arc21 RESIDUAL WASTE TREATMENT PROJECT

INVESTIGATION INTO THE PRESENCE OF MINERAL ERIONITE IN THE DEVELOPMENT SITE LOCATED WITHIN HIGHTOWN QUARRY AND RISK ASSESSMENT REVIEW

Technical Report Prepared For

arc21

Technical Report Prepared By

TERI HAYES

Our Reference

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| Name     | Teri Hayes | Dr. Fergal Callaghan |
| Title    | Director   | Director       |
| Date     | 07 March 2019 | 07 March 2019 |
EXECUTIVE SUMMARY

Within the geology, soils and agriculture chapter contained within the 2014 Environmental Statements zeolites were identified as being present on the application site. Following a concern raised regarding the potential presence of a hazardous mineral (erionite, part of the zeolite group of minerals) at the Hightown quarry, and the associated risk this might present during the construction and operation of the consented residual waste treatment facility, a geological site survey was performed. This geological site survey focused on geological features that can be indicative of the minerals presence, and in areas where ground works and quarrying would be required.

Representative samples were sent to a specialised laboratory for geochemical and microscopic analysis. The results of this analysis do not indicate the presence of the mineral in question.

Despite the absence of the mineral in question during this investigation, a precautionary approach is being taken to further safeguard the health and wellbeing of staff and neighbouring communities alike. This is done through an updated Construction Management Plan (CMP) to manage any risks from rock breaking during the construction programme and through ongoing monitoring and the provision of hardstanding and planting during operation of the facility.

When considering how the consented development will effectively sterilise the use of the site as an active quarry (removing the primary activity with the potential to excavate such hazards, if present), and given the further mitigation and monitoring offered in the absence of any proven hazard, it can be concluded that the construction and operation of the facility does not present any material risk to public health.
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1.0 INTRODUCTION

1.1 OBJECTIVE OF STUDY

AWN on behalf of arc21 has prepared this independent environmental risk assessment in relation to the potential for environmental and human health impact as a result of redevelopment of Hightown Quarry for a waste to energy development.

It is noted that the potential for an impact on public health from exposure to a natural mineral, namely erionite during the redevelopment of the quarry site for a proposed industrial facility has been raised as a community concern and submitted as a representation to the Department as a material consideration. This report has been undertaken to assess the potential presence of erionite through site investigation and collecting representative sampling on site for laboratory analysis.

It is noted that erionite only poses a health risk if it is present in a fibrous form, becomes airborne and can be breathed in, i.e. if a source – pathway - receptor linkage exists. The design and development of the project includes a Construction Environmental Management Plan (CEMP). This assessment This assessment has been undertaken to inform the construction management plan (CMP) and specifically an update of the relevant mitigation measures which are contained therein in adopting a precautionary approach to safeguarding the health and wellbeing of workers and communities neighbouring the site. This will ensure that if erionite is present in a form that presents a credible hazard, the further mitigation and monitoring contained in the CMP will ensure that the construction and operation of the facility does not present any material risk to public health.

The site has been extensively quarried since 1965 and remains an active quarry. The proposed development will mostly be developed on the existing land surface but will require some additional removal of rock along the southern slope during site development. A CMP exists for management of risks during construction and has been updated to form part of the FEI. (Hightown Quarry, Residual Waste Treatment Project Environmental Statement March 2014). The imbedded mitigation intended to address general dust and particulate matter risk to staff and neighbouring communities alike is already planned, and has been updated to manage any potential risk from the mineral in question.

During operation, all areas pertinent to the proposed development will be covered in hard standing thereby covering and encapsulating any potential mineral presence, removing any credible mobilisation of the mineral through erosion or transport movements, and is complemented by dust management within the CMP. The plant will operate under an IPPC permit issued by the NIEA.

1.2 METHODOLOGY

In preparing this risk assessment, AWN has followed relevant UK EA and EPA guidance documents, including:

- EPA Contaminated Land & Groundwater Risk Assessment Methodology

The basis of the risk assessment methodology is the development of a reliable conceptual
site model (CSM) for the site. This requires an understanding of any source (contaminant in the form of a natural mineral erionite present within the existing geology), pathways for migration (in this case primarily dust generation including potential erionite fibres), and identification of receptors (on site workers, site visitors and off site inhabitants - during construction and operation) in order to confirm if any pollutant linkages are present. Where no pollutant linkages are identified there is no credible risk, and no further action is required. Where potential linkages are identified, assessment of the suitability of the mitigation measures proposed is undertaken to confirm the likely risk management plan is adequate for the protection of human health.

As outlined in section 1.1, the primary risk for potential exposure of any fibrous erionite which may be present is during localised rock removal along the southern slope of the quarry during the construction programme. There is no likely pathway during site operation as the developed area of the quarry will be capped by buildings and hardstand limiting any potential for erosion of rock surface. As such there is only potential for exposure to visitors or workers should the mineral (if present) become exposed on rock faces by natural erosion resulting in airborne fibre.

This independent assessment has been undertaken by AWN scientists experienced in risk assessment (human health and environmental). Teri Hayes, BA (Mod), MSc, Professional Geologist (PGeo) is a senior hydrogeologist and Dr Fergal Callaghan BSc PhD MRSC AMI ChemE MCIWM is a chemical engineer. Both have over 25 years’ experience in geology, chemistry, risk assessment and environmental impact assessment and mitigation.

Geological expertise (including site specific representative sampling) has been provided by David Stewart PGeo(1) and Dave Blainey PGeo.

Laboratory analysis (Fibre content using optical microscopy methods and Scanning Electron Microscopy/Energy Dispersive X-ray Analyser (SEM/EDXA)) was undertaken by the Institute for Occupational Medicine (IOM) Consulting Ltd. IOM is an established specialist laboratory for fibre type analysis and other occupational health issues. IOM is a UKAS accredited (ISO/IEC 17025:2005) testing laboratory (No. 0374).

This combination of experience together with available information gathered for the project allowed development of a robust conceptual site model (CSM) on which identification of, and assessment of, any feasible pollutant linkages could be determined.

1.3 BACKGROUND INFORMATION

This section summarises: (i) the methodology for identification of erionite and current knowledge of distribution and assessment; and (ii) the history of assessment of erionite in the Antrim Basalts.

(i) Erionite – Methodology for Identification

Zeolites (of which Erionite is one specific mineral) are widely distributed within the Antrim Basalts. Zeolites are a large group of hydrated aluminosilicate minerals that occur naturally worldwide (Coombs et al., 1997; IZA, 2019). Within the basalts, the potential likely areas for zeolite presence are basalt lava flow tops, highly -vesiculated zones and high fluid -flow zones such as igneous intrusions.

Chemistry

Due to its nature and chemistry, specific expertise in the field and laboratory are required to identify the presence of erionite. Erionite has the following general chemical formula:
(K\textsubscript{2} Na\textsubscript{2} Ca\textsubscript{3}) [Al\textsubscript{10} Si\textsubscript{26} O\textsubscript{72}] \cdot 30H\textsubscript{2}O \text{ (Passaglia et al., 1998)}

Three distinct erionite minerals are now recognised with potassium (K), sodium (Na) and calcium (Ca) end members (e.g. IZA, 2019). Erionite is closely associated with another zeolite mineral, offretite, which has a similar chemical composition and structure.

In the laboratory, comparison of the EDXA spectra for samples with suspected erionite are compared with known EDXA spectra (Insert 1 below) for well known sites where erionite has been identified in USA and Turkey to confirm identification.

**Insert 1**: Energy dispersive spectrum for known erionite samples in Turkey and US.

**Mineral Habit**

In the field, erionite can occur in different mineral habits and as such requires an experienced geologist to undertake the site assessment:

- “Erionite composed of single fibres, bundles of fibres and radiating bundles of fibres” (DeMalo & Cahill, 2017);
- “golden-colored, hexagonal bundles of erionite prisms,” “very simple hexagonal prisms,” and “rarely, erionite forms soft, curly, wool-like masses” (Tschernich, 1992);
- “stocky-prismatic crystals with a solid appearance, through prismatic or acicular with rigid mechanical behaviour, to extremely fibrous crystals (asbestiform) with rigid to flexible behaviour” (Giordani, 2016).

Walker (1960) notes a wide distribution of zeolites from the Antrim Basalts from his examination of 670 locations in the Antrim area. The mapped zeolites in the Hightown area appear to be a regional chabazite-thomsonite zone, with a localised plumose-calcite-aragonite-quartz (i.e. non-zeolite minerals) assemblage superimposed.

Identification of erionite is often complicated by the intergrowth of other zeolite minerals, such as offretite or levyne, and the loss of volatiles under analysis and electron beam damage (e.g. DeMalo & Cahill, 2017; Harper et al. 2017; Sheppard & Gude, 1969; Triplett,
2012). Methods to improve the detection and identification of erionite are technical areas subject to academic interest e.g. work by DeMalo & Cahill (2017) and the University of Portsmouth (Fowler et al., 2017), for example, is ongoing in order to refine current methods and find new methods of detection and identification.

The details of the precise methodologies used in past identifications of erionite is not always available and it is quite possible that there could be some doubt of the correct speciation of erionite and associated zeolites in the pre-existing occurrences described in the literature due to the lack of an internationally-recognised analytical procedure (Dogan & Dogan, 2008; Dogan, 2012).

(ii) Existing information on Distribution in Antrim

As stated above, Walker (1960) notes a wide distribution of zeolites from the Antrim Basalts from his examination of 670 locations in the Antrim area. The Hightown locality is described by Walker as “a number of quarries near the hamlet of Roughfort, east of Templepatrick.”

There is some lack of clarity on past identification of erionite within the Hightown quarry itself. The relevant historically information on distribution in the general vicinity is as follows:

“Golden-coloured, hexagonal bundles of erionite prisms are found, up to 3mm long and 1mm in diameter, terminated by a rare hexagonal pyramid {1012} (Figs.181,182,198), in red vesicular basalt at Kane's Quarry, Glengormley, near Belfast (Harry Foy, pers.comm.). Many of the compound erionite bundles are composed of a dominant single crystal in the centre, surrounded by tiny parallel fibers, or they form a nearly rounded surface, due to numerous tiny terminations. Nearby cavities contain calcite, heulandite, stilbite, and, rarely, chabazite, leuye, offretite, and cowlesite.” (Tschemich, 1992, p. 163-164 & Figs. 181, 182 & 198 within.)

Passaglia et al. (1998) note samples of levyne-erionite from “Bog Hill Quarry”– which may be referring to Hightown Quarry. Both of these examples appear to be provided by the local amateur mineral collector Harry Foy (James, 2010).

The Bog Hill Quarry sample chemistry (presumed Hightown Quarry) published in Passaglia et al. (1998) has been classified as “positively identified erionite-Ca” by Dogan & Dogan (2008: Table 2).

Prior to the site visit by BRG Geologist David Stewart, a conference call was held with Dr. Mike Fowler and Dr. Dean Bullen (University of Portsmouth) to discuss the suitability of the field sampling and laboratory methodology.

2.0 SOURCE ASSESSMENT

This section summarises the source assessment completed by BRG (Geologists) and IOM (Laboratory) on behalf of AWN.

2.1 SITE INVESTIGATION & REPRESENTATIVE SAMPLE COLLECTION

Dave Stewart PGeo, an experienced geologist with BRG completed a site investigation of the Hightown Quarry on two days over 20-21/01/19. The survey focused on areas where zeolites were mostly likely to occur geologically, focusing on zones of increased vesiculation adjacent to red weathered basalt flow tops and black, weathered and friable basalts. Access was on foot and therefore limited to accessible areas of the rock faces. However, as the site
has been extensively quarried, there were ample areas of broken rock on the surface to provide reasonable assessment of the quarry area.

Representative samples were collected either directly for accessible areas of the rock face or from rock fall on the ground. Particular attention was given to the area of rock along the southern face which is proposed for blasting during construction and where suitable host rock for zeolites were identified. Loose rock on the ground was also examined as it provides an indication of the overall nature of the rock mass. A brief examination of available core data from boreholes within the southern rock face identified that there is suitable host rock for zeolite mineral along this southern face (BH 1 – assumed drill hole 92/1 and BH 2 - assumed drill hole 92/2).

Samples were directly collected from weathered out vugs in the rock fall or careful chiselling out from the rock itself. A list of the samples collected and descriptions are included in Appendix A along with Figure 1 which presents the location of the representative samples collected for geological identification and laboratory analysis. Three samples (54452, 54453 and 54454) were collected from the southwest of the quarry where suspected erionite samples may have previously been identified.

2.2. LABORATORY ANALYSIS

The Institute of Occupational Medicine (IOM) Consulting Laboratory is a specialist laboratory for occupational health issues including fibre analysis of natural and manufactured material.

The following eight representative samples were received (5/02/2019) for analysis by optical microscopy and scanning electron microscope (SEM). The Energy Dispersive X-ray Analyser EDXA method provides the chemical characteristics of the sample which is then used to identify the mineral species, whereas SEM provides pictures of the microscopic habit (shape) of the mineral.

<table>
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<tr>
<th>Sample ID</th>
<th>Location Irish Grid (E, N, Elevation)</th>
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<td>54451</td>
<td>328961.10E, 380065.05N, 247.71m</td>
<td>007</td>
<td>Sample 1; Photos 17-20; loose in gravel, white vug rimming zeolite + brown crystals extending out</td>
</tr>
<tr>
<td>54452</td>
<td>329029.03E, 379972.63N, 256.41m</td>
<td>009</td>
<td>Sample 3; radial, acicular habit in amygdale. Photos 29-31</td>
</tr>
<tr>
<td>54453</td>
<td>329048.00E, 379941.54N, 253.42m</td>
<td>010</td>
<td>Sample 4; white acicular clusters of 2-5cm; Photos 32-35</td>
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<tr>
<td>54454</td>
<td>329052.66E, 380009.18N, 251.60m</td>
<td>017</td>
<td>Sample 6; similar appearance to 54452-radiating crystals. Photos 16-22</td>
</tr>
<tr>
<td>54455</td>
<td>329183.27E, 380165.39N, 253.35m</td>
<td>024</td>
<td>Sample 7; acicular needles, red vesiculated lava; Photos 38-39</td>
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<tr>
<td>54456</td>
<td>329256.88E, 380052.75N, 264.79m</td>
<td>019</td>
<td>Sample 8; Photo 52; 8-10mm vugs with brown internal rims + fibrous habit, red lava</td>
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<tr>
<td>54457</td>
<td>329235.80E, 380035.56N,</td>
<td>021</td>
<td>Sample 9; 8mm amygdale within black, rotten basalts</td>
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Table 2.1 Samples submitted to IOM laboratory. Note sample locations are presented in Appendix A Figure 1

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<th>Sample</th>
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<tr>
<td>54458</td>
<td>329060.00E, 38100.00N, 242m</td>
<td>270.10m radiating white crystals; photos 57-59.</td>
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<td></td>
<td>BH2 or 92/2</td>
<td>From 26.0m depth; fine elongated crystals growing into open vugs.</td>
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The IOM laboratory report is presented in Appendix B.

Overall, the laboratory found a range of mineral morphology within the samples and identify them as “probably zeolites”, which confirms the geological site assessment.

Having compared the SEM/EDXA chemical analysis with known data for erionite samples (ref Insert 1), IOM have concluded that Erionite is not present in any of these samples based on the absence of a potassium (K) peak in the spectra analysis and the observed Silicon: Aluminium (Si:Al) ratio. It is noted that the absence of any hazard shown here is based on the representative samples collected. There is potential for the mineral to be present within the strata. On this basis a conceptual site model was performed regardless of the absence of a proven hazards to explore any precautionary measures that could be considered.

### 3.0 CONCEPTUAL SITE MODEL (CSM)

A conceptual model has been developed based on a review of the desk study and representative site sampling completed. The basis of the CSM is summarised below.

#### 3.1 SOURCE ASSESSMENT

The desk study confirmed that the Antrim basalts within which this quarry occurs does have potential for presence of zeolites including erionite. The site investigation and representative sampling has confirmed presence of zeolites in the quarry including the rock face which requires blasting during construction phase. However, no evidence of erionite were identified on site or were present in any of the representative samples collected and analysed by IOM laboratory.

It is noted that although erionite was not identified in this exercise, it is not possible to state that there is no occurrence of erionite present in this site or any area of the Antrim basalt. It is also noted that the presence of erionite in itself, is not necessarily a hazard unless it is present as fibres which can be released to air and there is an exposure route to a receptor by inhalation.

#### 3.2 PATHWAY ASSESSMENT

Currently it is considered that the potential for airborne erionite is low as there is no confirmed evidence of erionite in the known geology and rock breaking/blasting is not ongoing.

During operation, much of the area will be covered in hardstand which provides a barrier for any disturbance/erosion and there will be no requirement for rock disturbance. Rock faces will be assessed as part of the operational management plan and calcreted if required to reduce the potential for any erosion

During construction it is required to undertake localised rock removal including blasting to remove part of the southern rock face and removal of rubble on the quarry floor. Measures
for dust management are included in the existing CEMP “Hightown Quarry, Boghill Road, County Antrim: Residual Waste Treatment Project Environmental Statement March 2014, Appendix 3.1 Construction Management Plan” and discussed in Chapter 14 air quality.

Although no erionite has been detected on site as part of this investigation, as sections of this rock face is known to contain zeolite bearing material, a precautionary approach has been taken for the management of dust generation during these works and the following additional measures are to be included with the CEMP. The appointed Principal Contractor will prepare specific Risk Assessments in relation to working in areas where rock disturbance is required and will include the following conservative measures:

- Potential blasting areas to be inspected for geomarkers i.e. to establish areas where zeolites might be present and probed using suitable coring or fracturing equipment. Cores will be inspected for presence of zeolites by a geologists with laboratory analysis as required.
- To further confirm any risk of exposure to construction workers (and need for appropriate PPE), representative air sampling and laboratory analysis for fibre release testing will be conducted during initial “trial” blasting works.
- Dust suppression techniques as outlined in the CMP to be utilised. Techniques include:
  - Use wet methods to reduce dust generation where erionite is present (e.g., when drilling rock, apply water through the drill stem to reduce airborne dust, or use a drill with a dust collection system); and
  - Prohibiting dry sweeping or the use of compressed air for cleaning.
- If fibres found to be present within air above recommended occupational exposure levels then the applicable areas will be subject to same exposure measurements and mitigation techniques that apply to sites containing asbestos. Mitigation would include:
  - Avoid/minimise any areas identified as having geomarkers indicative of possible erionite presence,
  - Areas of infill that are identified as containing erionite to be capped with a “blinding” layer of aggregate / geomembrane (or equivalent) to protect area from abrasion and any potential fibre release;
  - Consider different construction techniques if areas contain erionite e.g. drilling instead of blasting rock;
  - Protecting employees with personal protective equipment, including respiratory protection. Note: An occupational safety and health professional would be consulted for specific guidance about the most appropriate personal protective equipment that should be used for the work being conducted and decontamination procedures required. Dampening and monitoring will be undertaken to avoid any potential for dust containing fibres extending beyond the works area
  - On-going monitoring of dust for fibres to manage the risk within the construction area and ensure no off site risk.

3.3 ASSESSMENT OF RISK TO RECEPTORS

The primary receptors identified are on site construction workers during blasting of rock faces and the exposure is considered to be low. No identified erionite has been identified within the quarry as part of this investigation, however, a precautionary approach is
planned to further investigate and manage any credible exposure risk to site workers by coring the rock mass and assessing some for erionite presence and assessing presence of erionite fibres in air during blasting works. Note the presence of erionite minerals alone within the rock matrix does not constitute a credible exposure risk to the construction workers, and fibre release testing is required to confirm this exposure pathway.

With the further assessment for blast areas and the incorporation of the mitigation measures outlined above, there is a low risk to on-site construction workers. Management of any generated dust within the blast area by dampening and monitoring of fibre release to air within the work zone and outside of the work area will ensure that there is no likely risk to near neighbours outside of the construction site.

During operation, there is no requirement for disturbance of any rock faces and much of the area will be in hardstand i.e. providing a barrier to any erosion of the natural rock. As such there is a very low potential for workers or visitors having exposure to any rock face, as such a very low likelihood for exposure to rock containing the mineral present in a fibrous form.

4.0 CONCLUSIONS

As no erionite was identified on the site as part of this investigation, there are no defined source -pathway -receptor linkages identified. Neither the chemical analysis or microscopy identified erionite, but did identify zeolites in general in a form that do not constitute a material environmental or public health hazard. In addition, a precautionary approach has been taken to consider the potential for unidentified erionite to release fibres during rock blasting within the construction phase, resulting in a potential exposure in dust during blast works. Further site-specific testing will be undertaken pre-blasting works (coring and sampling) and during blasting (fibre release tests in air) to further confirm the degree of mitigation required during these works. Should any risk of exposure to on-site workers be determined by this further testing, mitigation (similar to asbestos containing sites) have been outlined to prevent any exposure to on-site workers. Standard dust management measures and monitoring will ensure there is no potential release off site.

Therefore, based on the findings of this assessment the CMP and the relevant proposed mitigation measures are sufficiently robust to ensure that the potential for the presence of erionite in it's fibrous form during the construction phase of the proposed facility will not impact workers on, or near neighbours to the site.

No source - pathway - receptor linkages are identified for the operational phase. The public and commercial areas of the plant will be covered in hardstand which acts as a protective barrier. Rock faces will be assessed as part of the operational management plan and calcreted if required to reduce the potential for any erosion.

5.0 REFERENCES


Fowler, M., Bullen, D., Gibson, A., Dunlop, J. and Rust, D., Characterization of fibrous zeolites and their distribution in Antrim basalt quarries (conference presentation), 2017 Annual Conference of the International Network of Environmental Forensics (INEF), Beijing, China, July 2017.

Giordani, M., 2016, Mineralogical study of the fibrous zeolites erionite and offretite and hazard assessment, PhD thesis, University of Urbino Carlo Bo, Italy.


Hightown Quarry, Boghill Road, County Antrim: Residual Waste Treatment Project Environmental Statement March 2014, Chapter 14 Air Quality;

Hightown Quarry, Boghill Road, County Antrim: Residual Waste Treatment Project Environmental Statement March 2014, Appendix 3.1 Construction Management Plan.


James, K., 2010, Harry Foy – Zeolite Collector, Earth Science Ireland, 7, Spring 2010, p. 21-23,


Report to Client

Determination of presence of fibres in eight rock samples

for

AWN Consulting
The Tecpro Building
Clonshaugh Business & Technology Park
Dublin 17
Ireland

CONTRACT NO: S03625
DATE OF ISSUE: 13.02.19
CERTIFICATE OF ANALYSIS

ANALYSIS REQUESTED BY: AWN Consulting
The Tecpro Building
Clonshaugh Business & Technology Park
Dublin 17
Ireland

CONTRACT NO: S03625
DATE OF ISSUE: 13.02.19

DATE SAMPLE RECEIVED: 05.02.19

DATE ANALYSIS COMPLETED: 12.02.19

SAMPLES: Eight samples of rock fragments.

ANALYSIS REQUESTED: Determination of the presence of fibre content using optical microscopy methods and Scanning Electron Microscopy/Energy Dispersive X-ray Analyser (SEM/EDXA). The analysis should make particular reference to the presence of asbestos fibres or fibres with asbestiform morphology (It should be noted that the geological term “asbestiform” relates to a mineralogical habit, i.e. long, thin needles or fibres, rather than actual asbestos group minerals).

METHOD:

Each sample was transferred to an asbestos containment cabinet where the rock fragments were examined under stereo binocular microscope. During the course of this examination, any mineral fragments that were identified as having a fibrous component were transferred into a 25ml Sterilin tube to be prepared for more detailed analysis using SEM/EDXA. Recovered rock fragments/fibre bundles were gently ground and made up in solution using filtered distilled water. Aliquots of the resultant suspensions were filtered onto 25mm 0.4µm polycarbonate filters. Each polycarbonate filter was mounted on a 25mm aluminium, SEM pin-stub, coated with a thin layer of gold and examined by SEM/EDXS at between 500 – 5000X magnification. Any fibres detected are identified as closely as possible on the basis of their morphology and elemental composition.
RESULTS:

The fibres/cleavage fragments extracted from the eight samples displayed a variety of morphologies. These included examples of; cleavage fragments, fibrous bundles and fibres that could be described as having asbestiform morphology.

Sample numbers 54451, 54452, 54454 and 54457 where similar and contained a mixture of cleavage fragments and fibres with a “blocky” appearance that were not filamentous. These cleavage fragments/fibres were composed of silicon, aluminium, calcium and sodium.

Under stereo microscope sample 54453 contained soft white radiating crystals and when these were viewed on the SEM the material was fibrous but not asbestiform and was composed of silicon and calcium.

No fibres were detected in sample 54455, this sample comprised mineral particles that were composed of silicon, aluminium and calcium.

Material extracted from sample 54456 was taken from a depression in the rock fragment which contained soft brown material with fibres contained within it. This fragment contained a high proportion of fibrous material. These fibres included thin single fibres and larger fibre bundles with asbestiform type morphology. These were composed of silicon, aluminium, calcium and sodium.

Under stereo microscope sample 54458 contained mostly mineral particles and a large mass of white crystals running through the rock fragment. Some of the crystal mass was extracted and SEM examination identified fibres present within this fraction. Some of the fibres appeared filamentous and composed of individual fibrils rather than being solid “blocky” type fibres. These fibres were composed of silicon, aluminium, calcium and sodium.

EDXS traces and SEM images are provided below to demonstrate the elemental composition and the morphology of the fibres present in these samples.

EDXS Spectra showing examples of the compositions of fibres detected in samples 54451 (S03625-1), 54452, 54454 (S03625-4) and 54457. These were all very similar in composition, with similar amounts of silicon and aluminium with smaller amounts of calcium and sodium.
Low magnification (x250) SEM image showing a mixture of cleavage fragments and fibres detected in sample 54451 (S03625-1).

SEM image showing a cleavage fragment detected in sample 54454 (S03625-4).
SEM images showing fibres/cleavage fragments detected in samples 54451 (S03625-1) and 54452 (S03625-2).
EDX Spectra showing the composition of fibres detected in sample 54453.

SEM images showing non-asbestiform fibrous bundles in sample 54453.
EDX Spectra showing the composition of asbestiform like fibres detected in sample 54456.

SEM image showing fibre bundles with asbestiform like morphology in sample 54456.
SEM image showing further fibres/fibre bundles with asbestiform like morphology in sample 54456.
EDX Spectra showing the composition of fibres detected in sample 54458.

SEM image showing the morphology of a filamentous fibre detected in sample 54458.
COMMENTS/CONCLUSION:

There was considerable variation in the morphology of the fibres/cleavage fragments detected in these eight samples. Only one sample (54455) did not contain a fibrous component but the other seven contained artefacts that could be described as “fibres” to some extent. The majority of the samples contained “fibres” that were clearly non-asbestiform and these could probably more accurately be described as cleavage fragments. These cleavage fragments were composed of silicon and aluminium with smaller amounts of calcium and sodium. Sample 54453 was slightly different as the fibres/cleavage fragments in this sample were composed of silicon and calcium only. The two samples that did contain artefacts that could accurately be described as fibres were numbers 54456 and 54458. Sample number 54458 only contained a small number of fibres but they were prevalent in sample number 54456. These fibres displayed some aspects of asbestiform type morphology but not all. The fibres were clearly made up of individual fibrils however the fibres themselves had a rather “flatter” morphology than would be expected from asbestos fibres. These fibres were also composed of silicon, aluminium, calcium and sodium.

The results of our analyses suggest that the fibres/cleavage fragments present in these samples are probably Zeolites. There is a wide range of Zeolite minerals and the fibres associated with these have varying morphologies. The main elements present in Zeolites are similar but vary in proportion and some minor elements are present in some Zeolites but not in others. The composition of the majority of the fibres in these samples had silicon and aluminium as the main elements (in similar amounts) with calcium and sodium present in smaller amounts. The composition of one of the main Zeolites of interest, Erionite, has high silicon but with a smaller ratio of aluminium and also contain potassium. None of the fibres in the samples we tested had this composition.

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