NewRail at Newcastle University is now the UK centre for the study of Subway Climatology which is a relatively new field of study that was pioneered by Professor Andreas Pflitsch at the Ruhr University Bochum. The aim of this research is to gain a better understanding of how air moves between different regions in subway systems between the tunnels and over ground. Climatologists and engineers know little about subways as a component of the urban infrastructure. Thus there is little understanding the ventilation of a subway system at present but it is correct to say that the air flow in a subway station is driven by chimney effects within the underground buildings (for instance in escalator wells) and can be enhanced by waste energy from electric motors. The air flow is known from studies in large cave systems to exhibit an element of seasonality that can produce flow reversals at different times of the year as the underground system interacts with the local weather pattern.

Recent studies in partnership with Nexus Rail, Newcastle City Council and the team of Professor Pflitsch from Bochum have examined the air flow in the underground sections of the Newcastle Metro. This has involved air flow and temperature measurements and the release of tracer gas to explore residence times in the tunnels and stations. This study [1, 2] has shown the presence of a background air current which is independent of the train movements or the active ventilation system. Moreover, this current does not consist of simple, continuous and equally distributed air movements; it is, on the contrary a highly complex system of currents with spatial and temporal variations. There is a strong induced draft in the Newcastle tunnels that is quite different in character to the air flow that has been measured in other subway systems such as Berlin and Dortmund.

With reference to figure 1 the underground section is located completely within the

![Figure 1 layout of the Tyne and Wear Metro](image)
tunnel outlets. To the north the line runs under and is vented to the Eldon Square shopping centre and Jesmond is a densely populated suburb of Newcastle. An intermediate station on this route is Haymarket that is close to Newcastle University and is connected through tunnels to Newcastle Civic Centre. To the east lies a large University and student quarter at Manners leading to a dense residential area at Byker. To the south are the main railway station and another subterranean railway now disused that connects the Central Station to the Central Post Office Building (now a residential and commercial building). The short length of line to the west serves St James Park football ground. The potential for serious loss of life from a chemical or bacteriological agent at any of the locations mentioned is high especially during the normal working day when the population of Eldon Square and the University buildings is at its maximum. On a match day St James Park can contain in excess of 50,000 people. Gateshead Central Station is a major transport interchange at Gateshead City Centre serving the local and regional bus companies. An incident here would create a major disruption to traffic flow in the town centre and put at risk the commercial centre and Gateshead Stadium and adjoining large residential areas.

In the event of a chemical or biological based terrorist attack it is the background current in the underground sections which will be responsible for spreading the biological or chemical agents within the subway system and to surrounding areas. The Newcastle Monument station has been monitored for the last 5 years with measurements of internal air flow and temperature being recorded in order to develop a computer based diagnostic and predictive tool to assist in the development of evacuation strategies and to assist the search and rescue authorities to deploy their staff within the subway system in the most effective and appropriate manner. Although much of this work is based on computational fluid dynamics (CFD) we have been working with the Virtual Reality Suite at Northumbria University to produce an easily understandable visual image of the subway in virtual reality. We have been able through this approach to include pedestrian modelling, using Legion software, to simulate an emergency evacuation situation including reduced visibility due to smoke [3-5]. When the pedestrian modelling is combined with experiments in which tracer gas is released in the station [6] and monitored, it is possible to determine the exposure concentrations and residence times of the pedestrians and thus estimate the efficacy of a particular evacuation route as shown in figure 2 and 3 and 4.

![Figure 2 Concentration and residence time of SF6 in the station](image)
Extending the work to include the virtual reality expertise at Northumbria University is significant for two major reasons. The first that has already been mentioned is the ease of understanding the visual images but more importantly from an experimental point of view is the possibility of creating CFD models from the point cloud files produced from laser scans of the station. This will then enable other stations for which there are no CAD drawings available to modelled in CFD in a relatively straight forward way. This is shown in figures 5 and 6.
It is also important to interface the subway system with the above ground environment, to understand the mutual interaction of the flows emanating from the subway system with those within the urban canyons created by the city (Newcastle) and town (Gateshead) centre buildings. This is required in order to predict the spread of the agent above ground so that key areas of operation for the rescue personnel can be identified and evacuation procedures put into place in the most endangered areas. A series of measurements have been made over ground at the monument to establish the weather conditions at the entrances to the station and to determine if there is a correlation between the weather station data at the Ellison Building and at the station. The relationship of the station to the adjoining buildings is shown in figure 7 with the location of the measurement points and the relationship between the local measured wind speed and the weather station data is shown in figure 8.
There is still a lot of work to be done to validate the modelling work with experimental data but it is hoped that this study in Newcastle will serve as a pilot project within the UK. As the underground section of the Newcastle metro is relatively small it could serve as a demonstration facility for development of methods and measurement techniques and will be a platform for further research in other subway systems.

References