5.2.2. Trends in matrix data when each parameter is made the subject for viewing.

Tables 5.2.2.1 and 5.2.2.2 contrast the effects of three controlled variables (sample temperature, sparge gas flow rate and pollutant concentration) on the magnitude of sensor responses obtained for the pollutant compounds 2-chlorophenol and diesel. These two compounds were shown to be detectable at 5ppm in the preliminary test matrix. By collecting data in this manner trends would become evident lending to conclusions about the effects that each changing parameter has upon the sensor response generation, headspace character and sensor recognition, if any. The reproducibility of the system can be determined by assuming that under similar conditions a uniform RH value should occur. As shown earlier (Table 5.1.1.8) sample temperature is clearly the most significant and influential variable in determining RH generation. Similar RH values for each set of temperature values tested for both compounds should be observed.

The statistical significance of the sensor response data presented in Tables 5.2.2.1 and 5.2.2.2 are listed in according to pollutant type and sample temperature in section 5.4.3.

Table 5.2.2.1 2-chlorophenol testing matrix

Pollutant	2-chlorophenol																	
Concentration	5 ppm						10 ppm						20 ppm					
Sparge gas flow	50 ml/min		100 ml/min		200 ml/min		50 ml/min		100 ml/min		200 ml/min		50 ml/min		100 ml/min		200 ml/min	
Sample temperature	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃
Sensor 501	0	0	0.03	0.06	0.05	0.06	0	0	0.05	0.11	0.07	0.12	0.09	0.16	0.1	0.19	0.12	0.22
Sensor 502	0	0	0	0	0	0	0	0	0	0	0.08	0.04	0	0	0.02	0.06	0.09	0.15
Sensor 503	0	0	0	0	0	0	0	0	0	0	0.06	0	0	0	0	0	0	0.06
Sensor 504	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0.14	0.12	0.17
RH	29	30	32	35	36	45	31	33	32	31	33	44	29	39	32	39	32	41

Table 5.2.2.2 Diesel testing matrix

Pollutant	Diesel																	
Concentration	5 ppm						10 ppm						20 ppm					
Sparge gas flow	50 ml/min		100 ml/min		200 ml/min		50 ml/min		100 ml/min		200 ml/min		50 ml/min		100 ml/min		200 ml/min	
Sample temperature	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃	15 ℃	30 ℃
Sensor 501	0	0.04	0.04	0.14	0	0.12	0	0.04	0.07	0.3	0.11	0.62	0.05	0.04	0.19	1.45	0.12	0.68
Sensor 502	0.06	0.14	0.15	0.2	0.14	0.25	0.03	0.08	0.19	0.8	0.49	1.24	0.19	0.18	0.5	2.10	0.55	0.92
Sensor 503	0	0	0	0	0	0.1	0	0	0	0.14	0.08	0.44	0	0	0	0.9	0.07	0.55
Sensor 504	0	0	0	0.12	0	0.1	0	0	0	0.32	0.14	0.54	0	0	0.2	0.78	0.20	0.44
RH	31	34	28	47	32	46	38	33	28	39	33	42	32	32	29	44	33	48

Observing trends in the main test matrices (Table 5.2.2.1 and 5.2.2.2) are difficult, as the data can be view with respect to either of the experimental parameters. Sections 5.2.2.1 – 5.2.2.3 break these large matrices into small units and allows trends to be observed with respect to the changes in either pollutant concentration, sparge gas flow or sample temperature. When each parameter is made the main subject for viewing the data the effects the two remaining parameters have upon the change in the sensor response and the RH generated during each run can be observed.

Sample concentration can be held whist the trends occurring as a result of sample temperature on sparge flow and sparge flow on sample temperatures are observed. The change in sensor response (ΔR) is recorded as the pollutant is introduced.

5.2.2.1. Sample concentration - temperature by flow:

The RH is similar for each combination of variables for both 2-chlorophenol and diesel testing (Table 5.2.2.1.1). As the sparge gas flow rate increases the peak height and general trend in RH rise. At 5 ppm the peaks are small and the sensors are nearing their limits of detection. At 10 ppm the sensor responses (Table 5.2.2.1.2) for sample temperatures of 15°C, increase with a corresponding increase in sparge gas flow rate.

Table 5.2.2.1.1. Parameter comparisons and their effect on sensor and RH response.
Concentration held at 5ppm. Sample temperature at 15°C
Vs flows of 50, 100 and 200 ml/min.

	Sample temperature @ 15 °C					
5 ppm	2-chlorophenol			Diesel		
Flow rate	50 ml/min	100 ml/min	200 ml/min	50 ml/min	100 ml/min	200 ml/min
Sensor 501	0	0.03	0.05	0	0.04	0
Sensor 502	0	0	0	0.06	0.15	0.14
Sensor 503	0	0	0	0	0	0
Sensor 504	0	0	0	0	0	0
RH	29	32	36	31	28	32

Table 5.2.2.1.2. Parameter comparisons and their effect on sensor and RH response. Concentration held at 10ppm. Sample temperature at 15°C Vs flows of 50, 100 and 200 ml/min.

	Sample temperature @ 15 °C					
10 ppm	2-chlorophenol			Diesel		
Flow rate	50 ml/min	100 ml/min	200 ml/min	50 ml/min	100 ml/min	200 ml/min
Sensor 501	0	0.05	0.07	0	0.07	0.11
Sensor 502	0	0	0.08	0.03	0.19	0.49
Sensor 503	0	0	0.06	0	0	0.08
Sensor 504	0	0	0	0	0	0.14
RH	31	32	33	38	28	33

The data in Table 5.2.2.1.3 shows the effects that flow rate has upon 20ppm solutions of 2-chlorophenol and diesel at 15°C. With the exception of sensor 501 for diesel at 100ml/min all changes in sensor response increased as sparge gas flow rate increased. The RH values are very close for each of the six runs under these conditions.

Table 5.2.2.1.3. Parameter comparisons and their effect on sensor and RH response. Concentration held at 20ppm. Sample temperature at 15°C Vs flows of 50, 100 and 200 ml/min.

	Sample temperature @ 15 °C					
20 ppm	2-chlorophenol			Diesel		
Flow rate	50 ml/min	100 ml/min	200 ml/min	50 ml/min	100 ml/min	200 ml/min
Sensor 501	0.09	0.1	0.12	0.05	0.19	0.12
Sensor 502	0	0.02	0.09	0.19	0.5	0.55
Sensor 503	0	0	0	0	0	0.07
Sensor 504	0	0	0.12	0	0.2	0.2
RH	29	32	32	32	29	33

The data in Table 5.2.2.1.4 shows the effects flow rate has upon 5ppm solutions of 2-chlorophenol and diesel at 30°C. At sample temperatures of 30°C the magnitude of the RH response increases with sparge gas flow rate. Sensor 501 has the same results for 2-chlorophenol at 100 and 200 ml/min, but yields a larger response for diesel at 100ml/min then 200 ml/min. In both Tables 5.2.2.1.5 and 5.2.2.1.6 Sensor 502 gives bigger

responses to diesel than sensor 501 and does not respond to concentrations of 2-chlorophenol at 5 ppm and only just registers a response at 10 ppm. At 20 ppm sensor 501 responds for all flow rates (Table 5.2.2.1.6). More sensors respond to this particular 2-chlorophenol test than for any other combination of parameters.

Table 5.2.2.1.4. Parameter comparisons and their effect on sensor and RH response. Concentration held at 5ppm. Sample temperature at 30°C Vs flows of 50, 100 and 200 ml/min.

	Sample temperature @ 30 °C					
5 ppm	2-chlorophenol			Diesel		
Flow rate	50 ml/min	100 ml/min	200 ml/min	50 ml/min	100 ml/min	200 ml/min
Sensor 501	0	0.06	0.06	0.04	0.14	0.12
Sensor 502	0	0	0	0.14	0.2	0.25
Sensor 503	0	0	0	0	0	0.1
Sensor 504	0	0	0	0	0.12	0.1
RH	30	35	45	34	47	46

Table 5.2.2.1.5. Parameter comparisons and their effect on sensor and RH response. Concentration held at 10ppm. Sample temperature at 30°C Vs flows of 50, 100 and 200 ml/min.

	Sample temperature @ 30 °C					
10 ppm	2-chlorophenol			Diesel		
Flow rate	50 ml/min	100 ml/min	200 ml/min	50 ml/min	100 ml/min	200 ml/min
Sensor 501	0	0.11	0.12	0.04	0.3	0.62
Sensor 502	0	0	0.04	0.08	0.8	1.24
Sensor 503	0	0	0	0	0 14	0.44
Sensor 504	0	0	0.1	0	0.32	0.54
RH	33	31	44	33	40	42

Table 5.2.2.1.6. Parameter comparisons and their effect on sensor and RH response. Concentration held at 20ppm. Sample temperature at 30°C Vs flows of 50, 100 and 200 ml/min.

	Sample temperature @ 30 °C					
20 ppm	2-chlorophenol			Diesel		
Flow rate	50 ml/min	100 ml/min	200 ml/min	50 ml/min	100 ml/min	200 ml/min
Sensor 501	0.16	0.19	0.22	0.04	1.45	0.68
Sensor 502	0	0.06	0.15	0.18	2.1	0.92
Sensor 503	0	0	0.06	0	0.9	0.55
Sensor 504	0	0.14	0.17	0	0.78	0.44
RH	39	39	41	32	44	48

The sensor response profiles in Figures 5.2.2.1.1 and 5.2.2.1.2 show spiking episodes using 2-chlorophenol at 10 ppm for sensor 501 (from Table 5.2.2.1.5). The magnitude of the sensor response change is almost identical although a slight increase is observed for the higher sparge gas flow rate. The RH value in Figure 5.2.2.1.1 is 44% whereas that in Figure 5.2.2.1.2's is over 10% lower at around 31%. This is a result of the increase in sparge gas flow rate.

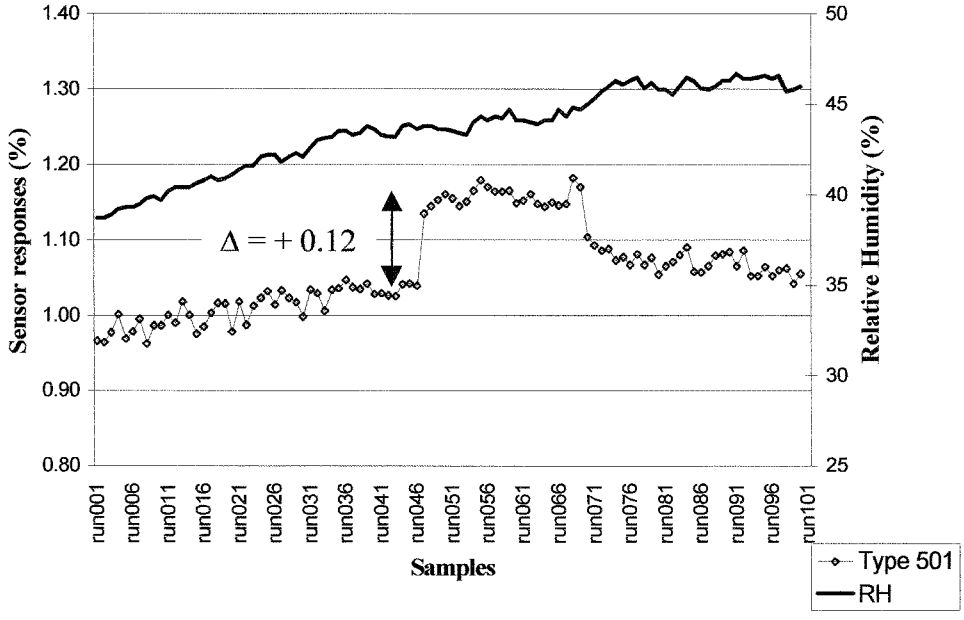

Figure 5.2.2.1.1 Sensor 501 between runs 1-101. 200 ml/min sparge flow rate. 10 ppm 2-chorophenol spike between runs 47-69. Liquid samples at 30°C

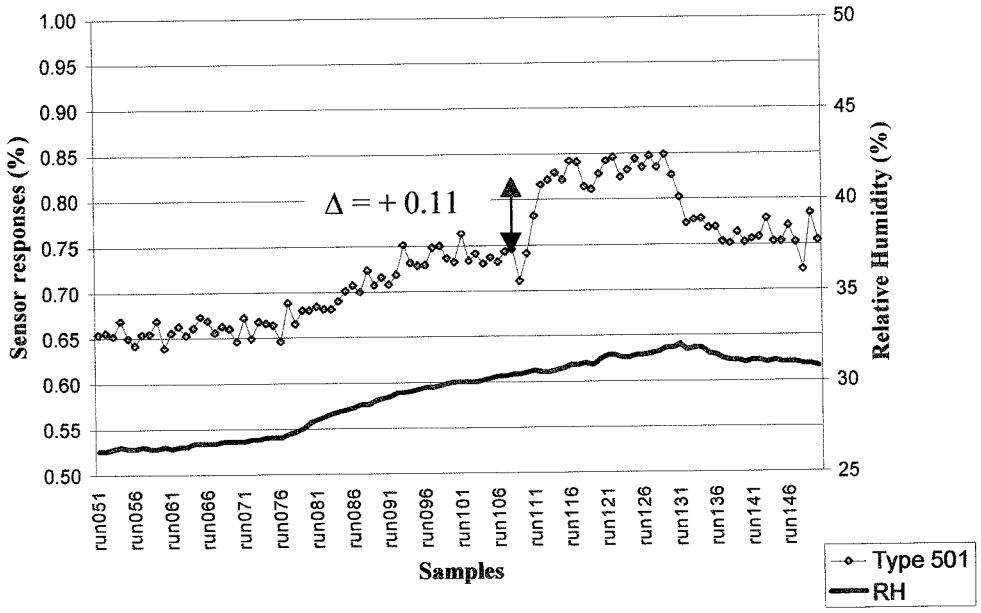

Figure 5.2.2.1.2 Sensor 501 between runs 51-150. 100 ml/min sparge flow rate 10 ppm 2-chlorophenol spike between runs 111-129. Liquid samples at 30°C

The plots in Figures 5.2.2.1.3 and 5.2.2.1.4 show spiking episodes using 2-chlorophenol at 20 ppm for sensor 501. Figure 5.2.2.1.4 exhibits a Δ response of + 0.22 for a 200 ml/min sparge rate and the 100 ml min sparge rate in Figure 5.2.2.1.3 is slightly less at Δ + 0.19, corresponding to the second and third columns in Table 5.2.2.1.6. The diesel responses are not increasing with the corresponding increase in sparge gas flow rate. At 20 ppm the 100 ml/min sparge yields the best responses, more than double that observed for 200 ml/min (Figures 5.2.2.1.5 and 5.2.2.1.6)

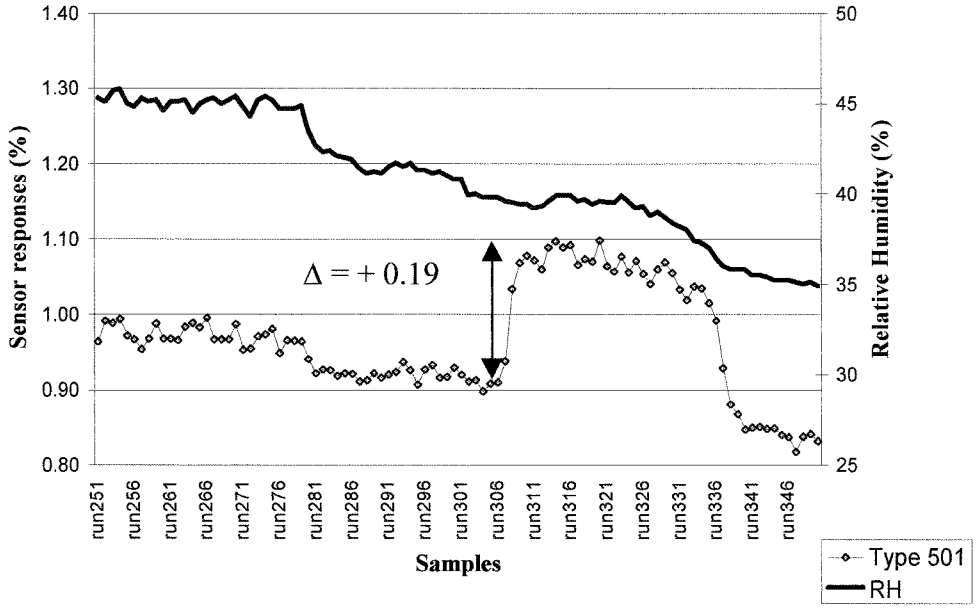

Figure 5.2.2.1.3 Sensor 501 between runs 251-350. 100 ml/min sparge flow rate. 20 ppm 2-chlorophenol spike between runs 307-335. Liquid samples at 30°C

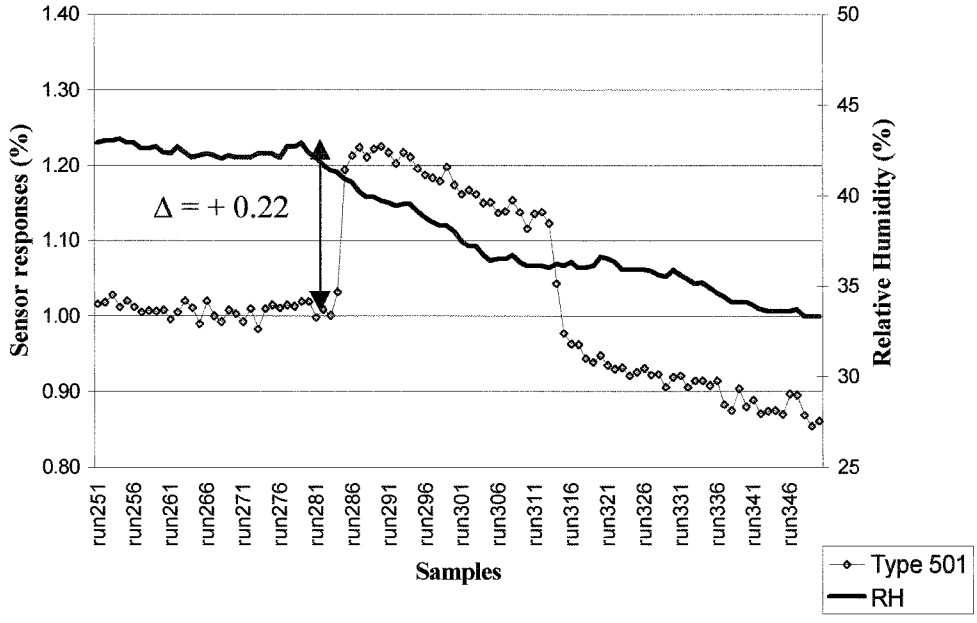

Figure 5.2.2.1.4 Sensor 501 between runs 250-350. 200 ml/min sparge flow rate. 20 ppm 2-chlorophenol spike between runs 284-312. Liquid samples at 30°C

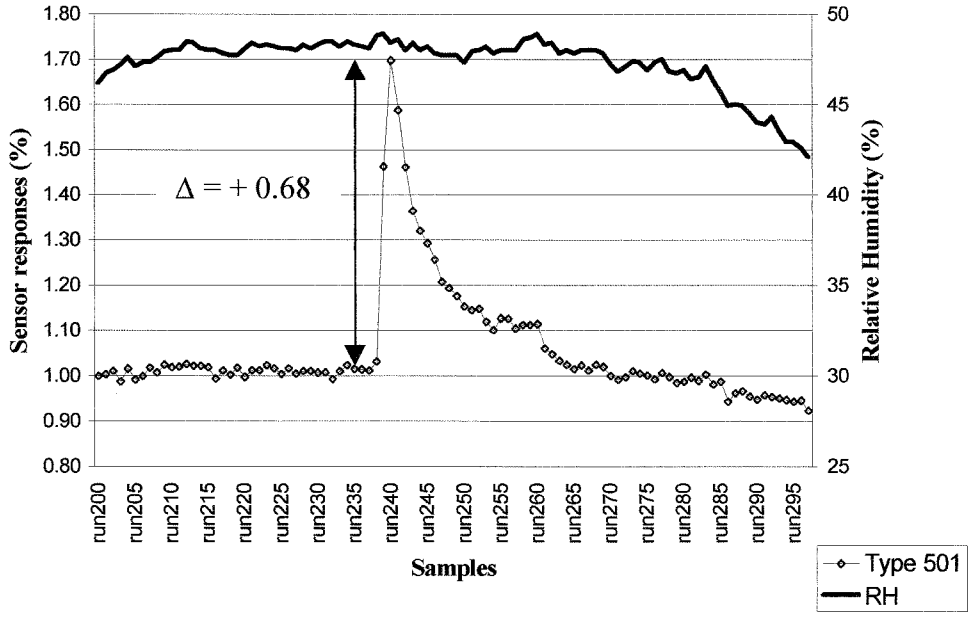

Figure 5.2.2.1.5 Sensor 501 between runs 201-300. 200 ml/min sparge flow rate. 20 ppm diesel spike between runs 240-260. Liquid samples at 30°C

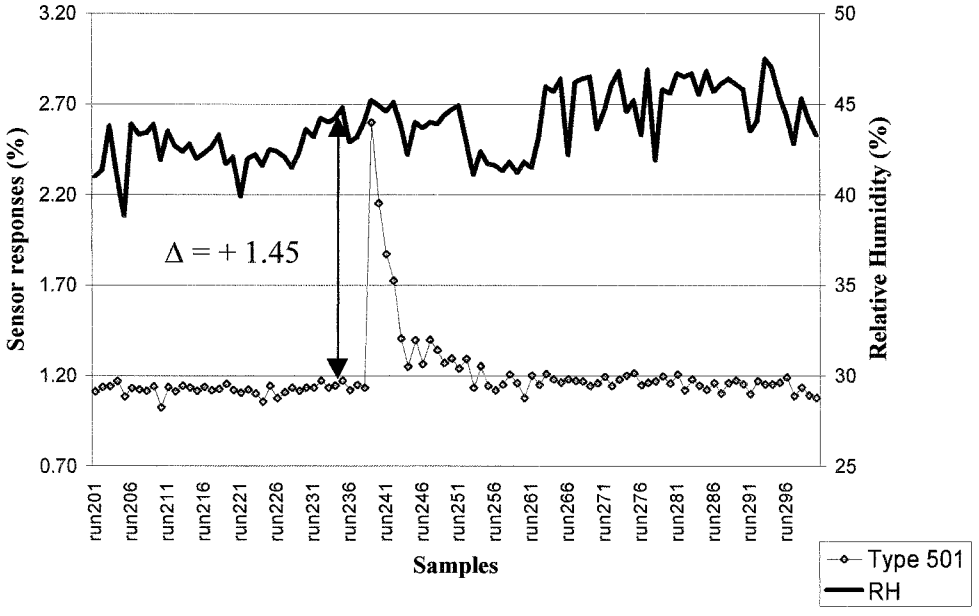

Figure 5.2.2.1.6 Sensor 501 between runs 201-300. 100 ml/min sparge flow rate. 20 ppm diesel spike between runs 239-263. Liquid samples at 30°C

The sensor response profiles in Figures 5.2.2.1.7, 5.2.2.1.8, 5.2.2.1.9 and 5.2.2.1.10 represent sensors 501, 502, 503 and 504 respectively for the spiking episode tabulated in

the last column of Table 5.2.2.1.6. The responses are to a 20 ppm diesel solution. The initial detection of the pollutant registers a significant jump in sensor response. As the pollutant remains in the flow-cell the diesel is stripped from solution by the flow of the sparge gas and as the concentration drops in the liquid phase the sensor response profile peters out to a stable level above that of the preceeding baseline for the DI water. The pollution does not completely disappear but would if left in the system for a longer time.

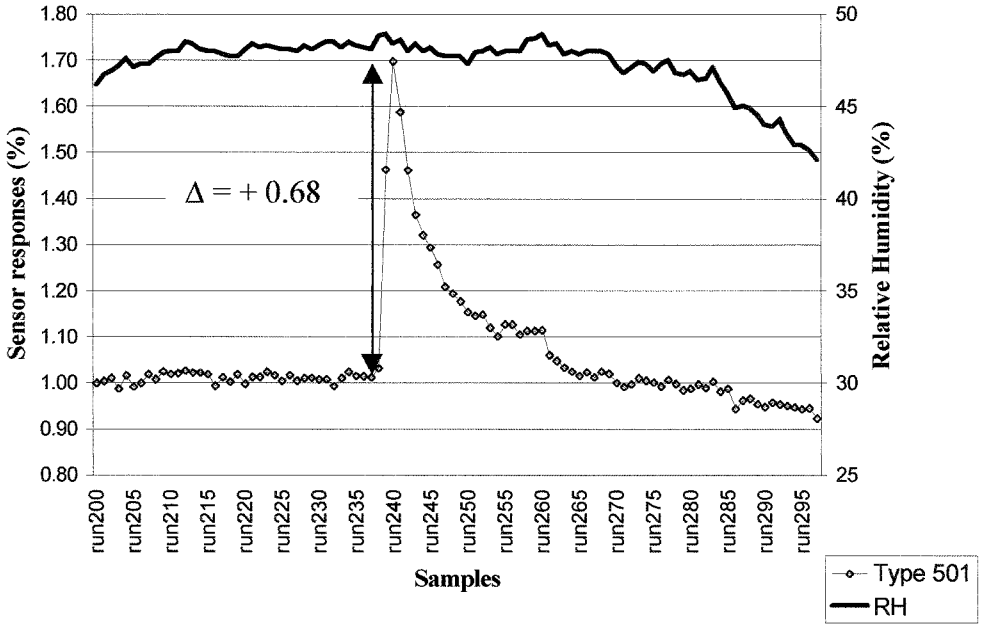

Figure 5.2.2.1.7 Sensor 501 between runs 201-300. 200 ml/min sparge flow rate. 20 ppm diesel spike between runs 240-260. Liquid samples at 30°C

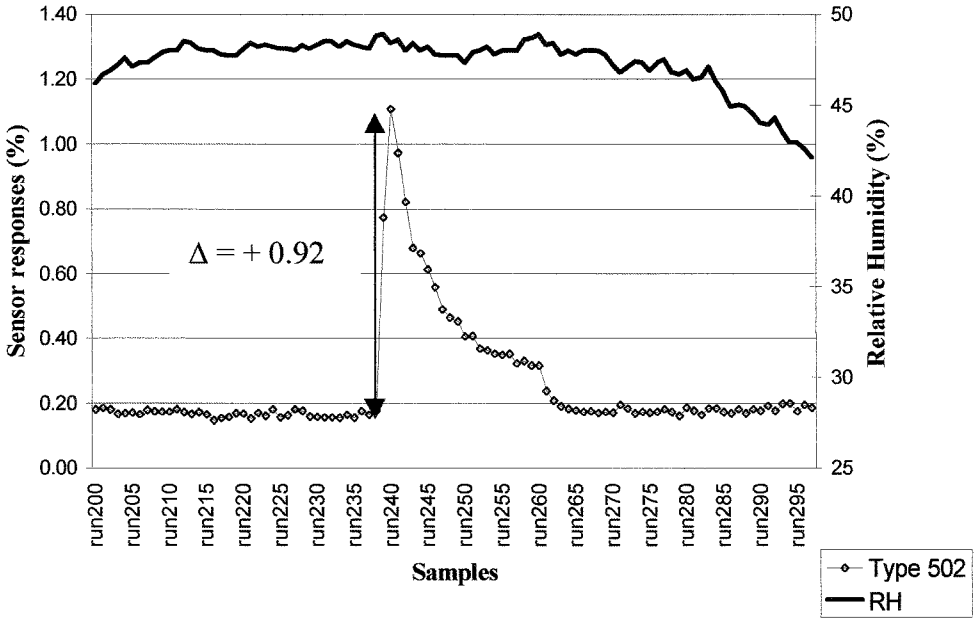

Figure 5.2.2.1.8 Sensor 502 between runs 201-300. 200 ml/min sparge rate. 20 ppm diesel spike between sample numbers 240-260. Liquid samples at 30°C.

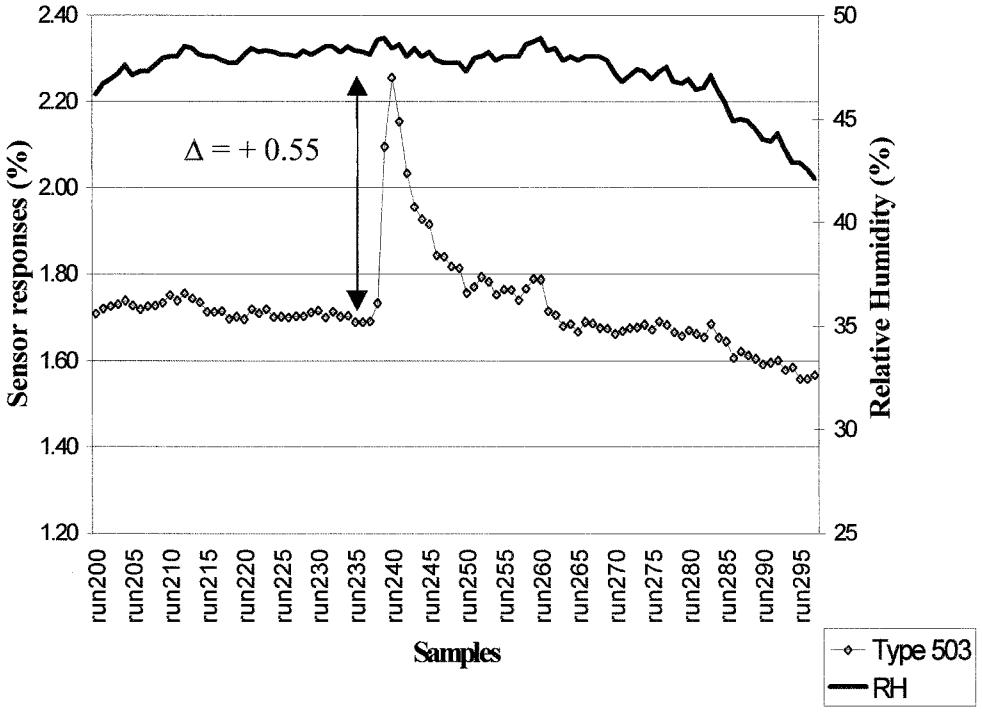

Figure 5.2.2.1.9 Sensor 503 between runs 201-300. 200 ml/min sparge rate. 20 ppm diesel spike between sample numbers 240-260. Liquid temperatures at 30°C.

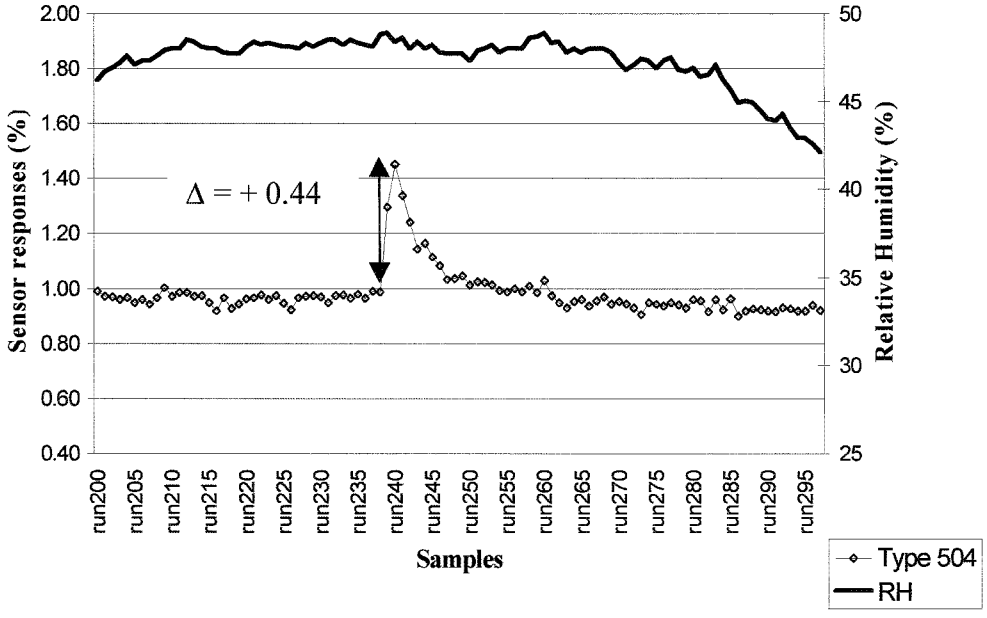

Figure 5.2.2.1.10 Sensor 504 between runs 201-300. 200 ml/min sparge flow rate. 20 ppm diesel spike between sample numbers 240-260. Liquid temperatures at 30°C.

5.2.2.2. Sample concentration - flow by temperature:

At 50 ml/min the sensors did not respond to the 5 ppm 2-chlorophenol regardless of sample temperature (Table 5.2.2.2.1). At both 100 and 200 ml/min only sensor 501 registered the presence of pollution. A greater response change was recorded as the sample temperature increased from 15 to 30°C. The RH value increases at higher sample temperatures.

Table 5.2.2.2.1 Parameter comparisons and their effect on sensor and RH response. 2-chlorophenol at 5ppm. Flows of 50, 100 and 200 ml/min Vs sample temperatures of 15°C and 30°C.

	5 ppm 2-chlorophenol					
Flow rate	50 ml/min		100 ml/min		200 ml/min	
Sample Temp	15 °C	30 °C	15 °C	30 °C	15 °C	30 °C
Sensor 501	0	0	0.03	0.06	0.05	0.06
Sensor 502	0	0	0	0	0	0
Sensor 503	0	0	0	0	0	0
Sensor 504	0	0	0	0	0	0
RH	29	30	32	35	36	45

Responses from sensor 501 at 100 and 200 ml/min sparge gas flows at 30°C (Table 5.2.2.2.2) are almost double that observed for the 15°C runs. All RH values are similar except for a higher result yielded from a high temperature and high flow rate combination.

Table 5.2.2.2.2 Parameter comparisons and their effect on sensor and RH response. 2-chlorophenol at 10ppm. Flows of 50, 100 and 200 ml/min Vs sample temperatures of 15°C and 30°C.

	10 ppm 2-chlorophenol					
Flow rate	50 ml/min		100 ml/min		200 ml/min	
Sample Temp	15 °C	30 °C	15 °C	30 °C	15 °C	30 °C
Sensor 501	0	0	0.05	0.11	0.07	0.12
Sensor 502	0	0	0	0	0.08	0.04
Sensor 503	0	0	0	0	0.06	0
Sensor 504	0	0	0	0	0	0.1
RH	31	33	32	31	33	44

The results from the 20 ppm 2-chlorophenol runs (Table 5.2.2.2.3) show that as the sample temperature doubles for each increasing sparge gas flow rate the change in recorded sensor response also doubles. In each case the RH has also shown an increase by about 10%. The graphics in Figures 5.2.2.2.1 and 5.2.2.2.2 illustrate this change upon

sensor 501 attributed to sample temperature for a sparge gas flow of 50 ml/min, corresponding to row 4, columns one and two in Table 5.2.2.2.3.

Table 5.2.2.2.3 Parameter comparisons and their effect on sensor and RH response. 2-chlorophenol at 20ppm. Flows of 50, 100 and 200 ml/min Vs sample temperatures of 15°C and 30°C.

	20 ppm 2-chlorophenol					
Flow rate	50 ml/min		100 ml/min		200 ml/min	
Sample Temp	15 °C	30 °C	15 °C	30 °C	15 °C	30 °C
Sensor 501	0.09	0.16	0.1	0.19	0.12	0.22
Sensor 502	0	0	0.02	0.06	0.09	0.15
Sensor 503	0	0	0	0	0	0.06
Sensor 504	0	0	0	0.14	0.12	0.17
RH	29	39	32	39	32	41

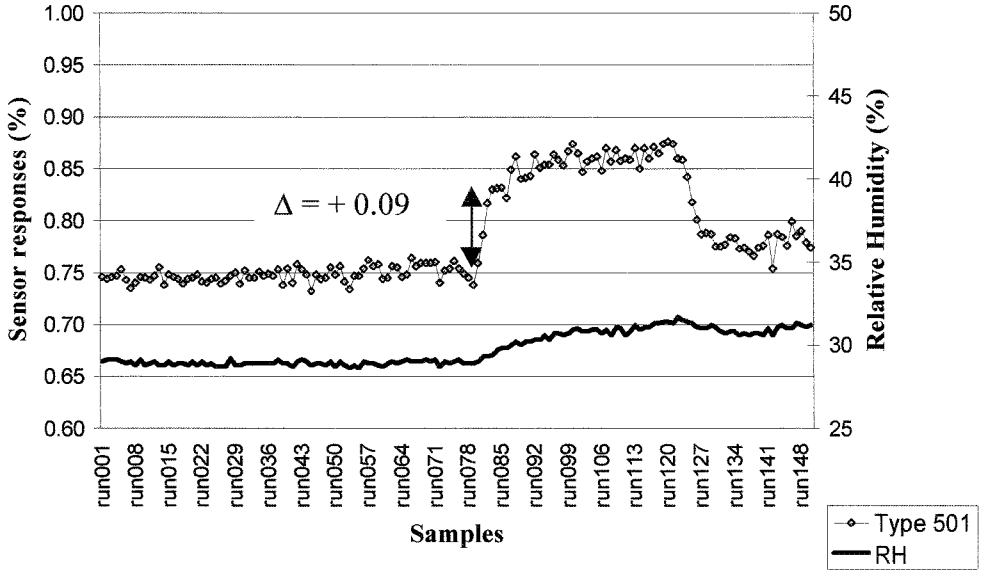

Figure 5.2.2.2.1 Sensor 501 between runs 1-151. 50 ml/min sparge flow rate. 20 ppm 2-chlorophenol spike between runs 81-126. Liquid samples at 15°C

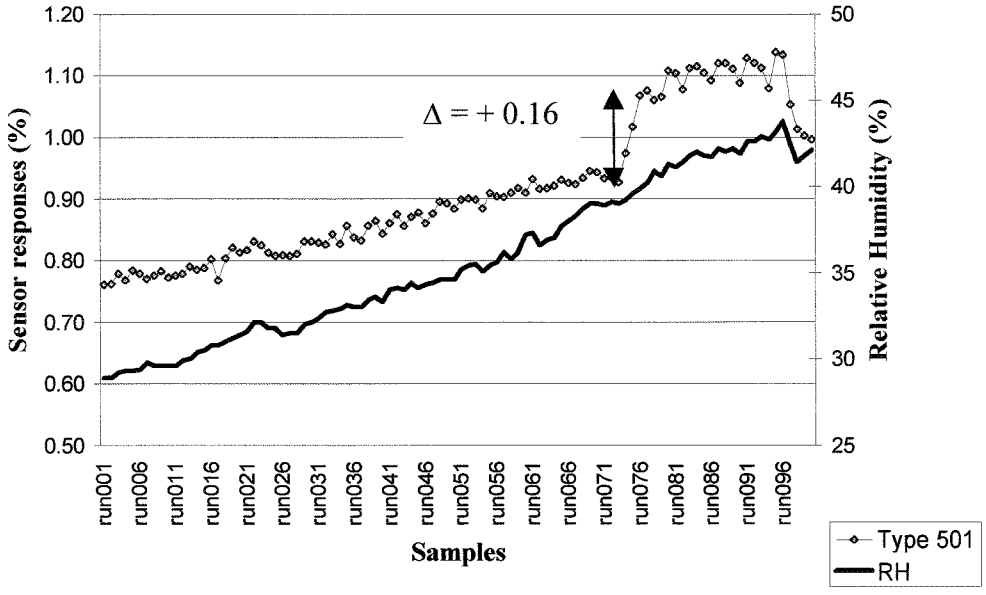

Figure 5.2.2.2.2 Sensor 501 between runs 1-101. 50 ml/min sparge flow rate. 20 ppm 2-chlorophenol spike between runs 74-96. Liquid samples at 30°C.

Higher sample temperatures yield increased sensor responses for each sparge rate (Table 5.2.2.2.4). Sensor 502 detects diesel at the lowest combinations of each parameter suggesting that lower levels of detection could be achieved. Sensor 501 is less likely to respond to diesel than sensor 502. The RH is higher for the 30°C runs than at 15°C in accordance with early experimental design trends.

Table 5.2.2.2.4 Parameter comparisons and their effect on sensor and RH response. Diesel at 5ppm. Flows of 50, 100 and 200 ml/min Vs sample temperatures of 15°C and 30°C.

	5 ppm Diesel					
Flow rate	50 ml/min		100 ml/min		200 ml/min	
Sample Temp	15 °C	30 °C	15 °C	30 °C	15 °C	30 °C
Sensor 501	0	0.04	0.04	0.14	0	0.12
Sensor 502	0.06	0.14	0.15	0.2	0.14	0.25
Sensor 503	0	0	0	0	0	0.1
Sensor 504	0	0	0	0.12	0	0.1
RH	31	34	28	47	32	46

With the exception of the 50 ml/min test the RH is greater for the increased temperature runs (Table 5.2.2.2.5). The 502 sensor responses increase as combinations of flow rate and sample temperature increase. As each combination of parameters increase the more sensors respond. The sensor response profiles in Figures 5.2.2.2.3 – 5.2.2.2.6 illustrate the influence sampling conditions of 10 pmm diesel spike at 100 ml/min and 30°C have upon sensor 501, 502, 503 and 504 respectively. Each sensor reacts differently to the same headspace sample; this is a desirable characteristic of an array of sensors. Sensor 502 yields the best result under these conditions, as it has done in all other diesel testing.

Table 5.2.2.2.5 Parameter comparisons and their effect on sensor and RH response.
Diesel at 10ppm. Flows of 50, 100 and 200 ml/min
Vs sample temperatures of 15°C and 30°C.

	10 ppm Diesel					
Flow rate	50 ml/min		100 ml/min		200 ml/min	
Sample Temp	15 °C	30 °C	15 °C	30 °C	15 °C	30 °C
Sensor 501	0	0.04	0.07	0.3	0.11	0.62
Sensor 502	0.03	0.08	0.19	0.8	0.49	1.24
Sensor 503	0	0	0	0.14	0.08	0.44
Sensor 504	0	0	0	0.32	0.14	0.54
RH	38	33	28	39	33	42

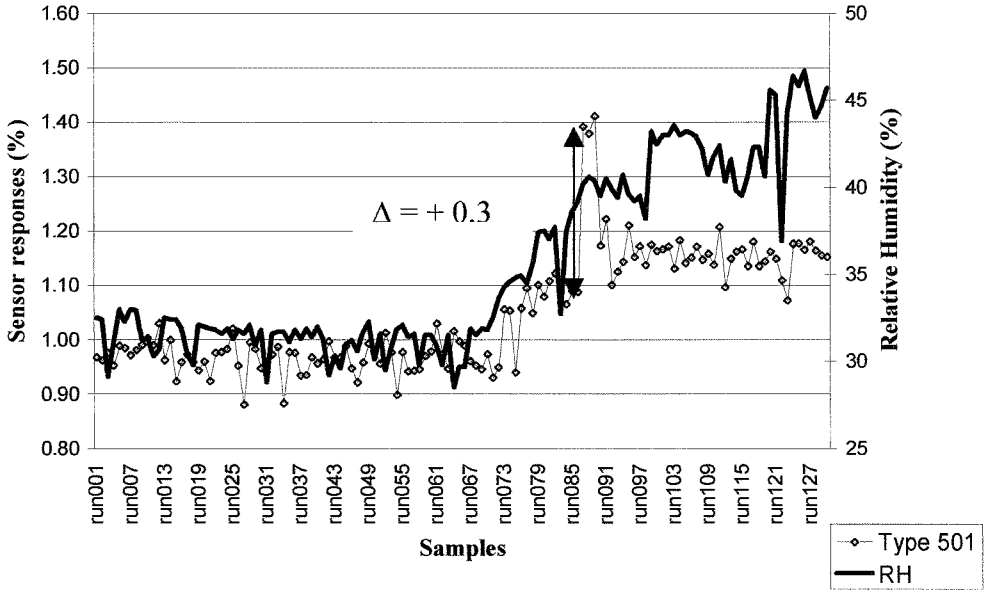

Figure 5.2.2.2.3 Sensor 501 between runs 1-130. 100 ml/min sparge flow rate. 10 ppm diesel spike between runs 87-119. Liquid samples at 30 °C.

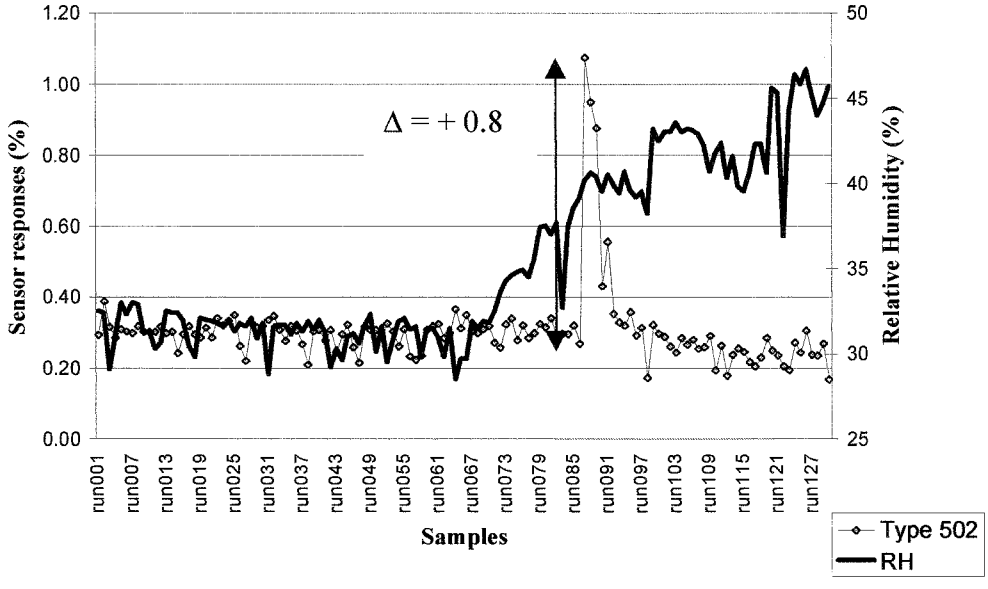

Figure 5.2.2.2.4 Sensor 502 between runs 1-130. 100 ml/min sparge flow rate. 10 ppm diesel spike between runs 87-119. Liquid samples at 30 °C.

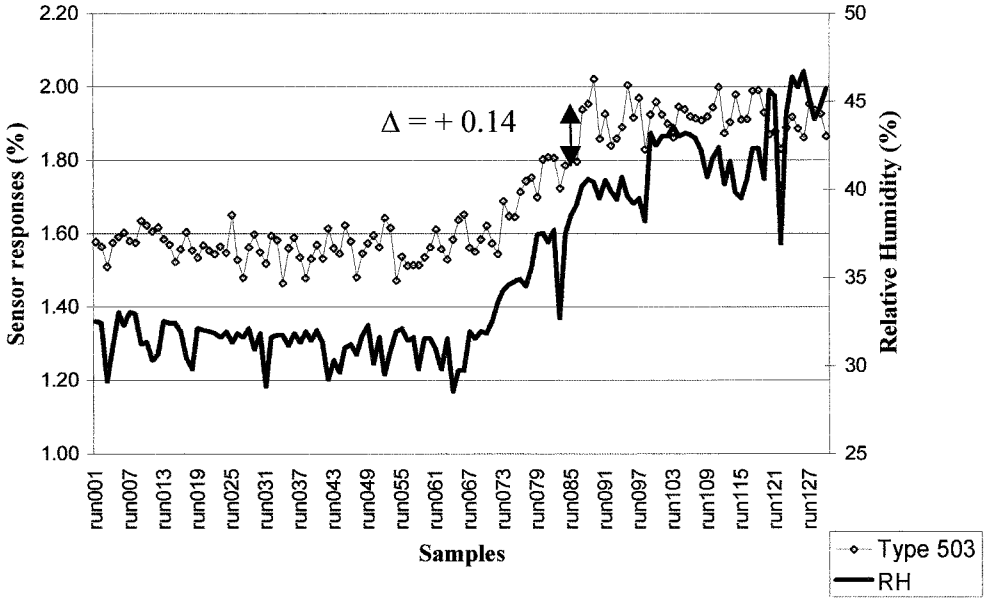

Figure 5.2.2.2.5 Sensor 503 between runs 1-130. 100 ml/min sparge flow rate. 10 ppm diesel spike between runs 87-119. Liquid samples at 30 °C.

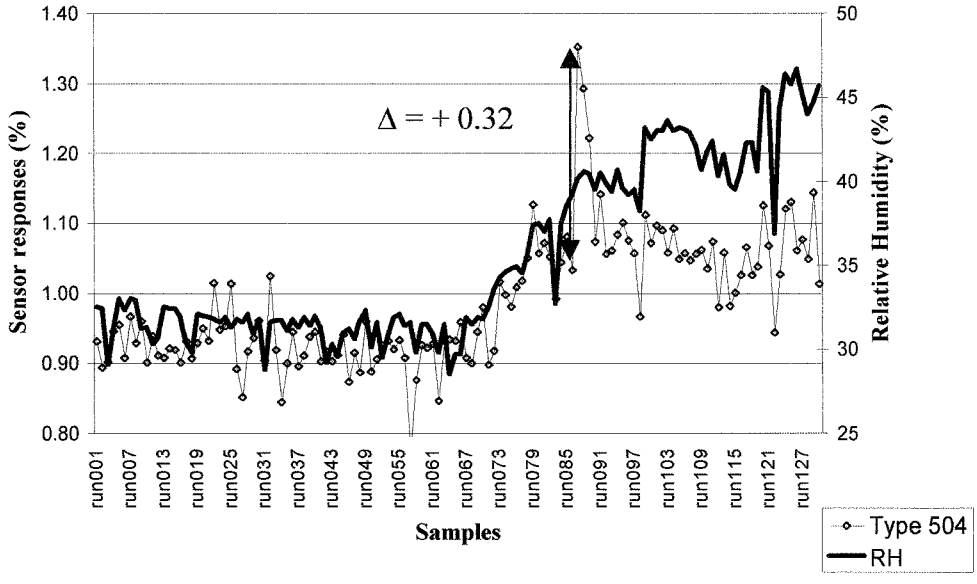

Figure 5.2.2.2.6 Sensor 504 between runs 1-130. 100 ml/min sparge flow rate. 10 ppm diesel spike between runs 87-119. Liquid samples at 30 °C.

Higher gas flows and corresponding sample temperatures yield larger sensor responses. The 100ml flow rate and 30°C (Table 5.2.2.2.6) give very large values for the 20ppm Diesel spike. The other conditions are following a trend yet at this increased concentration the 100 ml/min flow rate and 30°C sample temperatures are more effective at volatalising the diesel into the gas phase suggesting that sensor 502 does not behave in a linear relation ship for these parameters and compound.

Table 5.2.2.2.6 Parameter comparisons and their effect on sensor and RH response. Diesel at 20ppm. Flows of 50, 100 and 200 ml/min Vs sample temperatures of 15°C and 30°C.

	20 ppm Diesel					
Flow rate	50 ml/min		100 ml/min		200 ml/min	
Sample Temp	15 °C	30 °C	15 °C	30 °C	15 °C	30 °C
Sensor 501	0.05	0.04	0.19	1.45	0.12	0.68
Sensor 502	0.19	0.18	0.5	2.10	0.55	0.92
Sensor 503	0	0	0	0.9	0.07	0.55
Sensor 504	0	0	0.2	0.78	0.20	0.44
RH	32	32	29	44	33	48

5.2.2.3. Sparge gas flow rate - temperature by concentration:

The data presented in Tables 5.2.2.3.1 and 5.2.2.3.2 compare the effects of sample temperature Vs sample concentration for gas flows of 50 and 100 ml/min respectively on 2-chlorophenol spikes. At each temperature the higher sample concentration yields a larger sensor response. For the combinations of low concentration at 50 ml/min sensor is unable to detect the presence of either the 5 or 10 ppm spikes. More sensors react to the pollution as the flow rate, sample concentration and sample temperature increase. The RH values were constant across both tests.

Table 5.2.2.3.1. Parameter comparisons and their effect on sensor and RH response. 2-chlorophenol at flows of 50 ml/min. Sample temperatures of 15°C and 30°C Vs sample concentrations of 5, 10 and 20 ppm.

	50 ml/min 2-chlorophenol					
Sample Temp	15 °C			30 °C		
Sample Conc.	5 ppm	10 ppm	20 ppm	5 ppm	10 ppm	20 ppm
Sensor 501	0	0	0.09	0	0	0.16
Sensor 502	0	0	0	0	0	0
Sensor 503	0	0	0	0	0	0
Sensor 504	0	0	0	0	0	0
RH	29	31	29	30	33	39

Table 5.2.2.3.2. Parameter comparisons and their effect on sensor and RH response. 2-chlorophenol at flows of 100 ml/min. Sample temperatures of 15°C and 30°C Vs sample concentrations of 5, 10 and 20 ppm

	100 ml/min 2-chlorophenol					
Sample Temp	15 °C			30 °C		
Sample Conc.	5 ppm	10 ppm	20 ppm	5 ppm	10 ppm	20 ppm
Sensor 501	0.03	0.05	0.1	0.06	0.11	0.19
Sensor 502	0	0	0.02	0	0	0.06
Sensor 503	0	0	0	0	0	0
Sensor 504	0	0	0	0	0	0.14
RH	32	32	32	35	31	39