EPOS ANTHROPOGENIC HAZARDS

Anthropogenic Seismicity Educational Outreach Student Worksheets

Name – **Date –**

NB The Glossary at the end for some unfamiliar words 😊

Section 1 - Earthquake Strength (< 1 hour)

Earthquakes can be devastating. But what are the factors affecting their intensity and propensity to cause damage? And is there really such a thing as a harmless earthquake?

Watch the following short (~2 min) videos to help you answer the questions below -

https://www.iris.edu/hq/inclass/animation/take_2_magnitude_vs_intensity

https://www.iris.edu/hq/inclass/animation/take_2_epicenter_vs_hypocenter

QUESTIONS

1. What is the difference between an earthquake epicentre and hypocentre and what is another name for the latter?

2. Explain why earthquake depth is an important factor for potential surface damage.

3. What is earthquake magnitude a measure of?

4. Define Earthquake intensity and explain why it can vary significantly (or have multiple values) for one earthquake event.

5. Familiarise yourself with Earthquake intensities by looking at Table 1 below and giving the EMS intensities for earthquakes that are a) 'Not felt' and b) are 'Strong'.

6. REFLECT/RECAP - What do your answers and the information from this section tell you about earthquake strength in general? Do you think an earthquake could be harmless, explain your reasoning?

Table 1 - A Synopsis of the European Macroseismic Scale (EMS 98) for evaluating seismic intensity in Europe. Abstracted from - Grünthal, G., (ed.), (1998). Source - EMS Intensities Synopsis (bgs.ac.uk)

EMS	DEFINITION	DESCRIPTION
1	Not felt	Not felt, even under the most favourable circumstances.
2	Scarcely felt	Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.
3	Weak	The vibration is weak and is felt indoors by a few people. People at rest feel a swaying or light trembling.
4	Largely observed	The earthquake is felt indoors by many people, outdoors by very few. A few people are awakened. The level of vibration is not frightening. Windows, doors and dishes rattle. Hanging objects swing.
5	Strong	The earthquake is felt indoors by most, outdoors by few. Many sleeping people awake. A few run outdoors. Buildings tremble throughout. Hanging objects swing considerably. China and glasses clatter together. The vibration is strong. Top heavy objects topple over. Doors and windows swing open or shut.
6	Slightly damaging	Felt by most indoors and by many outdoors. Many people in buildings are frightened and run outdoors. Small objects fall. Slight damage to many ordinary buildings e.g.; fine cracks in plaster and small pieces of plaster fall.
7	Damaging	Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many ordinary buildings suffer moderate damage: small cracks in walls; partial collapse of chimneys.
8	Heavily damaging	Furniture may be overturned. Many ordinary buildings suffer damage: chimneys fall; large cracks appear in walls and a few buildings may partially collapse.
9	Destructive	Monuments and columns fall or are twisted. Many ordinary buildings partially collapse and a few collapse completely.
10	Very destructive	Many ordinary buildings collapse.
11	Devastating	Most ordinary buildings collapse.
12	Completely devastating	Practically all structures above and below ground are heavily damaged or destroyed.

Section 2 – Anthropogenic Seismicity (<1 hour)

induced earthquakes | induced earthquakes

Visit the above site, check out the home page and use your mouse to interactively explore the map at the top. Using the info from the site and the downloadable spreadsheet of data, answer the following questions -

QUESTIONS

1. Give 3 different anthropogenic (i.e. human induced) activities that can induce/trigger an earthquake that are a) associated with active georesource exploitation and b) not associated with active georesource exploitation (i.e., provide 6 in total).

2. From the text under the 'About Induced Seismicity Tab' at the top. List the three most common anthropogenic induction mechanisms and explain why a reduction in normal stress can cause an earthquake.

3. According to the interactive HiQuake map, what hemisphere has the most induced earthquakes and how many induced earthquakes have occurred in the UK? Try to also have a look at the density of these quakes in your own/home country.

4. Using Table 2 below (HiQuake data from 2017) determine what anthropogenic activity had the highest number of reported induced earthquake cases and its percentage of the HiQuake data?

5. From the homepage induced earthquakes | induced earthquakes
identify the current activity with the highest percentage of HiQuake data. Compare this answer to that from Q4 and then use the downloaded spreadsheet to compare the magnitude ranges of each activity by filtering on the 'Observed maximum magnitude' (Mmax).

6. According to the HiQuake database which anthropogenic activity has produced the largest magnitude earthquake?

7. Using the HiQuake data spreadsheet, identify the industries and magnitude range of induced earthquakes in the UK. Have a look also at the data for your own/home country.

8. REFLECT/RECAP - What do your answers and the information from this section (and your knowledge from the previous section) tell you about induced earthquakes/ anthropogenic seismicity?

Table 2 -The Numbers of Each Type of Anthropogenic Activity Proposed to Have Induced Earthquakes (Data from *HiQuake*) (From Wilson et al, 2017 - https://doi.org/10.1785/0220170112)

Anthropogenic Activity	Number of Reported Cases	Percentage of *HiQuake* to Nearest Integer (%)
Carbon capture and storage (CCS)	2	0
Construction	2	0
Conventional oil and gas	107	15
Deep penetrating bombs	4	1
Hydraulic fracturing for shale gas or oil	29	4
Geothermal	57	8
Groundwater extraction	5	1
Mining	271	37
Nuclear explosions	22	3
Research experiments	14	2
Unspecified oil and gas extraction; waste-fluid disposal	12	2
Waste-fluid disposal	36	5
Water reservoir impoundment	167	23
Total	728	

Section 3 – Exploring the EPISODES Platform (<1 hour)

EPISODES PLATFORM

[EPOS Thematic Core Service Anthropogenic Hazards (episodesplatform.eu)](https://episodesplatform.eu)

Visit the above site. Use the info from the site to answer the following questions -

QUESTIONS

1. What does this Research Infrastructure focus on and provide access to? (See Home Page)

2. What is an Episode? And how many are there? (See Home Page)

3. What is an application defined as here? (See Home Page)

4. Enter the platform by selecting the EPISODES Platform tab at the top of the home page (in the header). Under AH Episodes, select 'Impacting Factor' to see the different industries covered in the dropdown. Which industry has the highest number of Episodes?

5. Under "Impacting Factor" select 'Wastewater Injection' and then open the OKLAHOMA Episode. Read the description of the Episode.

   What kind of data is incorporated in this Episode? What is a) the magnitude range and b) time period of the earthquake events captured in this episode (this is given next to Catalog and Event related waveforms)?

   Scroll further down the page to hover over the 'Available Visualizations' Button and select 'Integrated Episode Data Visualization. Zoom in and out of the map presented and describe what can be seen (i.e., what data is plotted, the distribution of it, the general density and magnitude range of earthquake events, note by clicking on an earthquake event (plotted as a red circle) the magnitude value will be displayed).

6. Return to the AH Episodes Tab and from the 'Project Association' dropdown select SHEER. Work out what the letters in this project acronym stand for by opening the Wysin Episode and reading the description of the Episode.

   What is the magnitude range and time period for the earthquake events of this Episode (this is given next to Catalog and Event related waveforms)?

   Look at the list of data provided in this Episode and name the main headings that the data is grouped under.

   Scroll further down the page to the 'Available Visualizations' Button and select 'Integrated Episode Data Visualization'. Tick and untick the various monitoring stations and networks near the top of the page and comment on what you can see and how this compares to the Visualisation observed in the previous question.

7. REFLECT/RECAP - What do your answers and the information from this section (and your knowledge from the previous sections) tell you about induced earthquakes/ anthropogenic seismicity research and monitoring? (Reflect on what is required for valuable and comprehensive research in this area, its importance and the potential problems that need to be addressed).

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References

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Orlecka-Sikora, B., Lasocki, S., Kocot, J. et al. (2020) An open data infrastructure for the study of anthropogenic hazards linked to georesource exploitation., Sci Data 7, 89, doi: 10.1038/s41597-020-0429-3.

Wilson, M. P., Foulger, G. R., Gluyas, J. G. Davies, R. J., Julian, B. R.; HiQuake: The Human-Induced Earthquake Database. Seismological Research Letters (2017); 88 (6): 1560–1565. doi: https://doi.org/10.1785/0220170112

For queries &/or feedback on this worksheet please get in contact with the author - Glenda Jones - Keele University

Glossary –

Anthropogenic Seismicity	earthquakes/ tremors/seismic events related to human activity
Carbon Capture & Storage / CO2 sequestration	the process involved in carbon dioxide capture and long-term storage of either atmospheric carbon dioxide or carbon dioxide created by industrial processes to mitigate or defer global warming
Conventional hydrocarbon extraction	extraction of hydrocarbon resources (typically light crude oil and / or gas) from naturally pororous and/or permeable geological reservoirs using natural fluid pressure or standard pumping technologies
Episode	grouped dataset comprised of geoscientific and time-correlated industry data
Georesources	economically usable energy, space and raw materials of value from above or below Earth's surface
Geothermal energy production	technology using thermal energy generated and stored in the Earth for heat and/or electricity production
Hydraulic fracturing	fracturing of rock by high pressure fluid injection (most commonly done to release tightly held oil or gas)
Hydrocarbon	hydrogen & carbon compound (e.g. coal, natural gas, crude oil)
Mining	the extraction of raw materials (rock and/or minerals) from underground or above ground (opencast)
Permeable/ permeability	term describing a material that allows the passing of liquids or gas

Porous/porosity	term describing a material with pores/voids/holes (e.g. to hold a gas or liquid)
Reservoir	place where fluids or gas collect (e.g. water dam or sub-surface oil field)
Reservoir impoundment	process of filling a water reservoir
Unconventional Hydrocarbon Extraction	extraction of hydrocarbons not using standard techniques. Methods include hydraulic fracturing (reservoir stimulation) techniques to improve reservoir permeability, and heating of the geological reservoir to reduce the viscosity of heavy, super heavy oils and bitumens.
Underground gas storage	technology of gas storage in sub-surface rock formations
Viscous/viscosity	term describing a material (typically a fluid) that resists flow due to internal friction (in a thick/sticky state)
Wastewater injection	injection of waste fluids into rockmass (typically from hydraulic fracturing operations)