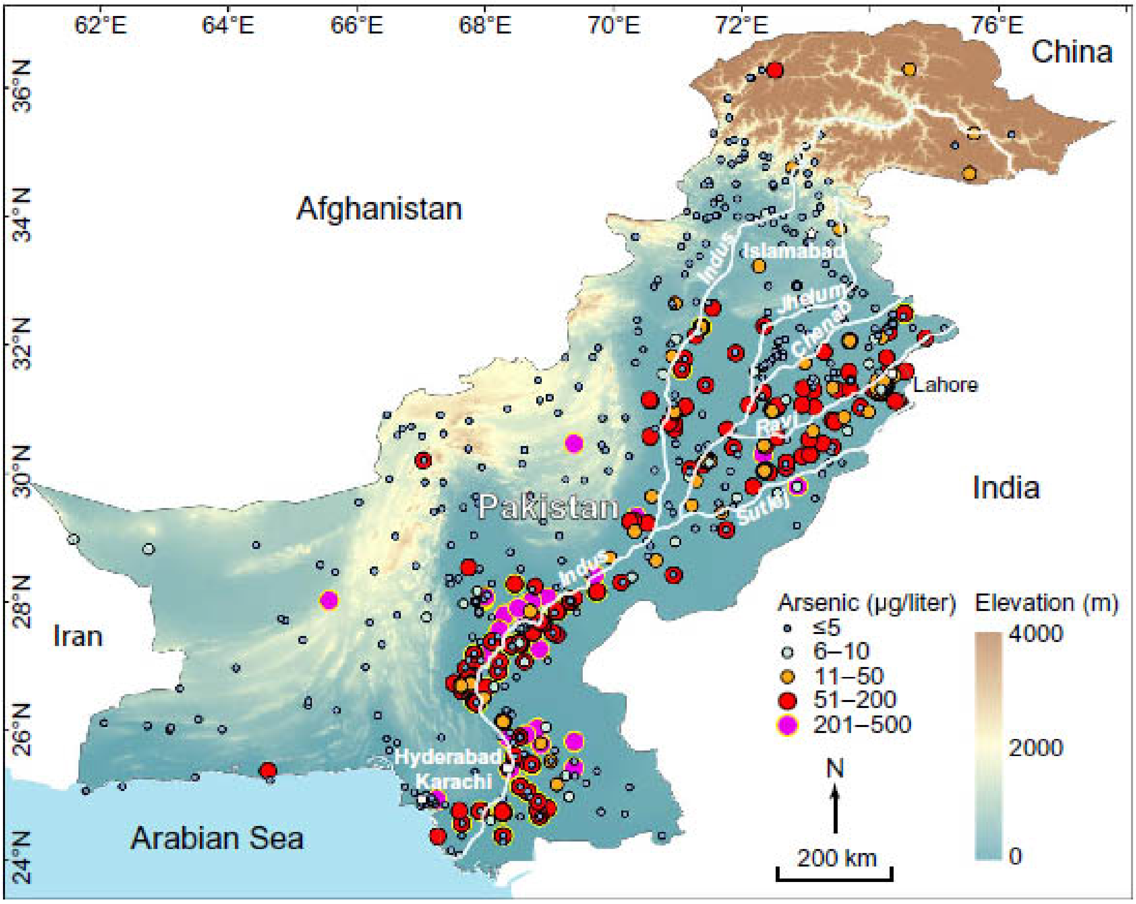
Geohazards

Water-borne arsenic back in the news (*August 2017*)

In the 1980s grim news began to emerge from the Indian State of West Bengal and a decade later from neighbouring Bangladesh. Villagers from the low-lying delta plains of the Ganges and Brahmaputra river systems at the head of the Bay of Bengal began to present at clinics with disfiguring skin lesions or keratoses on hands and feet, loss of feeling in fingers and toes and dark skin patches on their torsos. The latter were colloquially known as 'black rain'. The victims were often stigmatised, as their neighbours believed they were suffering from leprosy. These symptoms were followed a few years later by increased incidences of lung, liver, kidney and bladder cancers. The first medical practitioner to recognise these typical signs of chronic arsenic poisoning in 1983, Dr Depankar Chakraborti of Kolkata, was branded as a 'panic monger' by local authorities. His warnings, backed by evidence published by the World Health Organisation (WHO) in 1988 that there was a connection with high arsenic levels in West Bengal drinking water supplies from new tubewells, went largely unheeded for a decade. Tragically, as it turned out, thousands of tubewells had been sunk in the Bengali delta plains from the 1970s onwards, aimed at reducing the risk of disease from pathogens in the previously used surface water from ponds and streams. After a conference on the perceived problem, organized in Kolkata by Dr Chakraborti in 1995, the WHO declared the situation in Bangladesh to be a 'Major Public Health Issue', and the world's press took up the story. Clearly, millions of Bengali villagers were at risk or were already suffering from chronic arsenic poisoning. By the late 1990s thousands of samples of tubewell waters from the delta plains had been analysed, many of which revealed arsenic levels far above the 10 $\mu g\ l^{-1}$ safe threshold. In 2002, 400 Bangladeshi victims sued the British Geological Survey (BGS) for negligence. The BGS had analysed 150 water samples from the Bangladesh delta plains in 1992 and had not reported any risks, but arsenic was not among the elements being analysed. The civil action eventually failed.

Skin lesions or keratoses that are symptomatic of chronic arsenic poisoning

Almost two decades after the arsenic scandal on the eastern side of the subcontinent well-water analyses showing high arsenic values have been published from the Indus plains of Pakistan (Podgorski, J.E. *et al.* 2017. [Extensive arsenic contamination in high-pH unconfined aquifers in the Indus Valley](). *Science Advances*, v. **3**, e1700935; DOI: 10.1126/wsciadv.1700935). The Indus catchment having a similar Himalayan source and being at similar latitude it has long been considered to be at potential risk from arsenic derived from its thick alluvial sediments. The Swiss-Pakistani-Chinese team have produced geochemical data from 1200 tubewells throughout the catchment within Pakistan. A swath from Lahore to Karachi, with the country's greatest population density, is at high risk of water with arsenic concentrations above the WHO guideline safe concentration, suggesting some 50 to 60 million people being subject to its hazard.



Arsenic concentrations in Pakistan groundwater (Credit: Podgorski *et al.* 2017; Fig. 1)

Although the geological setting is similar to that in the Bengal plains, a different natural chemical process causes the high concentrations ultimately from the iron hydroxide veneer on sediment grains which selectively absorbs several trace elements, including arsenic, from river water. In Bangladesh arsenic is released from sediments as a result of highly reducing conditions due to organic matter buried in some layers of alluvium, by a process known as reductive dissolution. When insoluble ferric iron (Fe^{3+}) hydroxide (goethite) is exposed to a ready supply of electrons the iron is reduced to the soluble ferrous (Fe^{2+}) form and the mineral breaks down to release its absorbed trace elements. Most of the alluvium in the Indus plain contains little organic carbon, so another mechanism is implicated. The high arsenic levels correlate with high pH, indicating groundwater alkalinity, and therefore seem most likely to be released from goethite grain coatings by this alkaline water. That, in turn, is often a product of high evaporation and soil salinisation from widespread groundwater irrigation in semi-arid southern Pakistan. The alkaline water then returns to the underlying groundwater in the highly permeable Indus alluvium; i.e. it is a consequence of irrigated agriculture rather than of a natural geochemical process as in more humid Bengal.

Whereas a remedy in Bangladesh and West Bengal has been to sink new tubewells into oxidising alluvial strata (red coloured rather than the reducing grey sediments) that yield water with safe arsenic levels, the risky areas in Pakistan may need expensive use of absorbent filters on a large scale to remove the hazard. Because irrigation using groundwater is on such a large scale on the Indus plain there is also a definite risk of ingesting arsenic from crops produced there, principally rice but also unwashed leaf vegetables

See also: Arsenic in drinking water threatens up to 60 million in Pakistan (sciencemag.org)

Large earthquakes and the length of the day (*November 2017*)

Geoscientists have become used to the idea that long-term global climate shifts are cyclical, as predicted by Milutin Milanković. The periods of shifts in the Earth's orbital and rotational parameters are of the order of tens to hundreds of thousand years. The gravitational reasons why they occur have been known since the 1920s when Milanković came up with his hypothesis, and they were confirmed fifty years later. But there are plenty of other cycles with shorter periods. The last 115 years of worldwide records for earthquakes with magnitudes greater than 7 whose changing annual frequency shows a clear cyclical period of about 32 years. The records show peaks in 1910, 1943, 1970 and 2011 (Bendick, R. & Bilham, R. 1917. Do weak global stresses synchronize earthquakes? *Geophysical Research Letters*, v. **44** online; DOI: 10.1002/2017GL074934). Unlike Milanković cycles, these oscillations were not predicted, but something synchronous with them must be forcing this behavior: a sort of "cross-talk". Either global seismicity has a tendency for events to trigger others elsewhere on the Earth or some other process is periodically engaging with major brittle deformation to give it a nudge.

Rebecca Bendick, of the University of Montana, Missoula, and Roger Bilham of the University of Colorado, Boulder used a complex statistical method to check for synchronicity between the seismic cycles and other repetitive phenomena. It turns out that there is a close match with historic data for the length of the day which varies by several milliseconds. At first sight this may seem odd, until one realizes that day length is governed by the Earth's speed of rotation (about 460 m s^{-1} at the Equator). The correlation is between increases in both major seismicity and the length of the day; i.e. quakes increase as rotation slows. Day length can vary by a millisecond over a year or so during el Niño, which involves shifts of vast masses of Pacific Ocean water that affect rotation. But what of larger changes on a three-decade cycle? Seismic events and the forces that they release result from buildup of strain in the lithosphere, so the episodic earthquake maxima require some kind of transfer of momentum within the Earth. It does not need to be large, as the Milanković astronomical forcing of climate demonstrates, just a regular pulse.

Rescuer and sniffer dog search for survivors of the 12 November 2017 Halabja earthquake

One possibility is that, as rotation decelerates, decoupling between the liquid outer core and the solid mantle may change the flow of molten iron-nickel alloy. That may be sufficient to transmit momentum and thus stress through the plastic mantle to the brittle lithosphere so that areas of high elastic strain are pushed beyond the rocks' strength so that they fail. There are indeed signs that the geomagnetic field also changes with day length on a decadal basis (Voosen, P. 2017. Sloshing of Earth's core may spike big quakes. *Science*, v. **358**, p. 575; DOI: 10.1126/science.358.6363.575). Rotational deceleration began in 2011, and if the last century's trend holds there may be an extra five large earthquakes next year. Could the deadly 7.3 magnitude earthquake at the Iran-Iraq border on 12 November 2017 be the start? If so, will the 32-year connection improve currently unreliable earthquake forecasting? Probably the best we can expect is increased global readiness. The study has nothing to add as regards which areas are at risk: although there is clustering in time there is none with location, even on the regional scale.