Pipes to Earth's subsurface: The role of atmospheric conditions in controlling air transport through boreholes and shafts

Letter of response:

Reviewer 2:

Earth's atmosphere is extremely complex system oneself and its interaction with nearsurface targets, deep dynamic geological-geophysical regularities, and some cosmic
factors (e.g., tidal effects) increases the total complexness.

Without hesitation, Levintal et al. have arisen very important problem of interaction between the underground caves, boreholes and mines with the Earth's atmosphere. This publication obviously will trigger a series of new publications in this field.

For instance, in the world a lot (tens of millions) of comparatively deep (> 500 m) boreholes were drilled in different physical-geological environments. Many of them are open, semi-open or have indirect connection with the Earth's atmosphere. Calculation of the total effect of air transport from these objects is a difficult physical-mathematical problem.

We would like to thank the anonymous reviewer for his comments and fruitful review. A detailed response for each comment is presented below in blue font.

Some minor remarks are compiled below.

I believe that 'boreholes' and 'mines' cannot be included to the class of 'caves' since they are principally different targets. Besides this, most part of caves are the natural geological objects existing sufficiently long time, whereas boreholes and mines are the artificial targets which have been appeared mainly in 20th century.

We agree that indeed caves can be quite different than boreholes, and we deleted the reference to caves from the conclusions section.

Generally speaking, examination of two (three ?) targets only is insufficient one. I propose that general conclusions done in this MS for all types of underground objects is untimely one.

The sentence that generalized our finding to other underground cavities was deleted.

CO2 concentrations in various underground targets strongly exceed the value of 2000 ppm (e.g., Guillon et al., 2015).

This was also commented on by Reviewer 1, and thus we also added a suitable clarification for environments with elevated CO_2 concentrations in the introduction: "In environments of high CO_2 concentrations compared to the atmosphere, the importance of the gas composition on the *Tv* becomes more pronounced. Such underground environments can be karstic areas of carbonate rocks (Sanchez-Cañete et al., 2011), caves (Denis et al., 2005; Guillon et al., 2015), and soils (Amundson and Davidson, 1990) where CO_2 concentrations can be very high, ranging from 10,000 to 100,000 ppm and above." (Page 2, lines 23-27).

I can suggest that the role of viscosity in air transport (Finkelstein et al., 2006) may be more significant than presented in the MS. The authors assumed some physical parameters as constant (for simplicity of calculations). It is a widely distributed approach and it is acceptable, for instance, for gravity acceleration and thermal expansion. However, accepting viscosity as constant is under question (Finkelstein et al., 2006). From numerous thermal measurements in wells follows that the behavior of dT/dz is not constant one (e.g., Huang et al., 2000; Eppelbaum et al., 2014). It should be taken into account in the further extension of this approach.

The purpose of this section was to demonstrate an ideal comparison in order to show the transition between controlling mechanisms with the increase of diameter (from BP to TIC). Following this comment, as well as the comment from Reviewer 1 regarding this analysis, we agree that indeed our comparison and assumptions were oversimplified (mainly that *dT/dz* and viscosity cannot be taken as constant). Therefore, we deleted the comparison paragraph that contained the invalid assumptions and left only the theoretical equations that can be used for a general discussion regarding the impact of the radius on both mechanisms (i.e., BP and TIC).

Obviously, an interaction between the near-surface targets and Earth's atmosphere has nonlinear character (e.g., Kardashov et al., 2000). It cannot be realized in the presented study, but can be reflected in future investigations.

We added to the discussion a clarification regarding this issue (section 3.4):"Moreover, some of the parameters presented in Eqs. (2) to (10) can exhibit nonlinear behavior (Kardashov et al., 2000), mainly *dT/dz*, which suggests that a comparison between sites is highly complex." (Page 10, lines 8-11). We thank the reviewer for the suggestion to implement this issue in further research, and we will take this into consideration in our next study.

I propose that after a small revision, this MS may be accepted for publication.