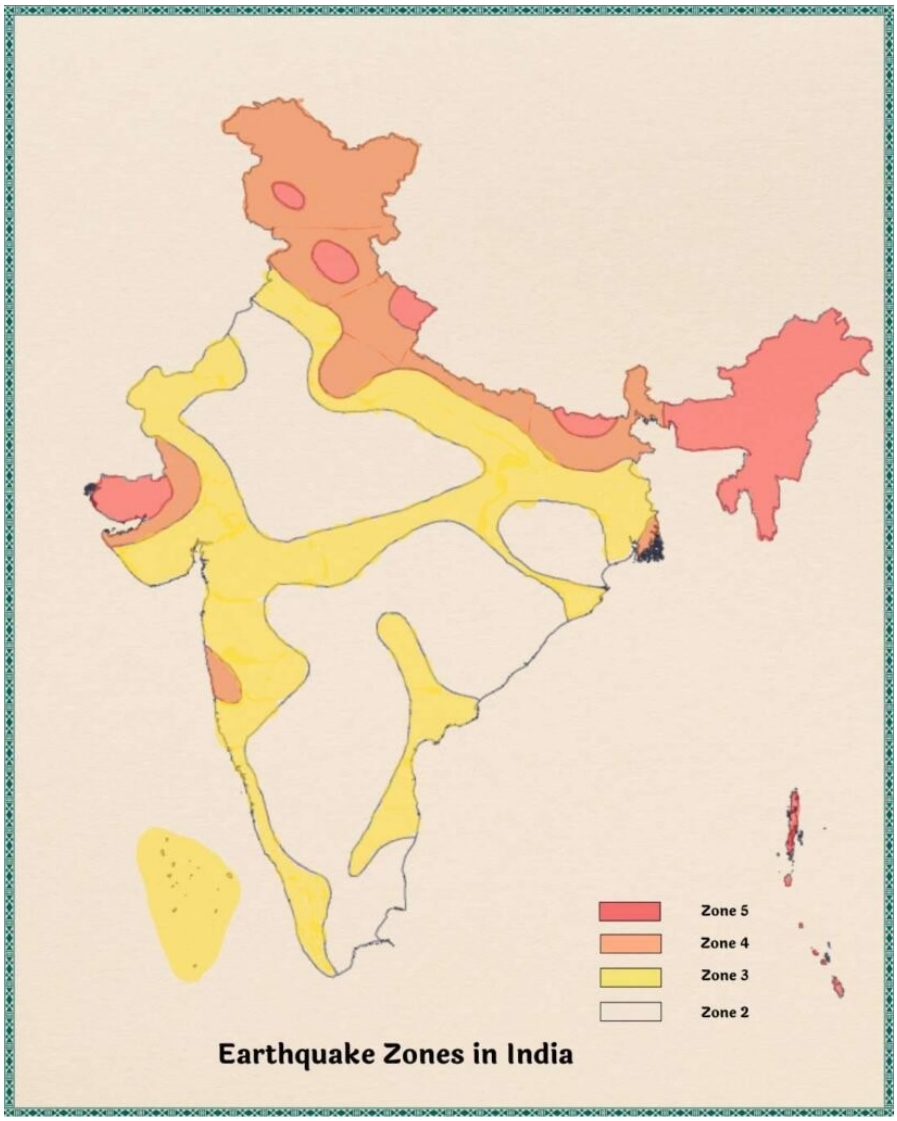
HUMAN-INDUCED EARTHQUAKES – GEOGRAPHY

NEWS: Recent studies and seismic data have highlighted the increasing frequency of human-induced earthquakes in India, with significant linkages to groundwater extraction, reservoir loading, and infrastructural activities in seismically vulnerable regions.

WHAT'S IN THE NEWS?

I. Concept and Mechanism of Human-Induced Earthquakes (HIEs)

- **Definition**:
    - Human-Induced Earthquakes (HIEs) are seismic events that are directly or indirectly triggered by human activities altering the stress distribution in the Earth's crust.
- **Global Trend**:
    - Over **700 HIE events** have been scientifically documented worldwide in the past **150 years** (*Seismological Research Letters, 2017*).
    - Most events were of low to moderate magnitude but have had considerable local impacts.



- **Underlying Mechanisms**:
    - Human actions cause **abrupt or gradual changes in subsurface pressure**, **fluid movement**, or **mass loading**, which disturb fault equilibrium.
    - These disturbances may **reactivate pre-existing faults**, leading to earthquakes.

II. India-Specific Observations and Case Studies

- **1. Koyna Earthquake (1967), Maharashtra**:
    - One of the **first confirmed cases** of reservoir-induced seismicity (RIS) globally.
    - Triggered by the filling of the **Koyna Dam** reservoir.
    - **Magnitude**: 6.3; **Casualties**: Over 180 people killed; **Impact**: Thousands of structures destroyed.
- **2. Delhi-NCR and Groundwater Extraction (2003–2012)**:
    - A 2021 study (*Scientific Reports*) linked shallow quakes to extensive **groundwater depletion**.
    - Quakes were concentrated in areas where the **water table dropped sharply** during this period.
    - After 2014, when groundwater levels began stabilizing, the **seismic frequency declined**.
- **3. Mullaperiyar Dam, Kerala**:
    - Built in 1895, situated in a **seismically active zone**.
    - Concerns stem from both **structural ageing** and **RIS potential**, given the dam's location on faulted rock beds.
- **4. Palghar District, Maharashtra**:
    - Experienced clusters of tremors in 2018–2020.
    - Suspected link with **fluid movements along faults**, possibly due to **subsurface water stress or crustal adjustments**.
- **5. Sahyadri Range (Western Ghats)**:
    - Episodes of seismic activity followed **extreme rainfall events** (e.g., 2019–2021).
    - Suggests a link between **rain-induced loading** and **fault reactivation**.

III. Anthropogenic Triggers of Earthquakes in India

- **1. Groundwater Over-Extraction**:
    - Leads to **decline in pore pressure**, making rocks more prone to shifting.
    - Also increases **vertical stress** due to the reduced buoyant support.

    - Particularly seen in north India, including **Delhi, Haryana, and parts of Rajasthan**.
- **2. Reservoir-Induced Seismicity (RIS)**:
    - Occurs due to the **weight of stored water** and **water seepage** into fault zones.
    - Faults near large reservoirs may become **lubricated**, enabling slippage.
    - Examples include **Koyna**, **Indira Sagar**, and concerns around **Tehri Dam** in Uttarakhand.
- **3. Fracking and Hydrocarbon Extraction**:
    - India has **56 fracking sites** across **Gujarat, Rajasthan, Andhra Pradesh, Tamil Nadu**, etc.
    - High-pressure fluid injection can **fracture rock layers**, create **new fault planes**, and induce tremors.
    - Studies suggest potential future risk as fracking expands without adequate regulation.
- **4. Urban Construction in Seismic Zones**:
    - High-rise buildings and metro projects in places like **Delhi NCR**, **Dehradun**, and **Shillong** impose **concentrated loads** on already stressed fault zones.
    - Lack of seismic compliance in construction worsens vulnerability.

IV. Emerging Role of Climate Change in Seismicity

- **1. Glacial Melting and Isostatic Rebound**:
    - Loss of glacial mass in regions like **Himalayas**, **Greenland**, and **Antarctica** reduces weight on tectonic plates.
    - This triggers **isostatic uplift**, changing **stress fields** deep within the crust.
- **2. Extreme Rainfall Events**:
    - Sudden heavy rainfall, such as in **Kerala (2018, 2019)** and the **Sahyadris**, adds surface weight.
    - Water infiltrates into faults, **increasing pore pressure** and reducing rock friction.
- **3. Drought-Induced Seismic Reactivation**:
    - Long-term droughts (e.g., **California 2014**) reduce groundwater, causing **drying and contraction** of crustal rocks.
    - Leads to **fault adjustments** and earthquake risk.

V. Policy and Scientific Recommendations

A. Scientific and Technical Measures

- **Expand Seismic Monitoring Network**:

    - Prioritize installation near **dams**, **fracking fields**, and **urban seismic hotspots**.
    - Use **real-time sensors** to monitor fluid movement and crustal stress.
- **Promote Earthquake Early Warning Systems (EEWS)**:
    - Pilot successful models from **Japan and California** in Indian metros.
    - Useful for even short lead-time alerts (10–30 seconds).

B. Regulatory and Planning Reforms

- **Dams and RIS Management**:
    - Implement **gradual reservoir filling/emptying** strategies to prevent sudden stress changes.
    - Follow models like the **Hoover Dam** in the U.S.
- **Fracking Controls**:
    - Enforce **seismic hazard mapping** before approving new fracking leases.
    - Mandate **cutoff thresholds**—automatic halting of operations if tremors exceed a given magnitude.

C. Groundwater Governance

- **Promote Managed Aquifer Recharge (MAR)**:
    - Use **check dams**, **percolation tanks**, and **urban recharge wells** to restore sub-surface equilibrium.
- **Link Groundwater Use with Hydrogeology**:
    - Integrate recharge zones into **urban planning**, **zoning regulations**, and **cropping patterns**.

D. EIA and Infrastructure Policy Reforms

- **Update Environmental Impact Assessment (EIA)** norms:
    - Mandate **seismic risk evaluation** for projects above a size threshold (e.g., large dams, metros, highways).
    - Require **climate-linked seismic vulnerability** assessment in EIAs.
- **Urban Planning Reforms**:
    - Enforce **building codes (IS 1893)** for seismic resistance.
    - Prioritize **risk-sensitive land use planning** in zones like Himalayan towns and Mumbai suburbs.

Source: https://www.thehindu.com/sci-tech/science/india-human-induced-earthquakes-water-energy-demand-risk/article69837667.ece