Figure.2: Colourless glass

Figure 3: Coloured glass fragments (green on the left, brown on the right and blue in the middle)

In addition to the material above there were many larger fragments which had been picked out during the excavation. Selections of these from the same contexts as the sieved material (see Table 13) were also analysed. These included what is described as ‘clay ring fragment’. This was probably part of a gathering ring, which floated on the surface of the molten glass allowing the gatherer to rest the blowing iron while he collects enough glass to produce the beginnings of a crown. The rings were placed in the bottom of a pot, the batch was then added and the ring was allowed to float to the surface. These rings were made of the same material as the pots and made in the same way (Parkin, 2000). The composition of the glass on the ring should have a similar chemistry to that of the glass produced at Nailsea, though with contamination from the ceramic material. Therefore a sample of this ring and the adhering glass was taken and a profile produced of the glass layer-ceramic interaction.

Analytical results

Qualitative XRF was undertaken on rough cleaned surfaces to aid sampling the large amount of glass recovered, the elements where reported are the ones that were most significant for each sample. From these results it was determined that most of the colourless glass and glass waste was of the same composition. Below is a summary table of the EDS results for each sample. These are the results illustrated by the graphs (see Figure 4, Figure 5 and Figure 6*Figure 6: EDS results for soda and potash*).

Table 4 : Average composition of material determined by EDS

Sample No	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	MnO	Fe_2O_3	As_2O_3	Total
2	10.3	0.2	1.1	68.8	0.2	15.2	0.1	0.0	0.3	0.3	97.3
3	8.0	0.3	1.5	66.7	0.6	19.1	0.1	0.0	0.4	0.4	98.3
4	12.4	0.0	0.9	70.1	0.1	13.5	0.0	0.0	0.3	0.5	98.9
7	15.3	0.2	0.6	68.1	0.0	12.6	0.1	0.0	0.3	0.3	98.5
8	11.3	0.1	0.8	69.7	0.1	12.3	0.1	0.2	0.2	0.3	95.9
9	14.3	0.3	0.7	69.4	0.1	13.1	0.0	0.1	0.2	0.2	99.0
10	12.9	0.2	0.6	67.8	0.1	13.0	0.0	0.1	0.1	0.1	95.7
11	14.6	0.4	0.8	70.1	0.2	13.3	0.1	0.0	0.2	0.3	100.6
12	14.8	0.4	0.7	70.1	0.1	12.8	0.1	0.0	0.3	0.2	100.0
13	12.4	0.1	0.6	66.1	0.1	12.4	0.2	0.0	0.2	0.2	92.9
14	12.6	0.2	0.8	68.0	0.0	12.9	0.2	0.0	0.2	0.2	96.1
15	14.5	0.3	0.7	70.7	0.1	13.3	0.1	0.1	0.2	0.2	100.7
16	13.4	0.2	0.7	68.4	0.1	12.8	0.2	0.1	0.2	0.2	96.9
17	16.2	0.4	0.7	71.2	0.1	13.4	0.0	0.1	0.2	0.1	103.2
1 (brown)	7.1	6.1	3.7	56.0	1.0	16.5	0.2	3.9	2.1	0.1	97.6
5 (green)	4.5	2.6	4.4	59.5	1.4	19.9	0.2	0.2	2.9	0.1	96.8
6 (painted)	2.0	0.0	0.3	76.8	9.7	7.0	0.0	0.0	0.1	0.3	96.8
All colourless (average)	13.1	0.3	0.8	69.0	0.1	13.5	0.1	0.1	0.2	0.2	98.2

Frothy glass waste

The surface appearance (Figure 1) suggests the glass is heavily weathered, which is born out by the high silica and low soda values in (Table 5). The material was not selected for further analysis for this reason. The other values are consistent with and indistinguishable from the other colourless glass analysed. Therefore this waste is likely to have been a primary product or waste material from producing the finished glass fragments found. The results shown are from four different pieces of this waste. There is no significant difference in composition between discoloured and colourless glass.

Table 5: XRF surface analyses of frothy waste glass from context 301

Na_2O	3.4	2.8	3.3	4.3
Al_2O_3	1.9	2.0	2.0	1.7
SiO_2	81.3	80.9	82.4	80.2
SO_3	0.7	0.7	0.7	0.7
K_2O	0.1	0.2	0.1	0.1
CaO	12.1	12.8	11.0	12.4
TiO_2	0.1	0.1	0.1	0.1
MnO	<0.1	<0.1	<0.1	<0.1
Fe_2O_3	0.2	0.3	0.2	0.2
As_2O_3	0.2	0.2	0.2	0.2
SrO	<0.1	<0.1	<0.1	<0.1

Colourless glass

Rough surface analysis was undertaken with no sample preparation to select a suitable sub-set for EDS analysis. The results of the XRF analysis showed a very tight clustering suggesting that the glass may have been produced using the same recipe with tight control of the quality and source of the raw materials. The EDS results also showed a tight clustering with some variability introduced from weathering of the alkalis. There is no evidence for chronological variation within the colourless group. The colourless lump has a different composition but not significantly so. It contains higher amounts of calcium and slightly higher alumina (see Table 4). The spread of alumina, iron, manganese and magnesium values is less than 1% in the colourless glass studied (see Figure 4). The colourless glasses are from both cone areas and various contexts, suggesting that there is no variation in the type of flux used over time for the colourless glasses, though the samples analysed may all come from relatively late phases of use of the site.

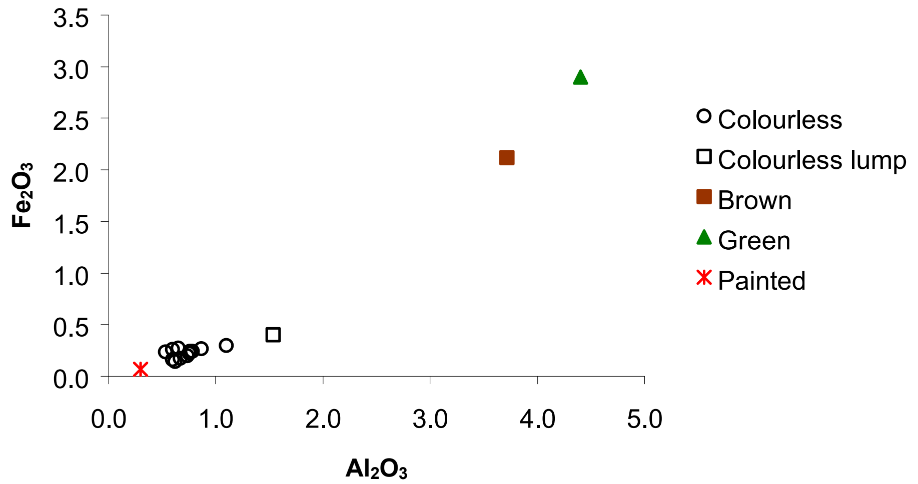

Figure 4: EDS results for Al_2O_3 and Fe_2O_3

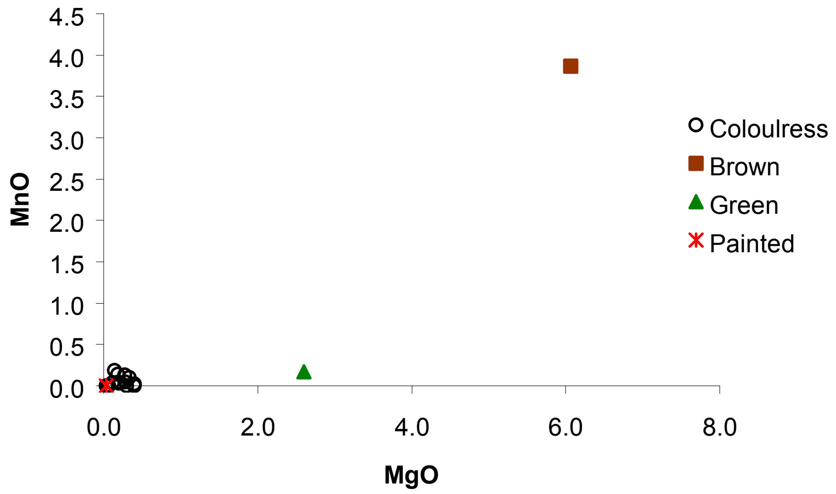

Figure 5: EDS results for MnO and MgO

The recipe given in Table 1 has been converted into the weights in kilograms of the oxides assumed in modern analysis of glass, and then into percentages (see Table 6). This composition can then be compared to the chemical data obtained by SEM-EDX (the last two columns in Table 6) which shows a good match, though with slightly more lime and less decolourisers than in the recipe.

Table 6: Nailsea glass recipe in kilograms and percent

	Kg	%	Average colourless glass	Normalised
SiO_2	14458.4	72.2	68.8	72.1
Na_2O	2667.9	13.3	13.0	13.6
CaO	2530.2	12.6	13.3	13.9
C	387.4	1.9		0.0
MnO	33.1	0.2	0.1	0.1
As_2O_3	76.2	0.4	0.2	0.2

Coloured glass

XRF analyses of the brown and green bottle glass fragments showed significantly higher magnesia, alumina and iron than in the colourless glass, with the brown glass also being high in manganese. The glass is also lower in arsenic. XRF suggested all the glass of the same colour had similar composition so only one sample of each colour was subjected to EDS analysis to determine if the colourless glass was used as a base glass or if they were of a separate composition (see data Table 4 and Table 15).

The EDS results show that the most significant shift in elemental composition, compared to the colourless glass, is both brown and green being higher in potash magnesia and iron. The brown glass also contains significantly more manganese and magnesia than the green (see Table 4 and Figure 5), confirming the results suggested by the XRF analysis.

Figure 6 shows the relationship between soda and potash in the glasses studied. As can be clearly seen there is a separation between the high soda/low potash colourless glass samples and the coloured glasses, which are slightly higher in potash and lower in soda. This suggests different sources of flux were used for the colourless and coloured glasses.

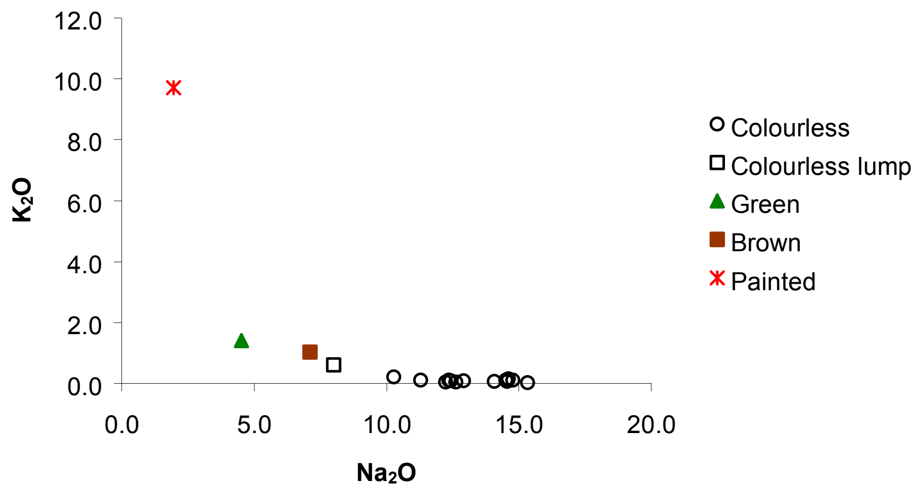

Figure 6: EDS results for soda and potash

Painted and blue glass

A single piece of colourless glass with a very thin layer of what appears to be red paint was examined. With the XRF and the EDS it was not possible to resolve a small enough area to determine the composition of the paint layer in cross-section, nor was it possible to determine its composition when surface analysis was undertaken due to its thinness. However the composition of the bulk glass was determined using EDS. As can be seen the painted glass is distinctly different from both the colourless and coloured glasses (*Figure 6: EDS results for soda and potash* Figure 6) as it is high in potash, suggesting another source for the flux. Examining the entire contents of the bag from 260 near building 802 only three further small pieces of this red-covered glass were found.

Three small pieces of blue glass were recovered but were not considered a significant product on site so only XRF was undertaken on one of them. As can be seen from the results of XRF on the surface of the blue glass (three areas on the sample piece of glass) the glass is heavily weathered resulting in low values for alkalis (soda and potash).