# CLIMATE CHANGE AND WET WINTERS:
## testing the diffusion of soluble salts in building stone under saturated conditions

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### 1. INTRODUCTION

Controls on stone decay processes are rapidly changing as a result of changing climate. There is thus a need to adapt stone decay experiments in the laboratory to reflect the environmental conditions being investigated. Future climate change scenarios for the NW of the UK typically project an underlying trend towards wetter winter conditions. Buildings appear to have respondedto these changing climatic conditions by algal 'greening' *(see Fig. 1)*

*Fig 1. 'Greening' of sandstone walls in Belfast, Northern Ireland (UK)*

### 2. FUTURE CLIMATE CHANGE IN THE UK

In projecting future climate change, uncertainty is related to choice of climate model, choice of emissions scenario, and choice of downscaling technique. However, several robust downscaled predictions have emerged. Temperatures are likely to increase across all months. Possibly more importantly, precipitation regimes are likely to become much more seasonal, as a function of wetter winters and markedly drier summers *(see Fig. 2)*

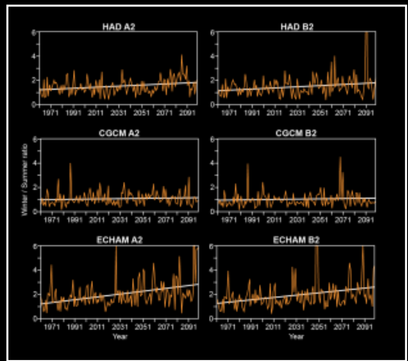


*Fig 2. Increased seasonality in precipitation (expressed as summer/winter ratio) across different models and emission scenarios, downscaled for a site in the west of Northern Ireland, Killyclogher*

### 3. WEATHERING IMPLICATIONS OF INCREASED SEASONALITY

Investigations into how salt weathering impacts natural stone have largely focused on how soluble salts move into stone via moisture flux, with periodic surface wetting events quickly followed by drying *(see Fig 3)*. However, with increased winter wetness in the NW UK, it is likely that the increased 'time-of-wetness' of stone blocks will lead to block saturation. But how do soluble salts behave if blocks become saturated and there is no moisture flux?

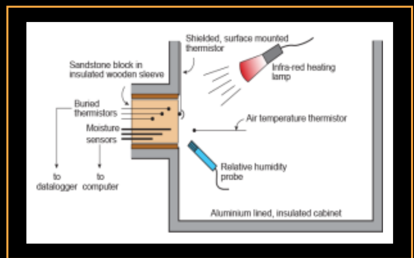


*Fig 3. Traditional salt weathering investigations with surface wetting and drying*

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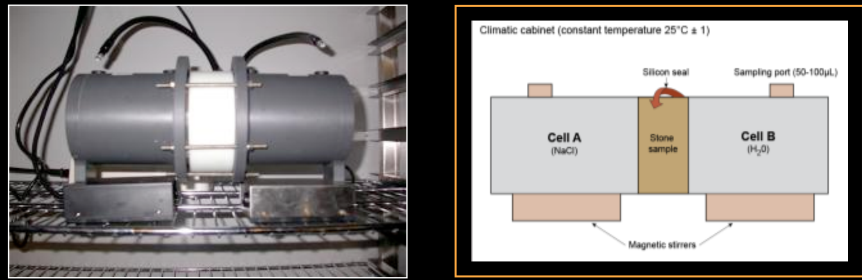


*Fig 4. Experimental set-up of diffusion cells*

### 4. IONIC DIFFUSION OF SALTS IN SATURATED STONE - METHODS

Diffusion in solution is the process whereby ionic or molecular constituents move from an area of high concentration to an area of low concentration under the influence of random kinetic motion of the constituent molecules or ions. Diffusion occurs without any bulk water movement. Diffusion ceases when there is no concentration gradient.

This paper suggests a method, adapted and refined from the study of chloride diffusion in concrete, to test the diffusion of salts within sandstones – the rate at which the ions move and the possible deleterious chemical effects that their passage might have on the stone itself. Cell A *(see Fig 4)* is filled with salt solution (0.55 molar), while cell B is filled with de-ionised water. Between the two cells, a sample of saturated stone sits, with the rounded edge sealed with silicon. Because of the concentration gradient set up by this apparatus ions diffuse from cell A to cell B, through the porous stone sample. IC is used to analyse the solution at regular intervals.

### 5. RESULTS

*Fig. 5* shows the results for diffusion rates of chloride in Dumfries Sandstone and Portland Limestone. Preliminary tests using the methods described above (using 20mm thick stone samples) show that salts diffuse through natural sedimentary stone relatively rapidly – within a day, IC detects an increase in Chloride concentration in cell B in the test using Dumfries Sandstone. The rate of diffusion differs for different stone types, based on specific stone characteristics (porosity, permeability) – thus, chloride diffuses much more slowly through the less permeable Portland Limestone.

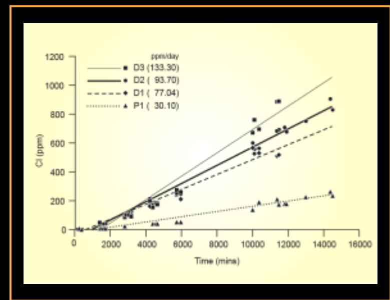


*Fig 5. Diffusion rates of chloride through samples of Dumfries Sandstone (D1, D2, D3) and Portland Limestone (P1)*

### 6. IMPLICATIONS FOR FUTURE RESEARCH

- In response to changing environments, the nature of decay processes change
- Downscaled projections show increased seasonality in the NW UK
- In NW UK, longer wetter winters mean that sandstone blocks in buildings may become saturated for long periods of time
- Increased seasonality means that complete drying out of blocks in summer following winter saturation could leave damaging sub-efflorescences deep within the stone
- There is a need to adapt laboratory testing of stone to reflect the changing nature of decay regimes
- Diffusion rates vary with type of salt and stone properties – future work will be carried out on salt mixtures, different stone types, and the analysis of the dissolution of cementing agents, for example, amorphous silica and iron