The reviewer raises a few points of clarification that we believe will help illustrate the implications of the Ra study we have performed here, and we have made some alterations reflecting those clarifications.

The first is the apparent contradiction between observed Ra in natural waters (subterranean groundwater or shale formation brines) and the results of our study that show pyrite can sorb significant amounts of Ra. We discuss this in context of estuarine waters in lines 327-337, and in the context of deep shale formations in lines 363-371. In short, while sorption was observed to pyrite surfaces, no sorption experiment including pyrite studied showed complete sorption of experimental Ra. Thus, no contradiction exists, as even in the case where geochemical conditions favor Ra sorption to pyrite, some will still remain in the supernatant. Indeed, for conditions that are representative of natural groundwaters (figure 2, 10 mM ionic strength mixed cation background solution), complete sorption of Ra was not observed.

The second point the reviewer raises deals with addressing how our results impact additional scenarios where Ra may pose a human health hazard, particularly with respect to hydraulic fracturing. While injected fluids may not contain Ra (though many do, since they are recycled from previous operations), the mixing of the injected fluids and formation brines lead to the Ra content observed in produced water. We discuss this linking in lines 298-304, as well as lines 354-362 and lines 371-376 of the updated manuscript. Additionally, this linkage points at the possibility of engineering hydraulic fracturing injections to reduce Ra load in produced water, which would reduce possible contamination risks during fluid handling. Lines 354-362 in particular address these contamination risks and discuss how the disparity between produced water and local groundwater would likely result in additional Ra retention by shallow aquifers.

Third, the reviewer requests that we analyze the impact of Ca/Na ratio on Ra sorption to the mineral phases studied here. While we agree that additional work investigating the impact of these different ions is necessary to constrain Ra sorption, we disagree with the reviewer’s assertion that this ratio alone would elucidate the mechanisms controlling Ra sorption. Figure 2 of this manuscript clearly highlights how even in single cation background solutions, stark differences in Ra sorption appear depending on the background cation. Based on this, studying the geochemistry of Ra would thus require a comprehensive experimental study, where multiple ratios of background cations and Ra are examined. At minimum, such a study would need to quantify the impact of Ca/Na, K/Na, and Mg/Na, but addressing the reviewer’s request here would likely require comparison other ratios, as well as the impact of mixtures of these background cations. This is beyond the scope of the work laid out in lines 84-94 of the manuscript.

Lastly, the reviewer states that the only novel contribution of this work is the data regarding Ra sorption to pyrite, given the failure of the SCM used here to predict the impact of different geochemical conditions. We disagree with this statement. While the literature does contain some work constraining the impact of specific cations as noted lines 67-78 and the associated references, the matrix of geochemical conditions (pH, ionic strength, background cation composition) and mineral phases studied here has not been previously addressed. Additionally, while the SCM used here lacks full predictive capability, the models were able to illustrate key mechanisms at play in Ra sorption. For example, Sodium Montmorillonite SCM required the inclusion of cation exchange, a mostly pH independent mechanism as compared surface site sorption seen in the (iron)hydroxides. We argue, therefore, that the work here provides key initial insights into the complex geochemistry of Ra.