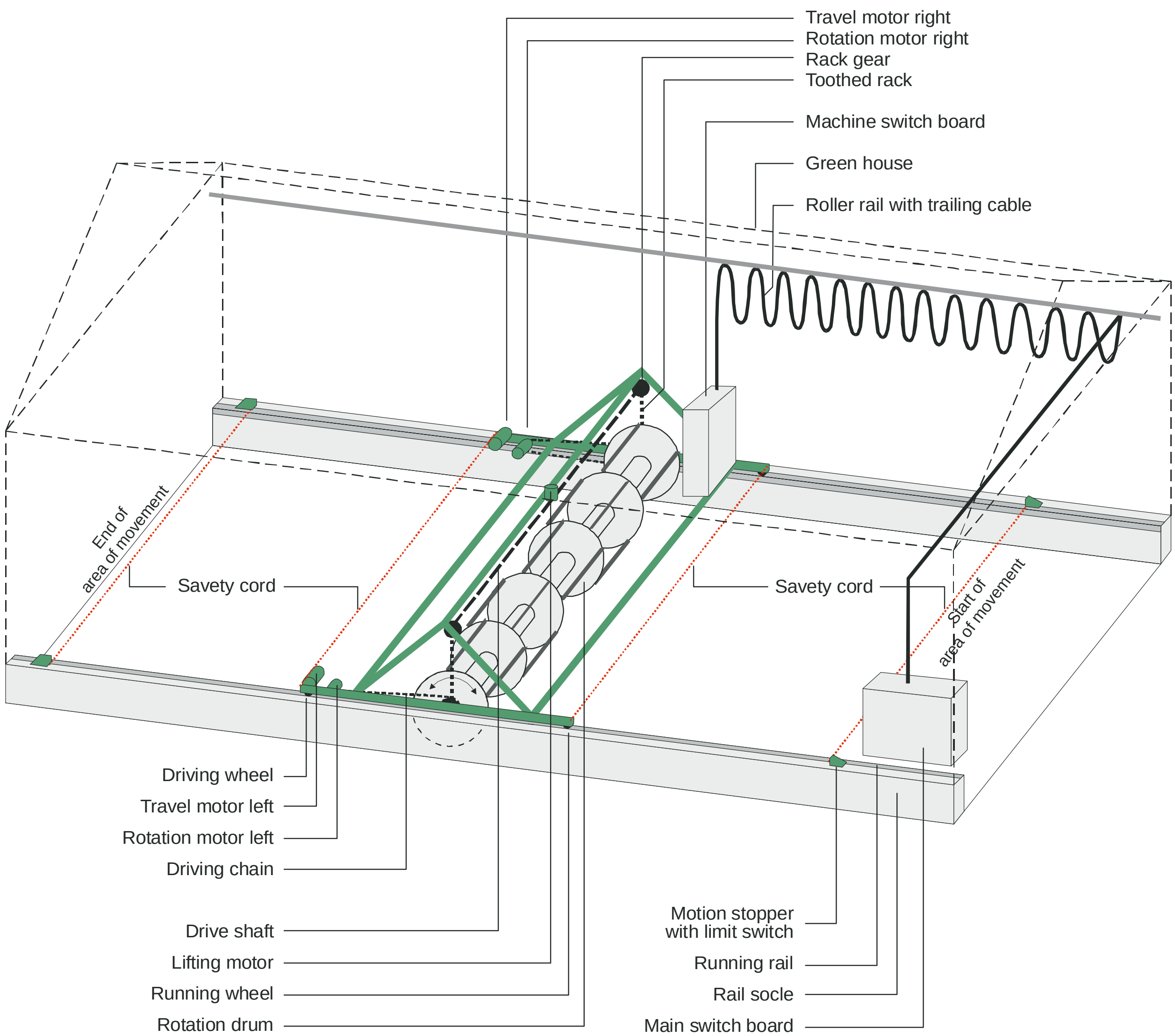
It is worthwhile to note that the total mass is reduced by 50% when the moisture content is increased from 15% to 30%. Further, the total mass is reduced by 70% when the moisture content is increased to 50%. When choosing a target finished product moisture content is it important to keep in mind that the mass reduction achieved is an exponential scale with the majority of the mass reduction occurring in the low % moisture range, therefore the optimal finished product moisture content will be between 30 and 50%.

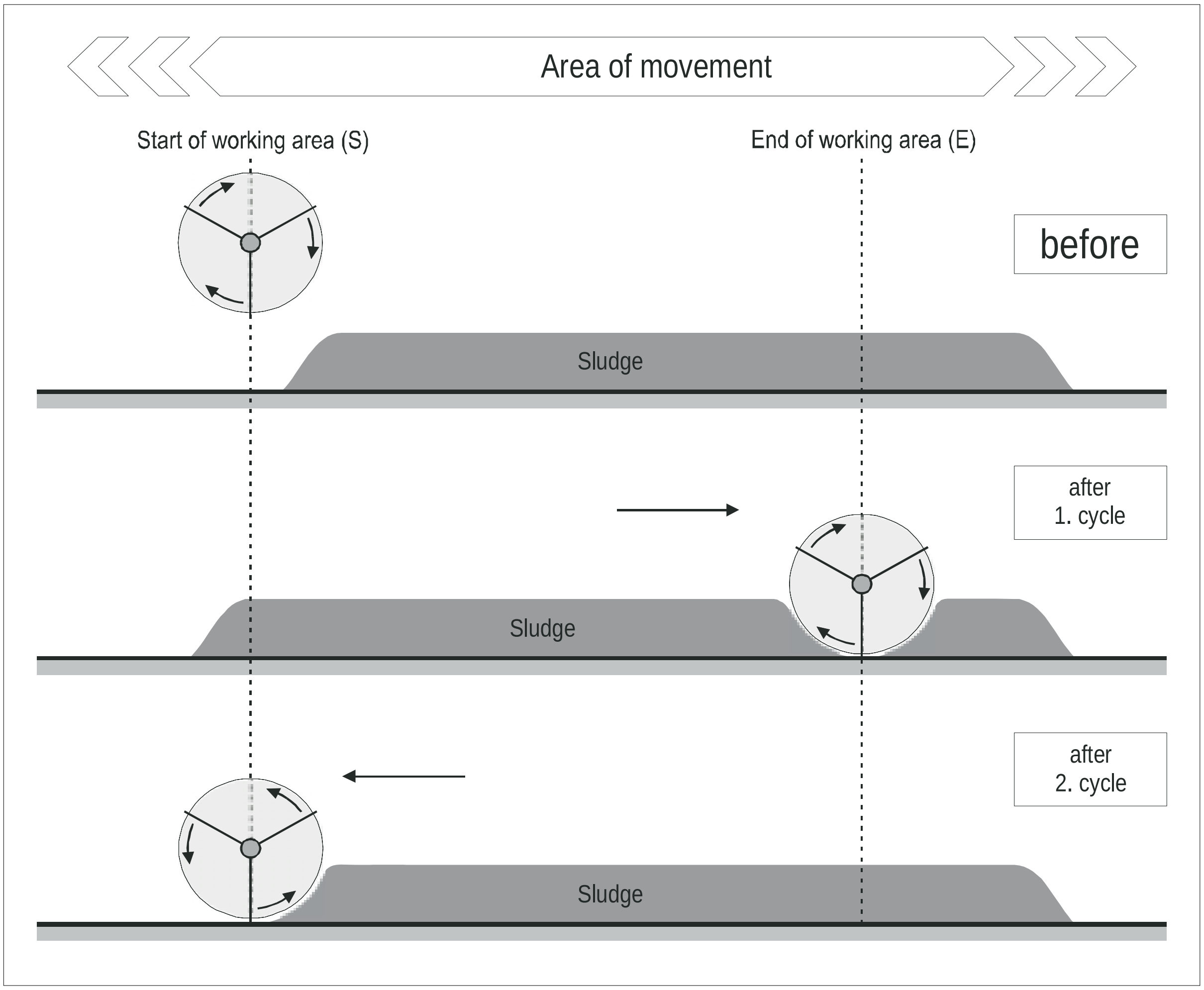
3.2 Process Description

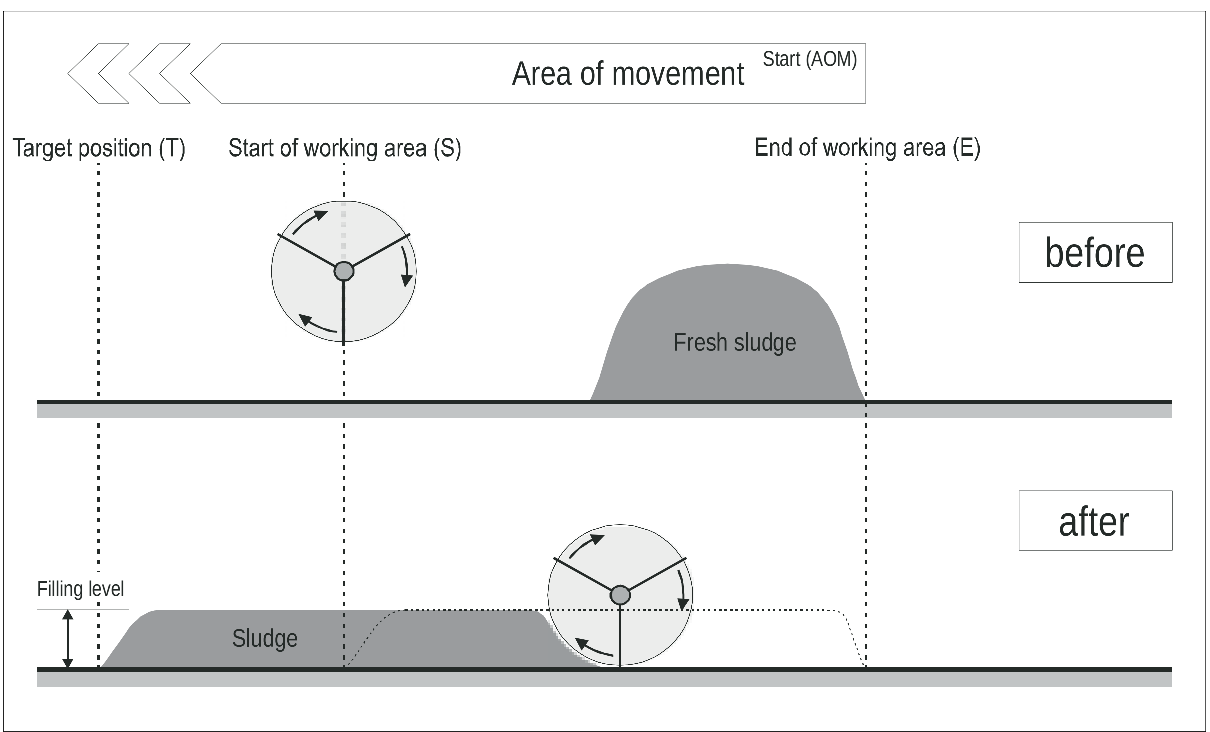
The ‘Solar Drying’ technology has utilised the traditional principals of air drying biosolids and enhanced the process to produce a consistent, quality controlled product. Unlike other ‘protected solar drying technologies’, the ‘SolarMix’ process does not work on a ‘Batch Basis’ and instead works on a continual input – continual output process. In the ‘SolarMix’ drying hall, the dewatered biosolids are loaded either manually or via a loading conveyor into the front of the cell and removed via an ‘in floor’ load-out conveyor at the rear of the drying hall. The cell is also equipped with a hall ventilation system which moves air through the drying hall and ventilates it directly to the atmosphere. The automated biosolids agitator moves along the drying hall and breaks the ‘crust’ formed on the biosolids (to accelerate the natural drying process) while forming pellets and progressing the biosolids along the drying cell. As the product is continually turned, the product is continually aerated and does not become anaerobic and odorous. Unlike other ‘protected solar drying technologies’, the automated biosolids agitator used in the ‘SolarMix’ process treats the entire cell evenly ensuring that no biosolids escape the agitation process and therefore a consistent quality controlled product is produced. The hothouse can be open ended to allow natural ventilation (like the East Burpengary facility) or can be entirely enclosed with forced ventilation to enable capture and treatment of the moisture laden exhaust air in areas where odour is a sensitive issue. The cell is 100 metres long and 10 metres wide and it generally takes between 18 to 28 days for the biosolids to proceed from start to finish depending on number of turns programmed per day. On average the agitator turns the biosolids 8 times a day and each turning cycle takes approximately 1.5 hours.

‘SolarMix’ Basic Description

Figure 1. Diagram of the East Burpengary WWTP ‘SolarMix’ (Note: diagram not to scale)




Area of movement
Start of working area (S)
End of working area (E)
before
Sludge
after
1. cycle
Sludge
after
2. cycle
Sludge


Area of movement
Start (AOM)
Target position (T)
Start of working area (S)
End of working area (E)
before
Fresh sludge
after
Filling level
Sludge

Capacity of Solar Drying Process Possible Savings

The capacity of the 'SolarMix' process mainly depends upon the floor area, evaporation factor (moisture evaporation rate), and the solids content required at the end of process. The evaporation factor is also influenced by the type of biosolids, ambient relative humidity, number of turns per day, and the amount of air flow through the drying hall. The following table displays the capacity of 'SolarMix' drying hall and the quantity of biosolids that can be processed per year depending on the target finished product % TSR. Please note that the Burpengary East WWTP 'SolarMix' facility has achieved a consistent average evaporation factor of 8.0 kg water/m^2/day during both summer and winter.

Final Solid Content (% TSR)	% of Mass Reduction	Evaporation Factor (kg of water lost/square metre/day)								
		2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
		Amount of Water Lost per Annum in Tonnes								
		657	**986**	**1314**	**1643**	**1971**	**2300**	**2628**	**2957**	**3285**
		Amount of Biosolids (at 15% TSR) Processed per Annum (Tonnes)								
20	**25**	2628	3942	5256	6570	7884	9198	10512	11826	13140
25	**40**	1643	2464	3285	4106	4928	5749	6570	7391	8213
30	**50**	1314	1971	2628	3285	3942	4599	5256	5913	6570
35	**57**	1151	1726	2301	2877	3452	4027	4602	5178	5753
40	**63**	1051	1577	2102	2628	3154	3679	4205	4730	5256
45	**67**	985	1478	1970	2463	2955	3448	3940	4433	4925
50	**70**	939	1408	1877	2346	2816	3285	3754	4224	4693
55	**73**	904	1356	1807	2259	2711	3163	3615	4067	4519
60	**75**	876	1314	1752	2190	2628	3066	3504	3942	4380
65	**77**	854	1282	1709	2136	2563	2990	3417	3845	4272
70	**79**	836	1254	1672	2090	2509	2927	3345	3763	4181
		Possible Amount of Savings (based on Caboolture Shire costings)								
20	**25**	32850	49275	65700	82125	98550	114975	131400	147825	164250
25	**40**	32860	49280	65700	82120	98560	114980	131400	147820	164260
30	**50**	32850	49275	65700	82125	98550	114975	131400	147825	164250
35	**57**	49386	65814	82243	98700	115129	131557	147986	164443	180871
40	**63**	49344	65781	82188	98625	115063	131469	147906	164313	180750
45	**67**	49333	65767	82167	98600	115000	131433	147833	164267	180667
50	**70**	49365	65780	82195	98610	115060	131475	147890	164340	180755
55	**73**	49373	65809	82209	98645	115082	131518	147955	164391	180827
60	**75**	49350	65775	82200	98625	115050	131475	147900	164325	180750
65	**77**	49346	65808	82231	98654	115077	131500	147923	164385	180808
70	**79**	49343	65764	82186	98607	115068	131489	147911	164332	180754

'SolarMix' Trial Results and Discussions

CabWater has used the following table to calculate the predicted moisture lost in the 'SolarMix' dryer. On average the dewatered biosolids produced at East Burpengary WWTP has a Total Solids Residue of approximately 15%.

Trial No 1 Winter Rate of Loading: 4200 wet tonnes/annum (11.5 wet t/day)

No of Days In Cell	**Solids Content (%)**					
	25-Jul-03	**14-Aug-03**	**19-Aug-03**	**22-Aug-03**	**26-Aug-03**	**Average**
1	14.60	13.81	12.88	13.41	14.33	13.80
2			14.35			14.35
3	16.15	15.56		14.50	15.65	15.46
4			15.51			15.51
5	17.78	16.72		16.03	14.50	16.26
6			15.46			15.46
7	19.26	17.52		17.64	16.69	17.78
8			22.56			22.56
9	20.75			17.61	17.65	18.67
10		18.12	24.48			21.30
11	24.93			20.29	19.35	21.52
12			18.55			18.55
13	26.31			21.42	21.52	23.08
14		22.01	23.00			22.50
15	21.95			21.62	21.99	21.85
16			22.58			22.58
17	24.35			21.68		23.01
18			22.88		26.27	24.57
19	26.32			26.39		26.35
20			23.86		25.00	24.43
21	26.52					26.52
Evaporation Factor	**8.3**	**9.51**	**7.28**	**7.8**	**7.62**	**8.10**

Trial No 2 Summer Rate of Loading: 3300 wet tonnes / annum (9.0 wet t / day)

No. of Days In Cell	**Solid Content (%)**						**Average**
	30-Sep-03	19-Oct-03	6-Nov-03	26-Nov-03	10-Dec-03	5-Jan-04	
1	16.2	15.4	15.7	14.7	15.8	14.2	15.3
2	17.0	17.1		18.2	15.9	15.5	16.7
3	17.2	17.2	16.9	18.2	17.2	16.9	17.3
4	17.6		17.7	21.1	17.2	17.8	18.3
5		18.9	20.3	23.8	18.3		20.3
6		19.5		29.1		18.6	22.4
7	20.4	20.5	23.7	31.6		20.0	23.2
8	20.7	22.8	25.2	35.6			26.1
9		25.3	26.9		22.0	23.2	24.4
10	25.3	26.2	29.2	39.0	24.4	23.7	28.0

11	30.0	28.2	32.9	40.7	23.8	23.7	29.9
12	34.6		39.2	41.0	28.7		35.9
13	42.4	33.3	56.3	51.4	29.3	26.7	39.9
14	52.7	30.6	63.2		35.7	32.4	42.9
15	60.0	39.5				40.7	46.7
16					46.3	47.0	46.7
17	66.9	59.2			53.0	51.0	57.5
Evaporation Factor	**8.1**	**8.81**	**8.5**	**7.32**	**9.2**	**8.2**	**8.4**

Trial No 3 Autumn Rate of Loading: 5300 wet tonnes / annum (14.5 wet t / day)

Date	**Distance From Start in meters**								
	0	20	30	40	50	60	70	80	90
18/04/04	15.2		17.4		19.2		24.8		30.4
19/04/04	14.9	17		18.8		20.8		25.9	
22/04/04	15.2		17.8		20.2		23.4		27.3
23/04/04	15	16.4		19.1		21.5		26.1	
25/04/04	15.3		17.3		19.8		23		29
26/04/04	15.1	15.4		18.6		21.8		25.6	
27/04/04	15		16.6		20		23.5		28.4
28/04/04	15	15.9		18		20.9		25.8	
01/05/04	15.3		16.9		17.5		21		26.8
02/05/04	14.5	15.5		17.5		18.6		22	

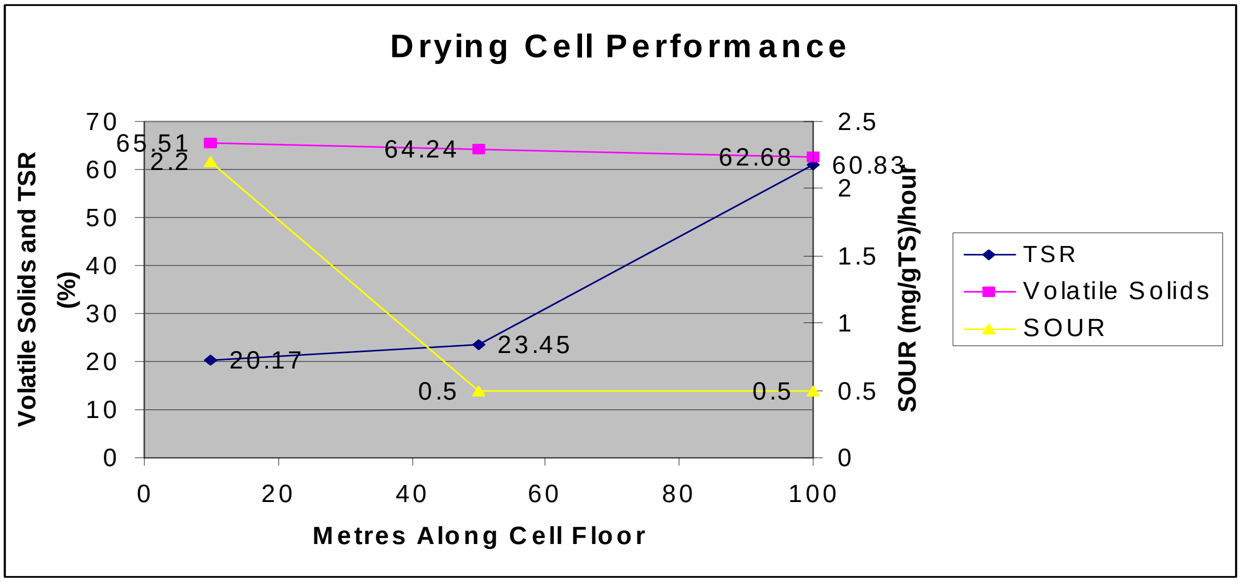
Evaporation factor (calculated): 8.18 kg per annum.

Total Solids Residue (TSR), Volatile Solids Reduction, Specific Oxygen Uptake Rate (SOUR)

The following table and figure depicts the observed changes in % Volatile Solids, % Total Solids Residue, and Specific Oxygen Uptake Rate (SOUR) as the biosolids proceed along the length of the ‘SolarMix’ drying cell.

	10 Metres	25 Metres	50 Metres	75 Metres	Final Product
TSR %	20.17	21.64	23.45	24.7	60.83
Volatile Solids	65.51	64.42	64.24	64.52	62.68
SOUR mgO2/gTS/h	2.2	1.6	<0.5	<0.5	<0.5

Figure 3: Drying cell performance to decrease Volatile Solids and Specific Oxygen Uptake Rate (SOUR) of the biosolids along the 'SolarMix' drying cell.



The 'SolarMix' drying cell performs slightly better during the summer months due to increase in day length and higher temperatures, however, the higher ambient humidity during summer prevents the 'SolarMix' drying cell from performing significantly than in winter. The drying efficiency achieved during winter is well beyond that expected from the European experience.

Total Solids Residue

Since the commissioning of the 'SolarMix' drying cell at East Burpengary WWTP in August 2003, CabWater staff have been undergoing a study to determine the total solids of the biosolids along the cell floor. Although there was a slight decline in the efficiency of the drier in winter, it still achieved an economical increase in TSR of the biosolids and a significant reduction in mass. The total mass of the biosolids in the drier was halved when the solids content was increased from 15% to only 30%. The total mass of the biosolids in the 'SolarMix' drier was reduced by approximately 70% when the solid content is increased from 15% to 50%.

Volatile Solids

Percent volatile solids only decreased slightly along the drying path of the 'SolarMix' process. Treated dewatered biosolids usually have a volatile solids percentage of around 68-65 as a finished product. The 'SolarMix' process further reduced the volatile solids percentage to 62.68% and although this reduction is only just significant, it indicates that the biosolids has stabilised and are not likely to have more than a 15% further reduction if incubated in a Bench Scale Reactor Test (Table 3-3 of the NSW Environmental Guidelines).

Specific Oxygen Uptake Rate

The results indicate a significant decrease in the Specific Oxygen Uptake Rate (SOUR) from 8.2 in the relatively fresh biosolids at the 20 metre mark to an undetectable level of 0.49 by the 80 metre mark. This demonstrates that the 'SolarMix' process easily achieves the SOUR reduction required for Vector Attraction Reduction according to Table 3-3 of the NSW Environmental Guidelines for Stabilisation Grade B. The drying cell was sampled in winter and in summer and the table below gives the individual SOUR results along the length of the drying cell.

Date Sampled	SOUR 20 metres	SOUR 40 metres	SOUR 60 metres	SOUR 80 metres
23/09/2003	2.2	1.6	<0.5	<0.5
05/04/2004	8.2	12	3.2	0.49
29/03/2004	6.6	4.3	2.4	0.03

Microbiological Populations

The 'SolarMix' process has proven itself to be an effective method of reducing the pathogen levels in the dewatered biosolids. The drying cell was sampled on two separate occasions and on each occasion, four separate samples where taken along the drying cell (at 20m, 40m, 60m, and 80m). These samples were analysed for Faecal coliforms (MPN), E. coli (MPN), and Salmonella spp (presence/absence) in accordance with Table 3-5 of the NSW Environmental Guidelines. The following table displays the results for the destruction of pathogens along the drying cell in the 'SolarMix' facility.

Sample Date	Analyte	Units	Burpengary East 20m	Burpengary East 40m	Burpengary East 60m	Burpengary East 80m
29/04/04	Faecal Coliforms	cfu/g (dry wt.)	35000	38000	1700	<5
	E. coli (MPN)	cfu/g (dry wt.)	35000	38000	1700	<5
	Salmonella spp	pres./abs.	absent	absent	absent	Absent
	Total Residue	%	25.8	23.6	30.0	64.8
	Moisture Calc.	%	74.2	76.4	70.0	58.2
	Fixed Residue	%	41.8	43.9	44.8	50.7
05/04/04	Faecal Coliforms	cfu/g (dry wt.)	>86000	>73000	6000	<3
	E. coli (MPN)	cfu/g (dry wt.)	>86000	>73000	830	<3
	Salmonella spp	pres./abs.	absent	absent	absent	absent
	Total Residue	%	18.5	21.9	26.5	64.8
	Moisture Calc.	%	30.1	34.8	44.8	46.9
	Fixed Residue	%	30.1	34.8	44.8	46.9

Figure 5: Destruction of Microbial Populations in the 'SolarMix' Hothouse

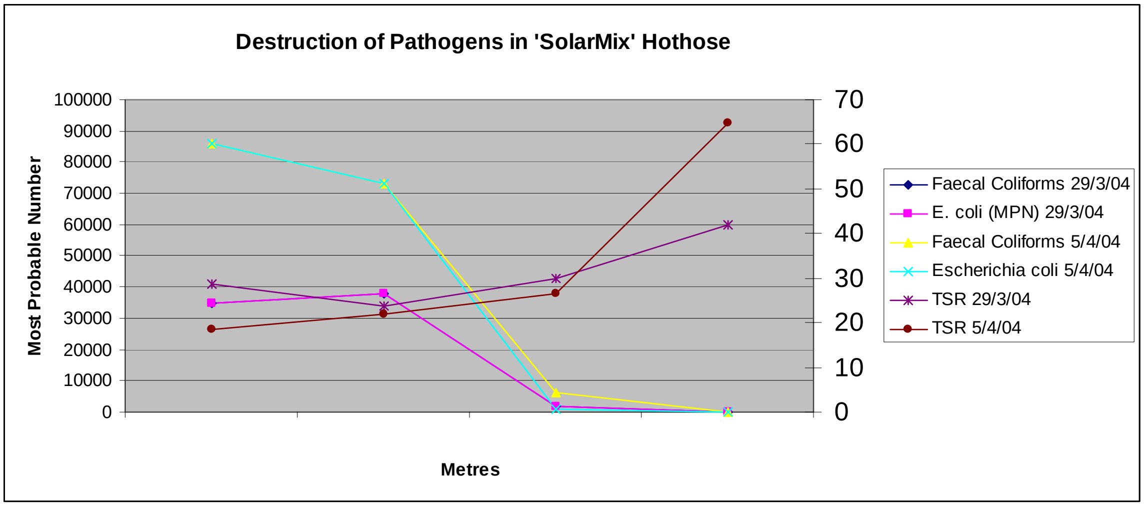
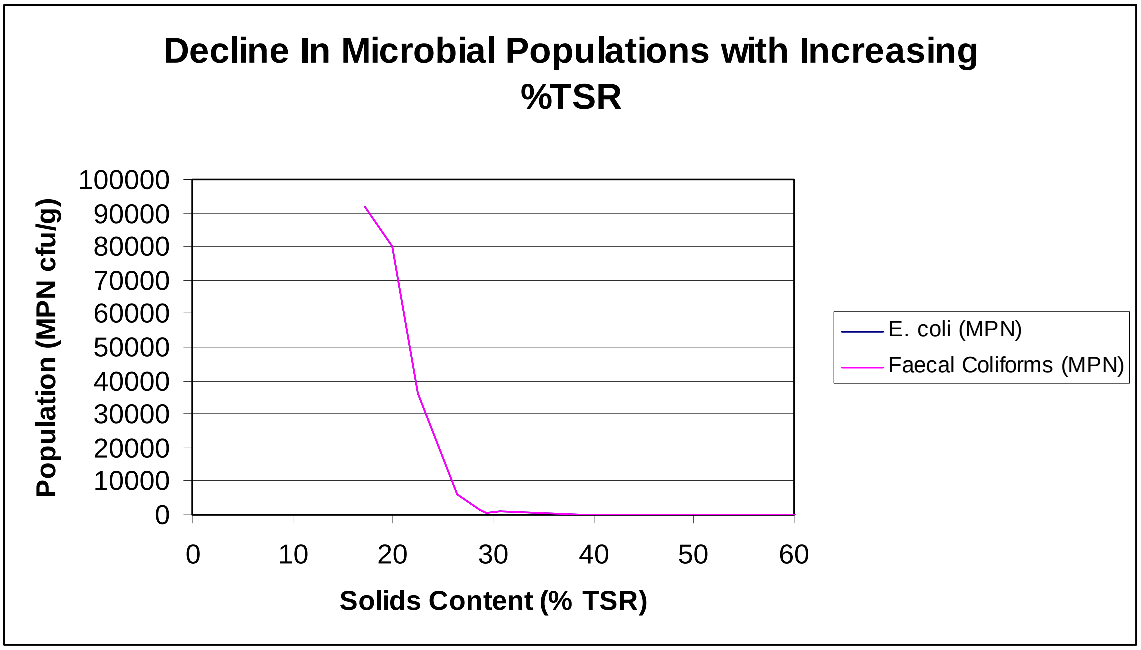


Figure 5 above shows that as the biosolids are dried and moved down the drying cell in the ‘SolarMix’ drying hall, the microbial population is significantly reduced and is easily able to meet the requirements of Stabilisation Grade A requirements for E. coli, Faecal Coliforms, and Salmonella spp by the 80 metre point (the total cell length is 100 metres).

The following table displays the relationship between % TSR of the finished product and the population of E. coli and Faecal coliform.

% TSR	E. coli (MPN)	Faecal Coliforms (MPN)
17.3	92000	92000
20.0	80000	80000
22.5	36000	36000
26.5	6000	6000
28.7	1700	1700
29.3	380	580
30.6	980	980
39.1	5	5
41.8	5	5
64.8	3	3

The following graph displays the decline in the population of E. coli and Faecal coliforms with an increasing %TSR in the ‘SolarMix’ facility. It can be seen that the majority of the pathogen destruction occurs between 20%TSR and 30% TSR and by the time the product reaches approximately 40% TSR, the pathogen populations are below the detectable limit of 5 MPN cfu/g (therefore meeting the microbial requirements of stabilisation grade A).



Teething Problems

During the commissioning of the 'SolarMix' facility, a couple of teething problems where encountered. It was discovered that if the Automated Biosolids Agitator made too many passes down the drying hall the biosolids became 'pastey' and would not dry effectively. When this 'pastey' biosolids was eventually dried, the dried biosolids produced was lumpy rather than being granulated. The automated biosolids agitator was programmed to do fewer passes and this eliminated the problem.

It was also noticed that the number of passes and the agitator speed has to be altered each time a new biosolids product was trialed in the drying cell (i.e. when South Caboolture WWTP anaerobically digested biosolids was dried instead of East Burpengary WWTP waste activated biosolids), however, once the programming parameters had been established for each biosolids product, the change-over was much easier. Changes in the agitator programming was also needed of a different polyelectrolyte was used in the dewatering process. Once these problems were overcome the biosolids were still effectively dried in the 'SolarMix' process with no change to the quality of the end product.

Cost Savings

Since the installation of the 'SolarMix' dryer, CabWater has estimated that it will have a cost saving of in excess of 50%. In real terms, it is expected that the 'SolarMix' process will remove a minimum of 3300 tonnes of water per annum from the fresh biosolids and will save CabWater approximately $80,000 to $100,000 at the Burpengary East WWTP for biosolids disposal / reuse (based on current prices).

Conclusions

The results to date indicate that the 'SolarMix' process is extremely effective at both stabilising the biosolids and dramatically reducing the volume and mass of the material to be transported and reused. The sampling regime has also indicated that the 'SolarMix' process is producing a dried biosolids product that meets the requirements of Stabilisation Grade A according to the NSW Environmental Guidelines when the TSR is above 45%, however, further sampling and analysis will be necessary to gain enough data to satisfy the requirements of the initial process verification according to the NSW Environmental Guidelines.

Even though the 'SolarMix' process has proven itself to work extremely well under Australian conditions, further improvements can be made to increase the dryer's efficiency and to further reduce the time to dry the biosolids. CabWater is planning to install a large blower to speed up the removal of moisture laden air out of the 'SolarMix' drying hall. Moisture droplets have been observed on the roof and walls of the 'SolarMix' drying hall as a result of less than optimal hall ventilation and it is anticipated that the blower will increase the exhaustion of moisture laden air more effectively than the current hall that relies on natural air movement.