Project done on behalf of
AURECON SOUTH AFRICA (PTY) LTD

IMPACT OF PROPOSED BRINE EVAPORATION AT TUTUKA POWER STATION (MPUMALANGA) ON PARTICULATE AIR EMISSIONS

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SUMMARY

Airshed Planning Professionals (Pty) Limited was appointed by Aurecon South Africa (Pty) Ltd to investigate the influence on particulate emissions when brine is injected into boilers at Eskom's Tutuka power station in Mpumalanga. This investigation forms part of the Environmental Impact Assessment (EIA) process completed by Aurecon.

Scope

The scope of the work was to analyse the particulate emissions monitoring data from Tutuka power station to determine whether the injection of brine into the boilers would result in any significant changes in particulate air emissions and in the event of increased emissions, to determine the resulting air concentrations and fallout rates.

Tutuka Test Data

The first emissions monitoring campaign was conducted on 30 June 2010 with brine injection at an average rate of 15.2 m^3/hr and 8 July 2010 without brine injection. Since the first monitoring campaign was performed for a relatively short period, a follow-up campaign was requested that extended over five days. The second monitoring campaign was conducted from 24 to 28 November 2010 with brine injection at an average rate of 9.1 m^3/hr and from 26 to 30 December 2010 without brine injection. The tests were done at Unit 2.

Conclusions

The emission monitoring results from these datasets show a particulate emission concentration reduction of up to 13% when brine is injected into the boiler. However, this could not be corrected for the potential increased moisture content with the introduction of brine, which could reduce the difference. Nonetheless, even if the moisture increased by 10% during the tests, the concentration would still be less or the same as without brine injection.

It can therefore be concluded with reasonable confidence that there would be no increase, even perhaps a decrease, in the particulate emission concentrations with the introduction of brine into the boilers at Tutuka Power Station.

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1.1 Scope of Work

The scope of the work was to analyse the particulate emissions monitoring data from Tutuka power station to determine whether the injection of brine into the boilers would result in any significant changes in particulate air emissions and in the event of increased emissions, to determine the resulting air concentrations and fallout rates.

1.2 Approach

The approach followed in the investigation was as follows:

- Step 1: Obtain, screen and complete a statistical analysis of the particulate emission monitoring data;
- Step 2: Depending on the significance, estimate a particulate emission rate due to the brine evaporation;
- Step 3: Complete a screening dispersion modelling exercise using the worst case meteorological conditions to illustrate the significance of these emissions at ground level. This will include the calculation of particulate air concentrations and estimated fallout rates;
- Step 4: If this is shown to be significant complete the same as Step 3, but with actual weather data for the site.

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1.3 Outline of Report

Section 2 summarises the results from the monitoring campaigns conducted during 2010. These results are analysed in Section 3 with the conclusion given in Section 4.

2. TUTUKA EMISSIONS MONITORING TEST RESULTS

Four monitoring datasets were provided for the analysis. These consisted of two sets for conditions without brine injection and two sets with brine injection. The results from these campaigns are provided below.

2.1 June and July 2010 Tests

The first monitoring campaign was conducted on 30 June 2010 with brine injection at an average rate of 15.2 m^3/hr and 8 July 2010 without brine injection. The results of the monitoring are summarised in Table 2-1. No temperature readings were provided.

Table 2-1: Measured particulate emissions at Tutuka Power Station (June/July 2010)

Time	With Brine Injection (30 June 2010)		Without Brine Injection (08 July 2010)	
	Particulate Emission (mg/m^3)	Load (MW)	Particulate Emission (mg/m^3)	Load (MW)
00:00	262.5	567	234.6	497
01:00	259.5	583	300.3	580
02:00	236.8	583	303.2	581
03:00	223.1	582	296	581
04:00	221.1	583	302.8	580
05:00	230.6	582	311.6	581
06:00	220.6	583	284.3	523
07:00	218.1	584	271	512
08:00	235.9	585	229	517
09:00	234.4	595	289	544
10:00	227.5	590	239	558
11:00	247.1	585	265.9	565.6
12:00	255.8	590	245.9	558.9
13:00	256.1	589	226.6	575.6
14:00	260.6	589	258	576
15:00	238	590	282	583
16:00	258.6	590	289.9	592
17:00	259.6	590	382.6	592
18:00	261	591	386.8	590
19:00	265.8	596	404.2	590
20:00	275.8	599	325.8	583
21:00	283.7	600	287.1	583
22:00	275.8	599	277.7	582
23:00	269.1	599	273.2	582

2.2 November and December 2010 Tests

Since the first monitoring campaign was performed for a relatively short period, a follow-up campaign was requested that would extend over a longer period and also with more variation in the loading. The second monitoring campaign was conducted on Unit 2 from 24 to 28 November 2010 with brine injection at an average rate of 9.1 m^3/hr and Unit 2 from 26 to 30 December 2010 without brine injection. The results of the monitoring with brine injection are summarised in Table 2-2 and without brine injection in Table 2-3. The concentrations were corrected for temperature with reference to 25 ℃. The average temperature at the electrostatic precipitator was 131 °C for both campaigns.

Table 2-2: Measured particulate emissions at Tutuka Power Station (Unit 2) with the injection of brine (24 to 28 November 2010)

Time	Particulate Emission Concentration		ESP Temperature (℃)	Load (MW)
	Actual (mg/m^3)	Normalised (mg/Nm^3)		
00:00	41	55	120	537
01:00	54	71	120	578
02:00	53	70	120	578
03:00	52	68	121	578
04:00	50	66	121	579
05:00	50	68	129	578
06:00	54	75	144	578
07:00	51	71	145	578
08:00	53	74	140	579
09:00	51	71	139	579
10:00	50	69	136	579
11:00	50	69	137	579
12:00	53	74	138	588
13:00	53	73	139	589
14:00	52	71	139	597
15:00	60	81	132	598
16:00	64	88	132	594
17:00	72	97	130	586
18:00	69	94	137	589
19:00	72	99	137	592
20:00	71	99	139	593
21:00	140	194	140	593
22:00	173	236	133	593
23:00	134	180	129	593
00:00	76	102	124	593
01:00	79	104	117	594
02:00	98	129	120	590
03:00	1[(a)]	2[(a)]	118	588
04:00	78	104	124	588

Time	Particulate Emission Concentration		ESP Temperature (℃)	Load (MW)
	Actual (mg/m³)	Normalised (mg/Nm³)		
05:00	72	96	123	588
06:00	82	109	123	588
07:00	84	114	132	590
08:00	83	113	135	595
09:00	106	144	134	599
10:00	104	141	133	598
11:00	82	111	132	598
12:00	85	112	123	599
13:00	80	105	122	599
14:00	96	127	123	598
15:00	119	159	124	597
16:00	98	131	125	598
17:00	92	122	125	598
18:00	93	124	125	597
19:00	94	126	125	598
20:00	108	147	132	598
21:00	88	119	129	598
22:00	88	117	124	598
23:00	94	125	125	598
00:00	95	127	123	598
01:00	92	122	123	598
02:00	141	187	122	598
03:00	91	122	125	598
04:00	92	123	125	600
05:00	92	125	131	598
06:00	88	120	136	598
07:00	130	182	142	597
08:00	150	210	144	595
09:00	152	213	144	595
10:00	155	216	143	599
11:00	152	210	139	598
12:00	163	226	140	599
13:00	153	210	135	598
14:00	152	206	131	598
15:00	154	208	129	596
16:00	147	202	137	597
17:00	165	230	142	598
18:00	139	193	141	600
19:00	151	210	142	600
20:00	151	211	142	599
21:00	140	195	142	600
22:00	152	202	122	600
23:00	150	198	121	600
00:00	152	201	121	600

Time	Particulate Emission Concentration		ESP Temperature (℃)	Load (MW)
	Actual (mg/m³)	Normalised (mg/Nm³)		
01:00	157	208	121	600
02:00	158	208	120	600
03:00	167	221	121	600
04:00	166	219	120	599
05:00	189	257	132	600
06:00	171	231	130	600
07:00	171	237	140	599
08:00	161	223	140	595
09:00	160	222	140	597
10:00	174	239	136	597
11:00	161	224	142	535
12:00	125	175	143	519
13:00	110	152	139	599
14:00	165	228	139	598
15:00	175	243	141	597
16:00	179	249	141	599
17:00	186	258	141	599
18:00	168	234	142	599
19:00	178	247	141	600
20:00	168	233	141	599
21:00	185	256	140	600
22:00	180	244	131	600
23:00	176	233	122	600
00:00	176	236	126	599
01:00	168	223	123	599
02:00	168	223	123	599
03:00	165	220	125	600
04:00	168	224	124	600
05:00	182	243	124	601
06:00	164	220	127	601
07:00	165	223	129	600
08:00	166	230	139	593
09:00	174	239	136	593
10:00	192	263	135	594
11:00	184	251	134	597
12:00	183	243	123	597
13:00	175	233	123	596
14:00	168	223	122	595
15:00	163	215	120	597
16:00	158	209	121	598
17:00	167	222	123	599
18:00	150	202	129	599
19:00	144	194	128	602
20:00	145	200	138	603

Time	Particulate Emission Concentration		ESP Temperature (℃)	Load (MW)
	Actual (mg/m³)	Normalised (mg/Nm³)		
21:00	141	192	132	602
22:00	147	198	128	604
23:00	156	206	120	508

Note: [(a)] – This low reading was considered to be an outlier and not included in the analysis

Table 2-3: Measured particulate emissions at Tutuka Power Station (Unit 2) without the injection of brine (26 to 30 December 2010)

Time	Particulate Emission Concentration		ESP Temperature (℃)	Load (MW)
	Actual (mg/m³)	Normalised (mg/Nm³)		
00:00	54	71	120	350
01:00	57	75	120	350
02:00	54	71	120	350
03:00	60	79	121	350
04:00	73	97	121	385
05:00	147	198	129	536
06:00	206	288	144	596
07:00	233	327	145	598
08:00	197	273	140	599
09:00	203	281	139	599
10:00	175	240	136	599
11:00	185	255	137	599
12:00	190	262	138	598
13:00	171	237	139	595
14:00	109	151	139	455
15:00	110	150	132	451
16:00	103	140	132	451
17:00	133	180	130	479
18:00	153	211	137	528
19:00	174	239	137	551
20:00	179	248	139	579
21:00	146	202	140	547
22:00	104	142	133	472
23:00	91	123	129	438
00:00	70	93	124	382
01:00	55	72	117	269
02:00	53	70	120	291
03:00	65	85	118	394
04:00	61	81	124	379
05:00	58	77	123	370
06:00	78	104	123	422
07:00	104	141	132	470
08:00	98	134	135	470
09:00	103	141	134	470

Time	Particulate Emission Concentration		ESP Temperature (℃)	Load (MW)
	Actual (mg/m³)	Normalised (mg/Nm³)		
10:00	106	144	133	467
11:00	78	106	132	401
12:00	63	84	123	352
13:00	58	77	122	349
14:00	65	86	123	350
15:00	62	83	124	350
16:00	66	88	125	349
17:00	63	84	125	349
18:00	64	86	125	349
19:00	108	144	125	435
20:00	95	129	132	451
21:00	64	86	129	361
22:00	68	91	124	360
23:00	65	87	125	359
00:00	65	86	123	360
01:00	69	92	123	360
02:00	66	88	122	359
03:00	66	88	125	360
04:00	75	100	125	387
05:00	90	122	131	454
06:00	160	220	136	549
07:00	179	249	142	579
08:00	193	270	144	579
09:00	185	259	144	579
10:00	176	246	143	579
11:00	170	235	139	579
12:00	125	173	140	519
13:00	105	144	135	440
14:00	95	129	131	438
15:00	117	158	129	470
16:00	185	255	137	575
17:00	186	259	142	578
18:00	161	224	141	578
19:00	198	276	142	578
20:00	106	148	142	471
21:00	71	99	142	364
22:00	67	89	122	359
23:00	63	83	121	358
00:00	61	81	121	360
01:00	61	81	121	351
02:00	57	75	120	340
03:00	61	81	121	340
04:00	80	106	120	385
05:00	101	137	132	450

Time	Particulate Emission Concentration		ESP Temperature (℃)	Load (MW)
	Actual (mg/m³)	Normalised (mg/Nm³)		
06:00	138	187	130	520
07:00	193	268	140	604
08:00	186	258	140	600
09:00	149	207	140	527
10:00	167	229	136	535
11:00	216	301	142	594
12:00	206	288	143	597
13:00	185	256	139	598
14:00	183	253	139	598
15:00	178	247	141	598
16:00	185	257	141	597
17:00	166	231	141	598
18:00	182	254	142	598
19:00	198	275	141	598
20:00	161	224	141	599
21:00	177	245	140	599
22:00	124	168	131	479
23:00	83	110	122	403
00:00	74	99	126	350
01:00	59	78	123	330
02:00	62	82	123	330
03:00	63	84	125	330
04:00	60	80	124	330
05:00	77	103	124	355
06:00	89	120	127	400
07:00	101	136	129	426
08:00	121	167	139	507
09:00	120	165	136	509
10:00	132	181	135	515
11:00	140	191	134	492
12:00	82	109	123	446
13:00	71	94	123	420
14:00	68	90	122	379
15:00	69	91	120	378
16:00	78	103	121	385
17:00	92	122	123	430
18:00	99	134	129	449
19:00	175	236	128	517
20:00	165	228	138	537
21:00	107	145	132	431
22:00	72	97	128	358
23:00	69	91	120	350

3. ANALYSIS OF MONITORING RESULTS

Comparisons between the two operating conditions, *viz.* with and without brine injection, for the two monitoring campaigns are shown in Figure 3-1 and Figure 3-2, respectively. In both cases, the injection of brine has led to emission concentrations lower than without brine. It must be recognised though that with the first set, no temperature, moisture and oxygen corrections could be applied to normalise the concentrations. With the second campaign, the concentrations could be normalised for temperature but not moisture and oxygen. Since the oxygen content in the flue gas may be similar for the two campaigns it could be expected that oxygen correction may not be as significant as moisture correction. Emissions of stack gases are usually expressed on a dry gas basis so that variations in the moisture content of the stack gas do not affect the assessment of the emissions. It is expected that the evaporation of brine will result in increased moisture in the off gas, however the significance of this increase is not known. Since the brine injection rate of 9.1 m³/hr is relatively small compared to the amount of coal used, it is not expected to raise the moisture content of the flue gas substantially, perhaps 5%. The correction is a follows:

$$Dry\,Gas\,Concentration\left(\frac{mg}{m^3}\right) = Wet\ Gas\,Concentration\ \ x\ \frac{100}{100-\%H_2O}$$

To illustrate the sensitivity of the correction, if it is assumed that the moisture before the injection is about 5% and after the injection 10%, the correction factor is 1.05 compared to 1.11, i.e. a difference of about 5.6%.

The operating conditions for the first campaign is summarised in Table 3-1. The power loads during the two periods were fairly similar, although slightly higher during the brine injection test. The average particulate concentration is less for the brine injection, even if the moisture differed by up to 17%.

Table 3-1: Range and average load and emission concentrations (first campaign)

	Brine Injection		No Brine Injection	
	Load (MW)	**Particulate Emission Concentration (mg/Nm³)**	**Load (MW)**	**Particulate Emission Concentration (mg/Nm³)**
Minimum	567	218 [263] [(a)]	497	227 [235] [(a)]
Average	589	245	567	290
Maximum	600	289 [284] [(b)]	592	494 [383] [(b)]

Notes:

[(a)] – value in brackets is the concentration at the minimum load

[(b)] – value in brackets is the concentration at the maximum load

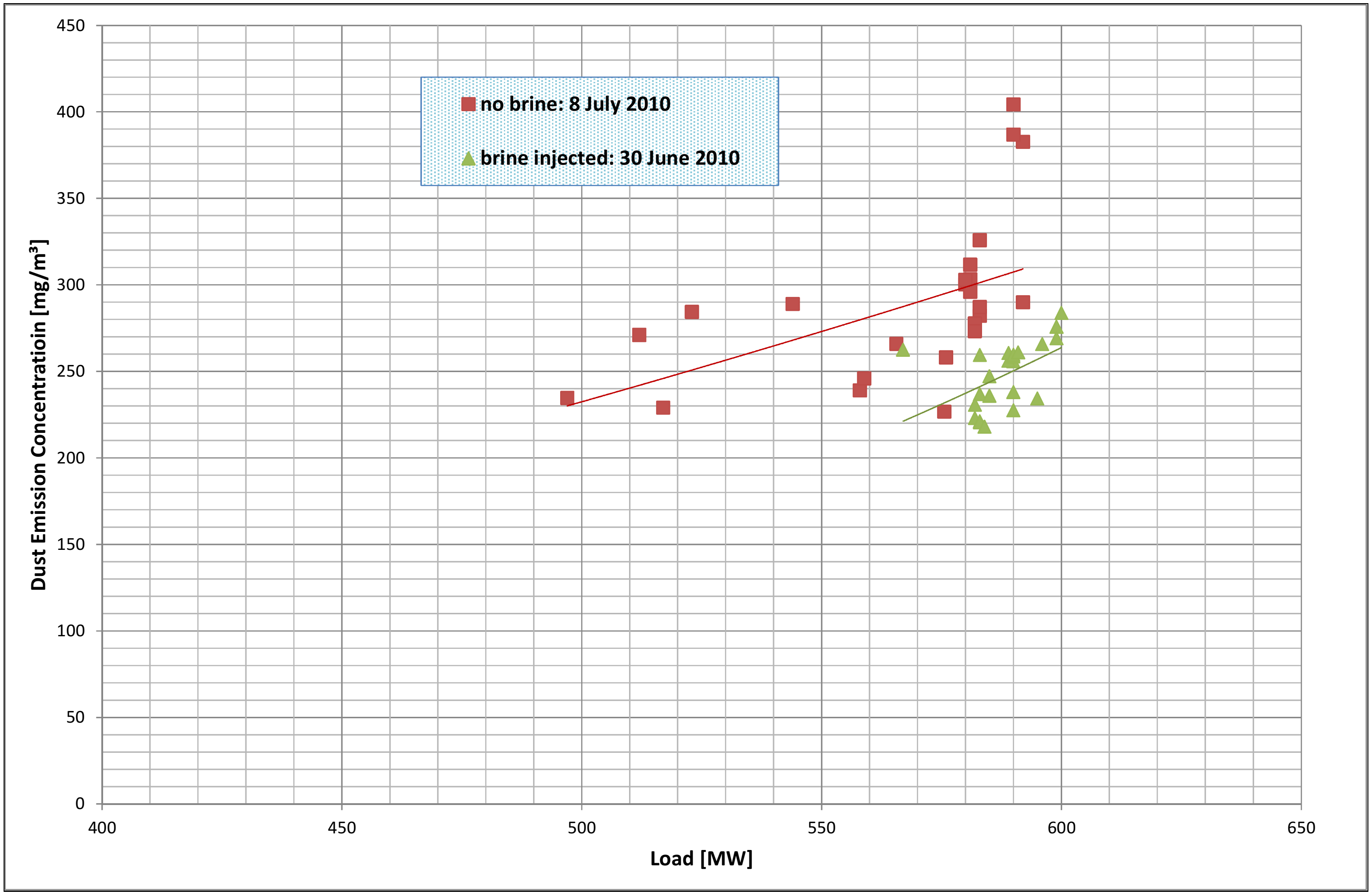

Figure 3-1: Comparison between the conditions with and without brine injection observe during the 24-hour monitoring campaign

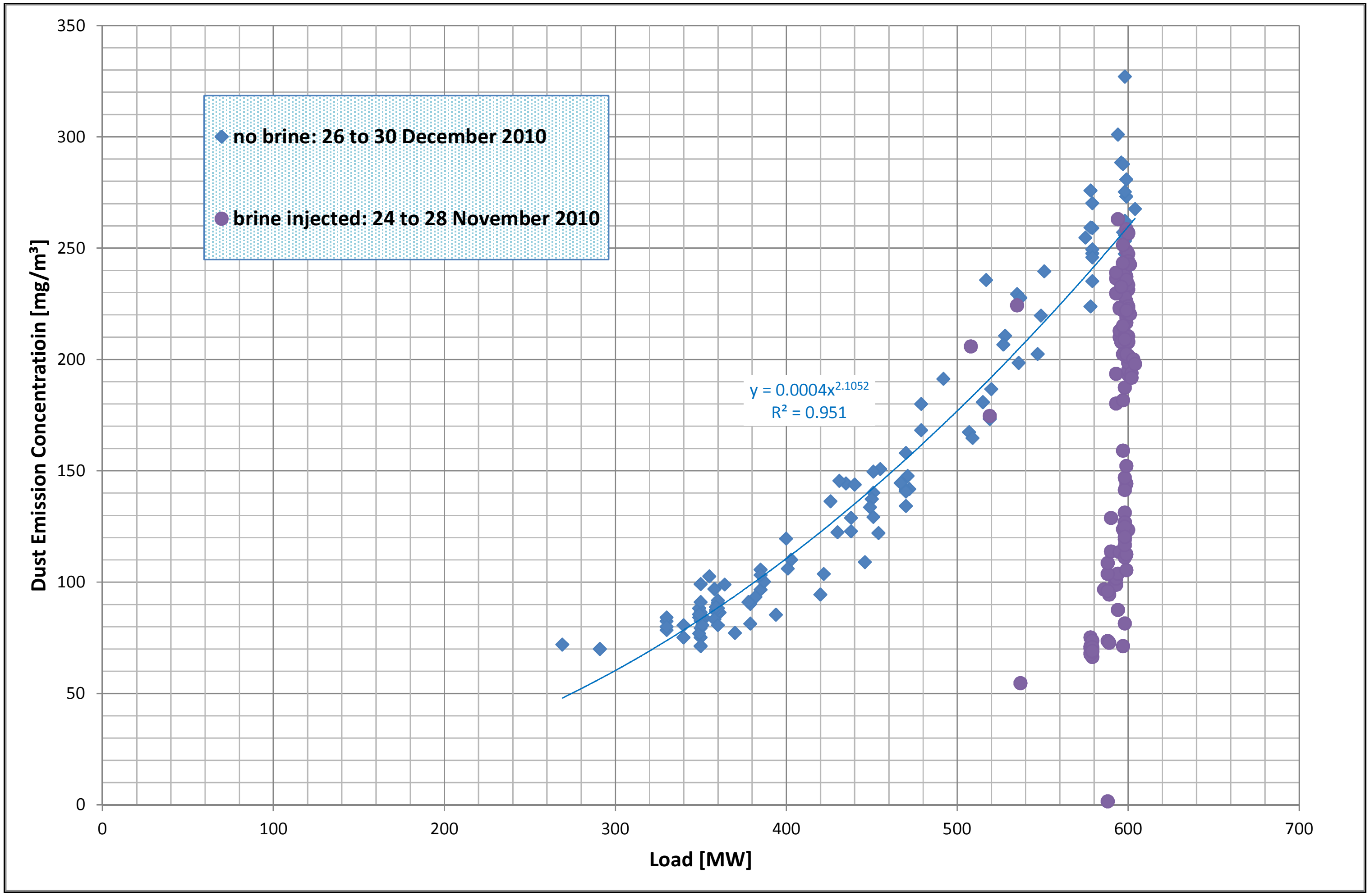

Figure 3-2: Comparison between the conditions with and without brine injection observe during the 5-day monitoring campaign

The conditions for the second campaign are summarised in Table 3-2. In this campaign, brine was only injected when the load was above 500 MW. The average concentration with no brine was about 157 mg/Nm³ and the average when brine was introduced is slightly higher at 168 mg/Nm³. However, the average load without brine was significantly less, i.e. 459 MW when compared to the 593 MW with brine. For an average load of 580 MW, based on the results for the case without brine, the projected average concentration[1] would be 194 mg/m³. This implies that the brine results in an emission concentration of about 13% lower. However, this result does not take moisture correction into account and may be less significant. Nonetheless, even if the moisture rose by 10%, the particulate emission concentration would still be less than or the same as without brine injection.

Table 3-2: Range and average load and emission concentrations (second campaign)

	Brine Injection		No Brine Injection	
	Load (MW)	**Particulate Emission Concentration (mg/Nm³)**	**Load (MW)**	**Particulate Emission Concentration (mg/Nm³)**
Minimum	508	55 [206] (a)	269	70 [72] (a)
Average	593	168	459	157
Maximum	604	263 [198] (b)	604	327 [268] (b)

Notes:

(a) – value in brackets is the concentration at the minimum load

(b) – value in brackets is the concentration at the maximum load

Since the average temperatures in the electrostatic precipitator remained similar, the resulting plume will have the same buoyancy and should therefore not affect ground level particulate concentrations.

The results from the sampling campaigns indicate that there would be no significant difference in particulate emission concentrations, perhaps even a lowering of the concentration with brine injection. It is not clear why there is the potential reduction in concentration with the injection of brine, although it may be related to a change in the resistivity of the ash as a result of the brine injection, and a resultant improvement in the efficiency of the electrostatic precipitators.

[1] A good correlation (R=951) exists between the particulate emission concentration and the load, as shown in Figure 3-1. The best fit to the results is $\chi = 0.0004L^{2.1052}$ where χ the emission concentration in mg/Nm³ is and *L* is the load in MW.

In accordance with our approach, we would only proceed with Steps 2 to 4 if the emissions were found to be significantly higher with the evaporation of brine in the boiler. Since the results did not show an increase, these steps were not completed.

4. CONCLUSIONS

The conclusion is based on two sets of emission monitoring conducted at Unit 2 of Tutuka Power Station. The first monitoring campaign was conducted on 30 June 2010 with brine injection at an average rate of 15.2 m^3/hr and 8 July 2010 without brine injection. The second monitoring campaign was conducted from 24 to 28 November 2010 with brine injection at an average rate of 9.1 m^3/hr and from 26 to 30 December 2010 without brine injection.

The emission monitoring results from these datasets show an emission concentration reduction of up to 13% when brine is injected into the boiler. However, this could not be corrected for the potential increased moisture content with the introduction of brine, which could reduce the difference. Nonetheless, even if the moisture rose by 10% during the tests, the concentration would still be less than or the same as without brine injection.

It can therefore be concluded with reasonable confidence that there would be no increase, even perhaps a decrease, in the particulate emission concentration with the introduction of brine.