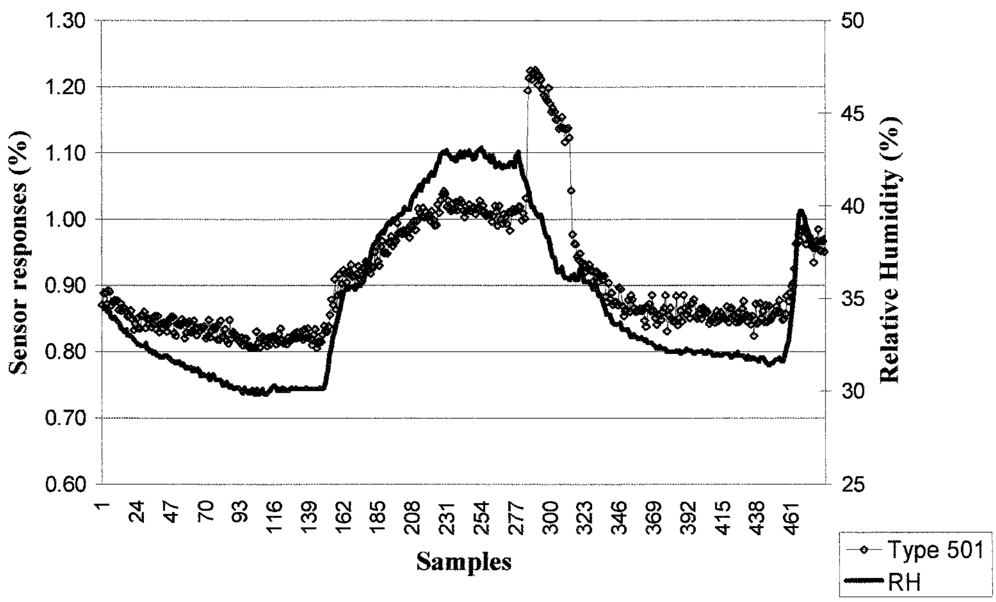

Figure 5.4.1.1 Sensor 501 between runs 0-483.
20 ppm 2-CP spike between runs 284-314. 200ml/min sparge rate.
Liquid temperatures at 30°C

PCA is a chemometric tool used to reduce the number of dimensions in a data set for visualising the information contained therein. PCA is a non-supervised linear technique that reduces the data and number of variables in the system e.g. The variations in the data (the number of sensors) are reduced giving principal components containing 99% of the systems variance. This has reduced the multivariate data into two dimensions. Plots of these data should exhibit grouping of odour types and concentration. Table 5.4.1.1 summarises the importance of each component and the influence it has within the PCA plots. Component one accounts for 71% of the variance and component two accounts for 27%. Components 3 and 4 share the remaining 2%. Figure 5.4.1.2 plots component one by component two for the 20ppm 2-chlorophenol spike. Two distinct clusters are present, one being the main body of water and the other being the pollution episode, clearly separated from the main body. Figure 5.4.1.3 provide the same data but plotting component two by component three. The polluted water is still clear but as there is less variance between the two components represented. The grouping is looser, as suggested in Table 5.4.1.1, due to the degree of variance between the data sets (2%).

Table 5.4.1.1 Variance Table for PCA of sensors 501, 502, 503 + 504 from plot 5.4.1.1

Component	Percent	Cumulative
1	0.71	0.71
2	0.27	0.98
3	0.01	0.99
4	0.01	1.0000

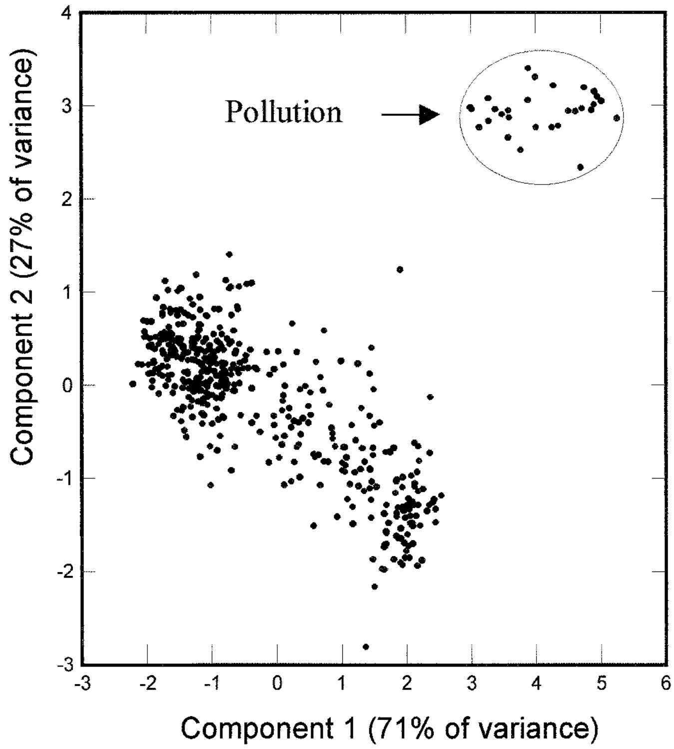

Figure 5.4.1.2 PCA analysis of a 20ppm 2-chlorophenol spike.

Component 1 by component 2.

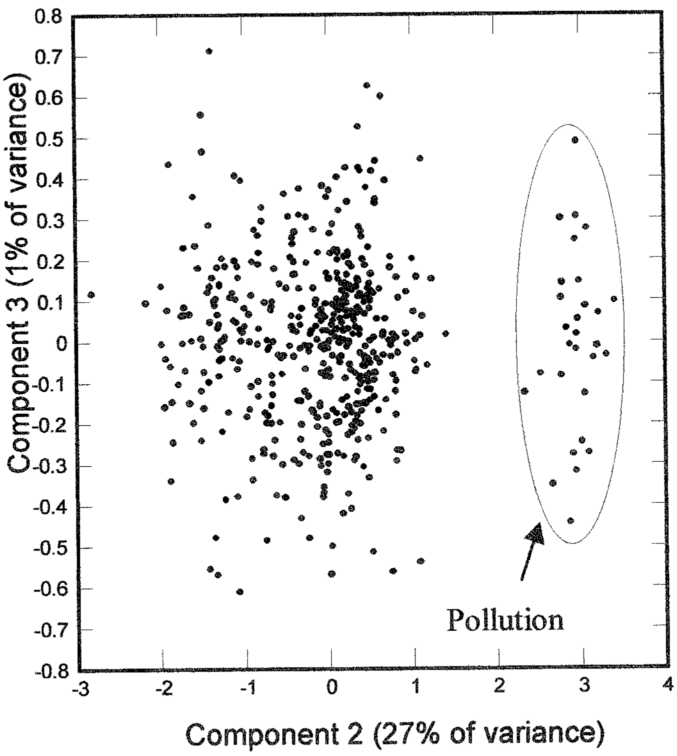

Figure 5.4.1.3 PCA analysis of a 20ppm 2-chlorophenol spike.
Component 2 by component 3.

Figure 5.4.1.4 shows a 20 ppm diesel spike for sensor 502, indicating the presence of the pollution. Figure 5.4.1.5 shows a plot obtained after the data from Figure 5.4.1.4 had been analysed with respect to its principal components.

Figure 5.4.1.5 plots component one by component two for a 20ppm diesel spike. Components 1 and 2 account for 80% and 19% of the variance, respectively. Components 3 and 4 share the remaining 1%. The main body of water represents the background sensor response variation for the unpolluted waters whist the boxed points shows the diesel spike. The furthest point from the main body represents the point at which the pollutant enters the flow-cell. As the diesel is purged from the solution into the headspace, reducing the sample's concentration, the characteristics return to coincide with the background sensor response levels, hence the drifting sample points back to the main body. This demonstrates that PCA is concentration sensitive and that for lower concentrations PCA may prove unreliable in representing changes in sample characteristics. PCA can only show the trends in the data that are already apparent in the graphical analysis.

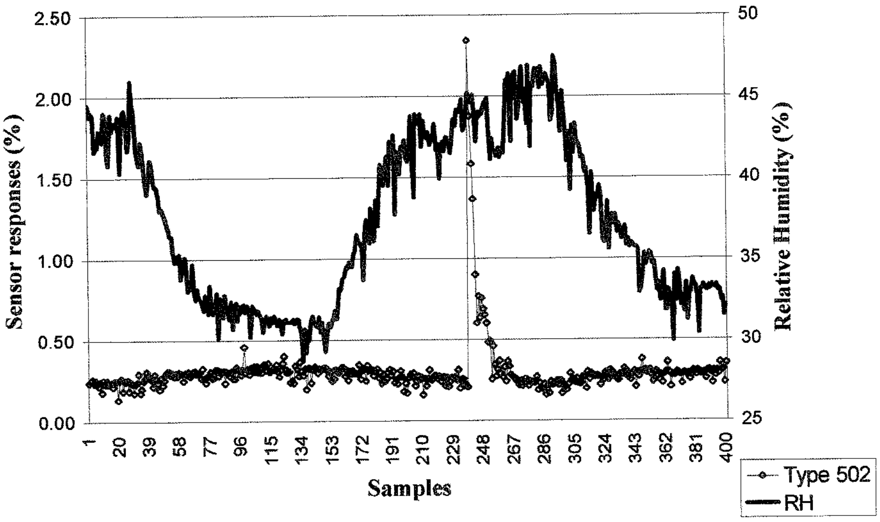

Figure 5.4.1.4 Sensor 501 between runs 0-400.
20 ppm diesel spike between runs 240-260. 100ml/min sparge rate 30°C.

Table 5.4.1.2 Variance Table for PCA of sensors 501, 502, 503 + 504 from plot 5.4.1.4.

Component	**Percent**	**Cumulative**
1	0.80	0.80
2	0.19	0.99
3	0.01	0.99
4	0.001	1.0000

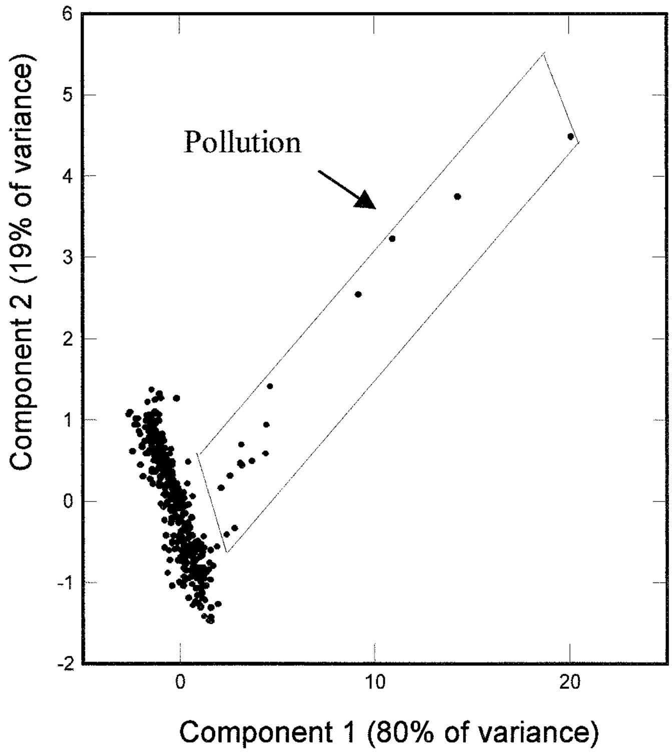

Figure 5.4.1.5 PCA analysis of a 20ppm diesel spike. Component 1 by component 2.

5.4.2. Statistical analysis of testing matrix – effects on sensor response.

If the sensors in the array are behaving in a reproducible manner it should be possible to place specific response values into a mathematical model to enable predictions for parametric changes. For this analysis to work only combinations of the variables where changes in the sensor response have occurred can be used. Tables 5.2.2.1 and 5.2.2.2 indicate the actual results from combinations of the three variables: sparge gas flow rate (V1), sample temperature (V2), and sample concentration (V3). For each compound tested there is a dominant sensor. Sensor 501 responded to all but four of the 18 combinations for 2-chlorophenol whilst sensor 502 responded to all of the 18 combinations for diesel. Only parameters where a positive sensor response change has been recorded can be used within the prediction. RH is considered first in Table 5.4.2.1.1. Tables 5.4.2.2.1 and 5.4.2.3.1 indicate the variables and their corresponding response change for the selected sensor.

5.4.2.1. Δ Sensor response (RH)

Table 5.4.2.1.1 shows the experimental design matrix used to observe the main variable effects of RH for the 2-chlorophenol and diesel testing matrices (Table 5.2.2.1 and 5.2.2.2). The matrix values for the RH responses from sets of data are presented in Table 5.4.2.1.2.

Main effects:

Table 5.4.2.1.1 Experimental design matrix including variable values

Run	**Sparge gas flow rate (V1)**	**Sample temperature (V2)**	**Sample concentration (V3)**	**Response**
1	50	15	5	?
2	200	15	5	?
3	50	30	5	?
4	200	30	5	?
5	50	15	20	?
6	200	15	20	?
7	50	30	20	?
8	200	30	20	?

Table 5.4.2.1.2 RH responses from experimental design (two separate runs, A and B).

	Response Run A (2-CP spikes)	**Response Run B (Diesel spikes)**
Run	**RH. (%)**	**RH. (%)**
1	29	31
2	36	32
3	30	34
4	45	46
5	29	32
6	32	33
7	39	32
8	41	48

The average result was calculated for each of the runs where a given variable is at its low level (simply by summing and dividing by 4). This is then repeated for all the runs when the variable at its high value. The average effect of the variable is then found by calculating the difference of the average contributions at the two different levels, this is repeated for all three variables (Tables 5.4.2.1.3 and 5.4.2.1.4).

Table 5.4.2.1.3 Average contribution and effect of temperature, flow rate and concentration on RH levels, run A (2-chlorophenol).

Variable	**Level**	**Average**	**Difference**
Temperature (°C)	15 30	31.5 38.75	7.25
Sparge gas flow rate (ml/min)	50 200	31.75 38.5	6.75
Sample concentration (ppm)	5 20	35 35.25	0.25

Table 5.4.2.1.4 Average contribution and effect of temperature, flow rate and concentration on RH levels, run B (diesel).

Variable	**Level**	**Average**	**Difference**
Temperature (°C)	15 30	32 40	8
Sparge gas flow rate (ml/min)	50 200	32.25 39.75	7.5
Sample concentration (ppm)	5 20	35.75 36.25	0.5

By ranking the individual average effects (according to their magnitude), the relative contribution of each factor becomes evident (Table 5.4.2.1.5). The two sets of ranked effects appear in the same order and have similar magnitudes for each run. The difference in trends can be attributed to drifting ambient laboratory conditions and differences occurring during separate tests. This is a clear indication that the testing matrix is reproducible in terms of the RH generated for each combination of parameters.

Table 5.4.2.1.5 Ranked average effects of sample temperature, gas flow rate and concentration (relative to RH)

Run A	Run B
Temperature 7.25	Temperature 8
Flow rate 6.75	Flow rate 7.5
Concentration 0.25	Concentration 0.5

Variable interactions:

This section makes use of a simple mathematical model to detect and measure any possible interaction between the variables. This model contains a number of coefficients calculated by the method of "contrast patterns" and generated from the design matrix of the experiment (Table 5.4.2.1.6).

Table 5.4.2.1.6 Contrast pattern matrix generated for runs A and B.

Run	V1	V2	V3	V1V2	V1V3	V2V3	V1V2V3	RH Run A	RH Run B	RH Ave (A+B/2)
1	-1	-1	-1	+1	+1	+1	-1	29	31	30
2	+1	-1	-1	-1	-1	+1	+1	36	32	34
3	-1	+1	-1	-1	+1	-1	+1	30	34	32
4	+1	+1	-1	+1	-1	-1	-1	45	46	45.5
5	-1	-1	+1	+1	-1	-1	+1	29	32	30.5
6	+1	-1	+1	-1	+1	-1	-1	32	33	32.5
7	-1	+1	+1	-1	-1	+1	-1	39	32	35.5
8	+1	+1	+1	+1	+1	+1	+1	41	48	44.5

V1 = Gas flow rate, V2 = Sample temperature and V3 = Sample concentration.

All coefficients are calculated by the relevant contrast pattern and the value of each is provided in Table 5.4.2.1.7. A1 is the coefficient of variable V1, A2 is the coefficient of V2 and A12 is the coefficient of the combined effects of Variables V1 and V2 etc. The results for each coefficient can be averaged for the two runs to provide one set of generalised coefficients (represented in column three, Table 5.4.2.1.7).

Table 5.4.2.1.7 Main effect coefficients and interaction coefficients generated for runs A and B worked from Table 5.4.2.1.6

Coefficient	Run A	Run B	Average
A1	3.37	3.75	3.56
A2	3.63	4	3.81
A3	0.13	0.25	0.19
A12	0.87	3.25	2.06
A13	-2.13	0.5	-0.81
A23	1.13	-0.25	0.44
A123	-1.13	0.5	-0.31
A0	35.13	36	35.56

Tables 5.4.2.1.8 – 5.4.2.1.10 show the significance of the interactions. The significance of each coefficient is calculated by dividing each separate coefficient by the value represented by coefficient A123 (the value calculated for the interactions between all three components).

Table 5.4.2.1.8 Significance of the coefficient values – Run A, from Table 5.4.2.1.7.

Coefficient	Run A	Significance
A1	3.37	-3
A2	3.63	-3.22
A3	0.13	-0.11
A12	0.87	-0.78
A13	-2.13	1.89
A23	1.13	-1
A123	-1.13	1
A0	35.13	-

Table 5.4.2.1.9 Significance of the coefficient values – Run B, from Table 5.4.2.1.7

Coefficient	Run B	Significance
A1	3.75	7.5
A2	4	8
A3	0.25	0.5
A12	3.25	6.5
A13	0.5	1
A23	-0.25	-0.5
A123	0.5	1
A0	36	-

Table 5.4.2.1.10 Significance of the coefficient values – average of Run A and Run B, from Table 5.4.2.1.7

Coefficient	Average	Significance
A1	3.56	11.4
A2	3.81	12.2
A3	0.19	0.6
A12	2.06	6.6
A13	-0.81	2.6
A23	0.44	1.4
A123	-0.31	1
A0	35.56	-

The same pattern is evident in each Table 5.4.2.1.8, 5.4.2.1.9 and 5.4.2.1.10, where variables V1 and V2 are statistically more significant, these being sparge gas flow rate and sample temperature, respectively. The interaction value of these two variables is also significant.

The RH for this experiment was predicted by using the following equation:

$$RH = A_0 + A_1.V1 + A_2.V2 + A_3.V3 + A_{12}.V1.V2 + A_{13}.V1.V3 + A_{23}.V2.V3 + A_{123}.V1.V2.V3$$

Where A1, A2 etc are the interaction coefficients and V1, V2 and V3 are the coded values for their respective variables. These are determined, assuming a linear relationship applies, in the form of a y = mx + c equation where y is the coefficient required, as follows:

V1 = 0.013 x Flow rate (ml/min) – 1.6
V2 = 0.133 x Concentration (ppm) – 1.667
V3 = 0.133 x Temperature (°C) – 2.99

Therefore each variable has a corresponding coefficient (Table 5.4.2.1.11)

Table 5.4.2.1.11. Coefficients for corresponding variables used in the prediction equation

Variable	**Value**	**Coefficient**
Flow rate (ml/min)	200	+1
	100	-0.3
	50	-1
Temperature (°C)	30	+1
	15	-1
Concentration (ppm)	20	+1
	10	-0.337
	5	-1

RH prediction:

The estimated RH value for a gas flow rate of 100 ml/min (coded value –0.3), a sample temperature of 30 °C (coded value +1) and a sample concentration of 10 ppm (coded value –0.337). Using the averaged values for the coefficients (as these provide a rounder picture of response similarity)

RH = 35.56 + (3.56 x -0.3) + (3.18 x 1) + (0.19 x –0.337) + (2.06 x -0.3) +
(-0.81 x 0.10) + (0.44 x –0.34) + (-0.31 x 0.10) = 36.7

Actual results for the RH under these conditions were 31 and 39 for 2-chlorophenol and diesel respectively. Further combinations of variables were predicted (Table 5.4.2.1.12)

Table 5.4.2.1.12 Δ Sensor RH. Response predictions.

Flow ml/min	**Temp. °C**	**Conc. ppm**	**Predicted Δ value**	**Actual Δ values**	**Average of actual value**	**Accuracy**
200	30	10	44.5	44 + 42	43	97 %
100	30	10	36.7	31 + 39	35	95 %
50	30	10	32.5	33 + 33	33	98 %
200	15	10	34.1	33 + 33	33	97 %
100	15	10	31.9	32 + 28	30	94 %
50	15	10	30.7	31 + 38	34.5	89 %

Five of the six predictions presented in Table 5.4.2.1.12 are within 6 % of the true value observed for each set of parameters. This proves that the system is reproducible, predictable and that sensor 501 behaves in a linear relationship with respect to RH. Assuming the RH sensor is an indication of water quality, such as the responses from the CP sensors, rogue results could be used to flag to occurrence of a change in water quality. This same approach was used upon the results gained from the sensors in the array. Sensors 501 and 502 have been predicted for response changes when 2-chlorophenol and diesel have been introduced, respectively.

5.4.2.2. Δ Sensor response (501, 2-CP)

Sensor 501 is the most sensitive for the detection of 2-chlorophenol so therefore has more data available for use within this statistical model. The main effects' experimental design matrix (Table 5.4.2.2.1) was constructed from data taken from Table 5.2.2.1.

Main effects:

Table 5.4.2.2.1 Experimental design matrix including variable values

Run	Sparge gas flow rate (V1)	Sample temperature (V2)	Sample concentration (V3)	Δ sensor response (501, 2-CP)
1	100	15	5	0.03
2	200	15	5	0.05
3	100	30	5	0.06
4	200	30	5	0.19
5	100	15	20	0.10
6	200	15	20	0.12
7	100	30	20	0.19
8	200	30	20	0.22

The average result was calculated for each of the runs where a given variable is at its low level (simply by summing and dividing by 4). This is then repeated for all the runs with this variable at its high value. The average effect of the variable was then found by calculating the difference of the average contributions at the two different levels. This is repeated for all three variables, Table 5.4.2.2.2.

Table 5.4.2.2.2 Average contribution and effect of temperature, flow rate and concentration on Δ sensor response (501, 2-CP)
(differences are in order of ranked effect.

Variable	Level	High and low Averages	Difference
Temperature (°C)	15 30	0.07 0.16	0.09
Sparge gas flow rate (ml/min)	100 200	0.09 0.14	0.05
Sample concentration (ppm)	5 20	0.08 0.16	0.08

Temperature is ranked highest therefore having the most contribution to the magnitude of the Δ sensor response generated. The sparge gas flow rate and sample concentrations are next in order of significance.

Variable interactions:

A contrast pattern (Table 5.4.2.2.3) is used to calculate variable interactions. Table 5.4.2.2.4 shows the significance of the interactions from the analysis matrix. Sample concentration is the most significant variable effecting the magnitude of the sensor response change. The sample temperature is also significant. Both trends were expected. The results prove the validity of using such a statistical approach.

Table 5.4.2.2.3 Contrast pattern matrix generated for the Δ sensor response (501 2-CP)

Run	**V1**	**V2**	**V3**	**V1V2**	**V1V3**	**V2V3**	**V1V2V3**	**Δ sensor response**
1	-1	-1	-1	+1	+1	+1	-1	0.03
2	+1	-1	-1	-1	-1	+1	+1	0.05
3	-1	+1	-1	-1	+1	-1	+1	0.06
4	+1	+1	-1	+1	-1	-1	-1	0.06
5	-1	-1	+1	+1	-1	-1	+1	0.1
6	+1	-1	+1	-1	+1	-1	-1	0.12
7	-1	+1	+1	-1	-1	+1	-1	0.19
8	+1	+1	+1	+1	+1	+1	+1	0.22

V1 = Gas flow rate, V2 = Sample temperature and V3 = Sample concentration.

Table 5.4.2.2.4 Main effect coefficients and interaction coefficients generated for the Δ sensor response (501, 2-CP)

Coefficient	**Δ sensor response (501, 2-CP)**	**Significance**
A1	-0.01	2.27
A2	0.03	7.67
A3	0.05	14
A12	-0.001	0.33
A13	0.004	1
A23	0.02	5
A123	0.003	1
A0	0.10	-

The Δ sensor response for this experiment was predicted by using the following equation: Using the coded values for the parameters not included in the model we can test this prediction by treating their responses as unknowns (Table 5.4.2.2.4).

$RH = A_0 + A1.V1 + A_2.V2 + A_3.V3 + A_{12}.V1.V2 + A_{13}.V1.V3 + A_{23}.V2.V3 + A_{123}.V1.V2.V3$

Where A1, A2 etc are the interaction coefficients and V1, V2 and V3 are the coded values for their respective variables. These are determined, assuming a linear relationship applies, in the form of a y = mx + c equation where y is the coefficient required, as follows:

V1 = 0.013 x Flow rate (ml/min) – 1.6

V2 = 0.133 x Concentration (ppm) – 1.667

V3 = 0.133 x Temperature (°C) – 2.99

Δ Sensor response predictions for sensor 501

The estimated Δ sensor response value for a gas flow rate of 200 ml/min (coded value +1), a sample temperature of 30 °C (coded value +1) and a sample concentration of 10 ppm (coded value –0.337) from Table 5.4.2.1.11.

Δ Sensor response = 0.10 + (-0.01 x 1) + (0.03 x 1) + (0.05 x –0.337) +
(-0.001 x 1) + (0.004 x –0.337) + (0.02 x –0.337) + (0.004 x –0.337) = 0.09

The actual Δ sensor response under these conditions was Δ+ 0.12. Further combinations of variables were predicted (Table 5.4.2.2.5)

Table 5.4.2.2.5 Δ Sensor 501. Response predictions.

Flow ml/min	**Temp. °C**	**Conc. ppm**	**Predicted Δ value**	**Actual Δ value**	**Accuracy**
200	30	10	0.09	0.12	75 %
100	30	10	0.11	0.11	100 %
200	15	10	0.05	0.07	71 %
100	15	10	0.06	0.05	83 %

The four predictions presented in Table 5.4.2.2.5 are within 71% - 100% of the actual Δ sensor response observed for the conditions in question. These predictions are close to the observed values for changes in sensor response but are not as good as observed for RH changes.

5.4.2.3. Δ Sensor response (502, diesel)

Sensor 502 is the most sensitive for the detection of diesel. It responded to all taintant levels and all parametric conditions. Lower levels of detection are expected with this compound. The main effects' experimental design matrix (Table 5.4.2.3.1) was constructed from data taken from Table 5.2.2.2.

Main effects:

Table 5.4.2.3.1 Experimental design matrix including variable values

Run	Sparge gas flow rate (V1)	Sample temperature (V2)	Sample concentration (V3)	Δ sensor response (502, diesel)
1	100	15	5	0.06
2	200	15	5	0.14
3	100	30	5	0.14
4	200	30	5	0.25
5	100	15	20	0.19
6	200	15	20	0.55
7	100	30	20	0.18
8	200	30	20	0.92

The average effect of the variable was then found by calculating the difference of the average contributions at the two different levels. This was repeated for all three variables, Table 5.4.2.3.2.

Table 5.4.2.3.2 Average contribution and effect of temperature, flow rate and concentration

Variable	Level	High and low Averages	Difference
Sparge gas flow rate (ml/min)	100 200	0.14 0.46	0.32
Sample concentration (ppm)	5 20	0.15 0.46	0.31
Temperature (°C)	15 30	0.23 0.37	0.14

Sparge gas flow rate and sample concentrations are ranked highest for sensor 502 during diesel spiking. Temperature having the least influence upon sensor 502's response change. This indicates that sensor 502 behaves differently to sensor 501 under the same conditions. Differing sensors will have varying characteristics adding to the requirement for an array of sensors in monitoring systems rather than single sensor systems.

Interactions:

A contrast pattern (Table 5.4.2.3.3) is used to calculate variable interactions. Table 5.4.2.3.4 shows the significance of the interactions from the analysis matrix. The concentration of the pollutant and the gas sparge flow rate are the significant variables effecting the response of sensor 502.

Table 5.4.2.3.3 Contrast pattern matrix generated for the Δ sensor response (502, diesel).

Run	V1	V2	V3	V1V2	V1V3	V2V3	V1V2V3	Δ sensor response
1	-1	-1	-1	+1	+1	+1	-1	0.06
2	+1	-1	-1	-1	-1	+1	+1	0.14
3	-1	+1	-1	-1	+1	-1	+1	0.14
4	+1	+1	-1	+1	-1	-1	-1	0.25
5	-1	-1	+1	+1	-1	-1	+1	0.19
6	+1	-1	+1	-1	+1	-1	-1	0.55
7	-1	+1	+1	-1	-1	+1	-1	0.18
8	+1	+1	+1	+1	+1	+1	+1	0.92

V1 = Gas flow rate, V2 = Sample temperature and V3 = Sample concentration.

Table 5.4.2.3.4 Main effect coefficients and interaction coefficients generated for the Δ sensor response (502, diesel)

Coefficient	Δ sensor response (502, diesel)	Significance
A1	0.15	2.53
A2	0.07	1.17
A3	0.16	2.69
A12	0.05	0.87
A13	0.11	1.94
A23	0.02	0.36
A123	0.06	1
A0	0.30	-

The Δ sensor response for this experiment was predicted by using the following equation:

Δ Sensor response = A_0 + A1.V1 + A_2.V2 + A_3.V3 + A_{12}.V1.V2 + A_{13}.V1.V3 + A_{23}.V2.V3 + A_{123}. V1.V2.V3

Where A1, A2 and A3 are the interaction coefficients and V1, V2 and V3 are the coded values for their respective variables. These are determined, assuming a linear relationship applies, in the form of a y = mx + c equation where y is the coefficient required, as follows:

V1 = 0.013 x Flow rate (ml/min) – 1.6
V2 = 0.133 x Concentration (ppm) – 1.667
V3 = 0.133 x Temperature (°C) – 2.99

Δ Sensor response predictions for sensor 502

The estimated Δ sensor response value for a sparge gas flow rate of 100 ml/min (coded value -0.3), a sample temperature of 15 °C (coded value -1) and a sample concentration of 10 ppm (coded value –0.337) from Table 5.4.2.1.11.

Δ Sensor response = 0.30 + (0.15 x –0.3) + (0.07 x -1) + (0.16 x –0.337) + (0.05 x 0.3) + (0.11 x 0.1011) + (0.02 x 0.337) + (0.06 x –0.10) = 0.16

The actual result for the Δ sensor response under these conditions was Δ + 0.19. Further combinations of variables were predicted (Table 5.4.2.3.5)

Table 5.4.2.3.5 Δ Sensor 502. Response predictions Vs actual results.

Flow ml/min	Temp. °C	Conc. ppm	Predicted Δ value	Actual Δ value	Accuracy
200	30	10	0.45	1.24	36 %
100	30	10	0.27	0.80	34 %
50	30	10	0.17	0.08	47 %
200	15	10	0.27	0.49	55 %
100	15	10	0.17	0.19	87 %
50	15	10	0.11	0.03	27 %

The predictions for sensor 502 during diesel spikes were not as successful as the RH or 2-chlorophenol sensor predictions. Only one of the predictions was within a reasonable degree of error. Significant error would be expected in attempting to predict this sensor's Δ response in a real situation using these coefficient values. Sensor 502 may not respond in a linear relationship to the presence of diesel rendering this mode of prediction inaccurate.

These three prediction models show that the system can be predicted (to a degree) when the sensors and compounds interact in a linear relationship. Further data collection and study is required to establish whether these findings are reproducible.

5.4.3. Statistical analysis of laboratory based spiking experiments

The data in tables 5.4.3.1 – 5.4.3.4 provide statistical information for sensors 501, 502, 503 and 504. The statistical data is calculated over a period or 18 sampling points prior to the introduction of each pollutant concentration. 18 points (~2 hours) were chosen to represent the baseline stability level for each sensor as the laboratory conditions should not change greatly within this period. The introduction of pollution is measured after the 18 sample points have been analysed. Each positive change in sensor resistance is listed in the final column of each table. In all cases of pollutant identification the 95% confidence level is exceeded; this indicates that all spike observations are statistically significant.

Table 5.4.3.1 Statistical data for sensors 501, 502, 503 and 504 for sampling periods prior to 2-chlorophenol spiking at sample temperatures of 15 °C.

Pollutant Conc.	Flow rate	Sensor	Mean	SE	SD	95% confidence limit	Observed sensor response (ΔR)
5 ppm	50 ml/min	501	0.7433	0.0016	0.0069	0.0034	0
		502	0.1683	0.0014	0.0060	0.0030	0
		503	1.2176	0.0013	0.0055	0.0027	0
		504	0.6767	0.0058	0.0245	0.0122	0
	100 ml/min	501	0.7211	0.0035	0.0149	0.0074	0.03
		502	0.1603	0.0047	0.0201	0.0099	0
		503	1.1795	0.0048	0.0205	0.0102	0
		504	0.6765	0.0062	0.0266	0.0133	0
	200 ml/min	501	0.7395	0.0018	0.0077	0.0038	0.05
		502	0.1265	0.0021	0.0089	0.0044	0
		503	1.1887	0.0025	0.0106	0.0053	0
		504	0.6286	0.0053	0.0227	0.0113	0
10 ppm	50 ml/min	501	0.766	0.0017	0.0074	0.0037	0
		502	0.1669	0.0015	0.0065	0.0032	0
		503	1.2626	0.0026	0.0112	0.0055	0
		504	0.676	0.0049	0.0210	0.0104	0
	100 ml/min	501	0.7823	0.0031	0.0130	0.0065	0.05
		502	0.1789	0.0027	0.0115	0.0057	0
		503	1.2464	0.0044	0.0185	0.0092	0
		504	0.7083	0.0044	0.0186	0.0093	0
	200 ml/min	501	0.7196	0.0018	0.0078	0.0039	0.07
		502	0.1571	0.0021	0.0090	0.0045	0.08
		503	1.1657	0.0023	0.0099	0.0049	0.06
		504	0.6437	0.0062	0.0265	0.0132	0
20 ppm	50 ml/min	501	0.7534	0.0015	0.0664	0.0033	0.09
		502	0.1746	0.0017	0.0074	0.0037	0
		503	1.2379	0.0018	0.0076	0.0037	0
		504	0.6901	0.0045	0.0191	0.0095	0
	100 ml/min	501	0.7423	0.0021	0.0089	0.0044	0.10
		502	0.1582	0.0028	0.0122	0.0061	0.02
		503	1.2344	0.0025	0.0108	0.0053	0
		504	0.6729	0.0066	0.0280	0.0139	0
	200 ml/min	501	0.7173	0.0022	0.0097	0.0048	0.12
		502	0.1555	0.0029	0.0124	0.0062	0.09
		503	1.1605	0.0021	0.0090	0.0045	0
		504	0.661	0.0071	0.0304	0.0151	0.12

Table 5.4.3.2 Statistical data for sensors 501, 502, 503 and 504 for sampling periods prior to 2-chlorophenol spiking at sample temperatures of 30 °C.

Pollutant Conc.	Flow rate	Sensor	Mean	SE	SD	95% confidence limit	Observed sensor response (ΔR)
5 ppm	50 ml/min	501	0.7981	0.0019	0.0082	0.0041	0
		502	0.1584	0.0019	0.0079	0.0040	0
		503	1.359	0.0041	0.0176	0.0088	0
		504	0.7312	0.0037	0.0158	0.0078	0
	100 ml/min	501	0.8110	0.0039	0.0166	0.0082	0.06
		502	0.1591	0.0050	0.0213	0.0106	0
		503	1.3893	0.0051	0.0219	0.0109	0
		504	0.7717	0.0112	0.0477	0.0237	0
	200 ml/min	501	1.063	0.0025	0.0109	0.0054	0.06
		502	0.2054	0.0034	0.0145	0.0072	0
		503	1.7677	0.0042	0.0181	0.0090	0
		504	1.053	0.0078	0.0331	0.0165	0
10 ppm	50 ml/min	501	0.813	0.0038	0.0164	0.0081	0
		502	0.1595	0.0029	0.0126	0.0063	0
		503	1.3816	0.0068	0.0288	0.0143	0
		504	0.7555	0.0050	0.0213	0.0106	0
	100 ml/min	501	0.7378	0.0027	0.0115	0.0057	0.11
		502	0.1668	0.0047	0.0201	0.0100	0
		503	1.2286	0.0033	0.0139	0.0069	0
		504	0.6900	0.0060	0.0255	0.0127	0
	200 ml/min	501	1.0294	0.0029	0.0126	0.0062	0.12
		502	0.1929	0.0017	0.0072	0.0036	0.04
		503	1.7530	0.0047	0.0199	0.0099	0
		504	1.0347	0.0047	0.0200	0.0099	0.10
20 ppm	50 ml/min	501	0.9008	0.0037	0.0159	0.0079	0.16
		502	0.1588	0.0042	0.0179	0.0089	0
		503	1.5673	0.0059	0.0253	0.0125	0
		504	0.8455	0.0082	0.0347	0.0172	0
	100 ml/min	501	0.9195	0.0025	0.0109	0.0054	0.19
		502	0.1637	0.0022	0.0096	0.0047	0.06
		503	1.5521	0.0057	0.0245	0.0122	0
		504	0.5659	0.0059	0.0252	0.0125	0.14
	200 ml/min	501	1.0073	0.0027	0.0115	0.0057	0.22
		502	0.1931	0.0036	0.0154	0.0076	0.15
		503	1.7096	0.0025	0.0107	0.0053	0.06
		504	1.0174	0.0047	0.0200	0.0099	0.17

Table 5.4.3.3 Statistical data for sensors 501, 502, 503 and 504 for sampling periods prior to diesel spiking at sample temperatures of 15 °C.

Pollutant Conc.	Flow rate	Sensor	Mean	SE	SD	95% confidence limit	Observed sensor response (ΔR)
5 ppm	50 ml/min	501	0.7785	0.0020	0.0087	0.0043	0
		502	0.1513	0.0016	0.0069	0.0034	0.06
		503	1.2611	0.0021	0.0090	0.0045	0
		504	0.6819	0.0043	0.0184	0.0092	0
	100 ml/min	501	0.6966	0.0035	0.0150	0.0075	0.04
		502	0.1478	0.0067	0.0286	0.0142	0.15
		503	1.1540	0.0048	0.0207	0.0103	0
		504	0.651	0.0070	0.0298	0.0148	0
	200 ml/min	501	0.0758	0.0026	0.0110	0.0055	0
		502	0.0145	0.0026	0.0112	0.0055	0.14
		503	1.2010	0.0035	0.0151	0.0075	0
		504	0.6811	0.0049	0.0208	0.0103	0
10 ppm	50 ml/min	501	0.8664	0.0028	0.0122	0.0061	0
		502	0.0935	0.0014	0.0061	0.0030	0.03
		503	1.3824	0.0023	0.0098	0.0049	0
		504	0.6964	0.0042	0.0179	0.0089	0
	100 ml/min	501	0.6837	0.0044	0.0189	0.0094	0.07
		502	0.1606	0.0051	0.0219	0.0109	0.19
		503	1.142	0.0056	0.0239	0.0119	0
		504	0.6363	0.0079	0.0337	0.0167	0
	200 ml/min	501	0.7632	0.0019	0.0084	0.0042	0.11
		502	0.1574	0.0032	0.0137	0.0068	0.49
		503	1.2216	0.0048	0.0205	0.0102	0.08
		504	0.6757	0.0059	0.0252	0.0125	0.14
20 ppm	50 ml/min	501	0.8061	0.0015	0.0063	0.0031	0.05
		502	0.1525	0.0015	0.0066	0.0053	0.19
		503	1.3014	0.0025	0.0107	0.0053	0
		504	0.6996	0.0044	0.0189	0.0094	0
	100 ml/min	501	0.7006	0.0029	0.0127	0.0063	0.19
		502	0.1482	0.0042	0.0180	0.0089	0.50
		503	1.1552	0.0052	0.0221	0.0109	0
		504	0.6339	0.0074	0.0317	0.0157	0.20
	200 ml/min	501	0.7547	0.0032	0.0137	0.0068	0.12
		502	0.1576	0.0025	0.0107	0.0053	0.55
		503	1.2035	0.0038	0.0163	0.0081	0.07
		504	0.6647	0.0053	0.0112	0.0112	0.20

Table 5.4.3.4 Statistical data for sensors 501, 502, 503 and 504 for sampling periods prior to diesel spiking at sample temperatures of 30 °C.

Pollutant Conc.	**Flow rate**	**Sensor**	**Mean**	**SE**	**SD**	**95% confidence limit**	**Observed sensor response (ΔR)**
5 ppm	50 ml/min	501	0.8580	0.0034	0.0144	0.0071	0.04
		502	0.1650	0.0019	0.0081	0.0041	0.10
		503	1.4677	0.0054	0.0231	0.0115	0
		504	0.7879	0.0068	0.0290	0.0144	0
	100 ml/min	501	1.1725	0.0085	0.0362	0.0180	0.14
		502	0.2149	0.0057	0.0242	0.0120	0.20
		503	1.9779	0.119	0.0506	0.0252	0
		504	1.0509	0.0056	0.0237	0.0118	0.12
	200 ml/min	501	0.9813	0.0032	0.0138	0.0069	0.12
		502	0.1801	0.0037	0.0160	0.0079	0.25
		503	1.6797	0.0031	0.0133	0.0066	0.10
		504	0.9536	0.0035	0.0148	0.0074	0.10
10 ppm	50 ml/min	501	0.8498	0.0026	0.0112	0.0056	0.04
		502	0.1586	0.0016	0.0069	0.0034	0.08
		503	1.4757	0.0054	0.0232	0.0115	0
		504	0.7980	0.0059	0.0252	0.0125	0
	100 ml/min	501	1.0427	0.0150	0.0640	0.0318	0.3
		502	0.3022	0.0057	0.0245	0.0122	0.8
		503	1.7075	0.0207	0.0881	0.0438	0.14
		504	1.0151	0.0136	0.0578	0.0287	0.32
	200 ml/min	501	0.9544	0.0023	0.0098	0.0048	0.62
		502	0.1924	0.0028	0.0121	0.0060	1.24
		503	1.6108	0.0034	0.0145	0.0072	0.44
		504	0.9363	0.0038	0.0162	0.0080	0.54
20 ppm	50 ml/min	501	0.8387	0.0053	0.0224	0.0111	0.04
		502	0.164	0.0016	0.0071	0.0035	0.18
		503	1.4466	0.0113	0.0481	0.0239	0
		504	0.7601	0.0074	0.0314	0.0156	0
	100 ml/min	501	1.125	0.0067	0.0285	0.0142	1.45
		502	0.246	0.0070	0.0298	0.0148	2.10
		503	1.8650	0.0109	0.0465	0.0231	0.90
		504	1.066	0.0078	0.0333	0.0166	0.78
	200 ml/min	501	1.0127	0.0020	0.0086	0.0043	0.68
		502	0.1645	0.0023	0.0098	0.0048	0.92
		503	1.7052	0.0027	0.0115	0.0057	0.55
		504	0.9667	0.0037	0.0156	0.0077	0.44