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Perspective

Boron in Geothermal Energy and its Effect on Environment, Water Treatment

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DESCRIPTION

An important environmental concern in the development of geothermal energy is the issue of toxic compounds in geothermal fluid. One of the dangerous pollutants found in geothermal fluids in high amounts in a number of nations is boron. Geothermal fluids can leak excessive amounts of boron into the environment through poor management and insufficient treatment, which can be hazardous to plants, people, and animals. Despite the significance of boron management in geothermal fluid, there are few and disparate resources that offer a thorough understanding of its sources, movement, and fate as well as the treatment approaches in the context of geothermal energy.

The application of five significant strategic technologies can reduce CO_2 emissions. These include fuel switching (10%), carbon capture and storage (15%), nuclear energy (11%), and greater energy efficiency (32%). Renewable energy sources are less expensive to operate and manage, believed to be non-polluting, and favorable to the environment. In terms of renewable energy, Geothermal Energy (GE) has garnered a lot of attention due to its potential to produce 1400 TWh of electricity annually by 2050 (or roughly 3.5% of the world's energy production). A contribution like that would cut CO_2 emissions by about 800 metric tons annually.

Although GE production is regarded as a clean form of energy, if improperly handled, it could cause significant environmental issues. One of the most significant environmental issues related to GE production is the management of geothermal fluids and the potential water pollution caused by them. This is because numerous hazardous substances may be present in high amounts in the geothermal fluid (outflow water). Boron (B), one of the significant compounds that can be detected in geothermal fluid, is one of the water pollutants. B frequently occurs at high concentrations in geothermal fluids, which is typically attributed to magmatic intrusion and leaching from the host rock. Large-scale GE exploration and exploitation has led to the contamination of nearby waters and soils with geothermal fluid that has been released and is B-rich. In two Tibetan geothermal locations (Yangbajing and Yangyi), for instance, significant geothermal fluid flow has increased B concentrations in the rivers to 3.8 mg/L and 0.7 mg/L, respectively. Geothermal fluids should therefore be treated before being discharged into water resources or used for any other purpose other than energy production. On the other hand, the baseline of water stress levels has increased to severe conditions, exceeding the capacity of freshwater resources due to water demands by various sectors. By investigating the possibility of wastewater reuse, this has led to a paradigm shift in the management of water resources. In many parts of the world, geothermal wastewater reuse for agriculture has garnered interest. For many delicate agricultural items, the B concentration should be decreased to less than 1 mg/L in order to use Geothermal Water (GW) for irrigation. B is also used as a raw material in many different industries, such as glass, agriculture, nuclear energy, military vehicles, aerospace, electronics, and fuel for fuel-cell cars. This opens up the possibility of B recovery from GWs for its management in GE.

The kind of host rock, temperature, the boiling and mixing process, and the addition of vapour and volcanic gases into thermal fluids are factors that primarily depend on the region's geological context in order to determine the composition of geothermal fluid. Arsenic (As), Boron (B), antimony (Sb), and Manganese (Mn) are present in the GWs of Western Anatolia, Turkey, which is an example of the complex system. This is because the area's unique geological features give rise to minerals that include these elements. Due to the close proximity of active magma layers and deep reservoirs with high temperature and pressure caused by geological fault lines, the dissolving of minerals in GWs is accelerated in this area. According to reports, poor well design, improper re-injection procedures, and the release of untreated spent geothermal fluids into surface waters are the main causes of the contamination of water resources with heavy metals originating from GE.

An important micronutrient for plant, animal, and human life is B. It is crucial for plants' cell wall stability, promotion of reproductive development, seed quality, and biosynthesis. B is involved in metabolism in humans; therefore, deficiencies can result in aberrant bone formation, low hormone levels, elevated calcium levels, and changes in the status of microminerals. Zebrafish, trout, and frogs are among the animals whose fertility has been linked to B deficiency. Despite being a necessary

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microelement, too much B can be hazardous to humans, animals, and plants. One of the significant possible environmental effects of GE manufacturing is B toxicity in plants.

It's possible that poorly constructed production/re-injection wells and unchecked GW discharge into surface waterways are to blame for the presence of boron at geothermal plants. The major strategies for controlling water pollution are the re-injection of used GWs and their treatment for reuse in agriculture. The range and speciation of boron, the cost of the treatment, and environmental considerations all affect the choice of treatment method. GW's total boron content, which may have been caused by magmatic intrusion, water-rock interaction, or both, can range widely from less than 10 to more than 500 mg/L, depending on the local geology. No matter the location, B is typically found at the natural pH of GW in the form of non-ionic H_3BO_3. This limits the options for the B treatment approach for GWs to membrane processes for size exclusion, sorption employing chelation by functional groups of NMDG and metal oxides, and combinations of these in hybrid processes.