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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Consequences and mitigation of saltwater intrusion induced by short-circuiting during aquifer storage and recovery (ASR) in a coastal subsurface" *by* Koen Gerardus Zuurbier and Pieter Jan Stuyfzand

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Referee #2 (Anonymous) General comments This manuscript describes solute transport modelling to evaluate the processes that contribute to salinisation of recovered water from an ASR well, along with possible mitigation strategies. Notably, the recovery efficiency of this ASR system is constrained by an extremely tight limit for chloride concentration in the recovered water of 50 mg/L. The content of this manuscript is suitable for publication in HESS, however considerable revision is required to provide the reader with adequate understanding of the site and the evaluation. It should be noted

that this ASR system is not typical of ASR operations internationally. General editing is required to improve the fluency and precision of the language used in the manuscript; particular attention should be paid to improved use of technical descriptions (some examples are outlined in the specific comments below). While this paper stemmed from an unplanned activity (high salinity), the paper should be presented in an organised framework; the current version reads as a somewhat haphazard approach. Author's response: The authors agree that the current version reads somewhat like a 'haphazard' approach. In some way, the study was haphazard: it was never the intention to study the effect of short-circuiting on ASR. It was the intention to increase freshwater recovery upon aquifer storage, despite buoyancy effects, using the multiple partially penetrating wells. However, the authors feel that it is relevant to report failures and surprises during the use of ASR, which is now not always the case (page 2, line 28). To make sure the reader is able to understand and follow the set-up of the system and the operational/monitoring approach, a rather chronological set-up was chosen.

Please refer to the specific comments outlined below. Specific comments Page – Line - Comment 1 14 Suggest insert 'confined' into description of aquifers. Author's response: will be amended as such

1 14 And elsewhere. Suggest replacing 'saltwater' with 'brackish'. Author's response: This is a very common discussions among hydrologists in this field and related to universal definition of freshwater, brackish water, and saltwater. Following the frequently used classification by Stuyfzand (1993), brackish water is limited to water with Cl concentrations <1.000 mg/l. We propose not to amend this choice of word.

1 16 Explain 'properly separated' – the role of the confining layer should be made clear. Author's response: We agree with the referee. We propose to add further explanation here.

1 17 Suggest replacing SEAWAT with ' variable-density solute transport modelling (SEAWAT)'. Author's response: We agree with the referee and propose to amend this

as such

1 22 MPPW has not been defined. Author's response: We agree with the referee, MPPW should first be defined before using its abbreviation. This should be done in the same sentence.

1 28-30 Explain the role of the confining layer and why confined aquifers are targeted for storage. Introduce impact of inter-aquifer leakage. Author's response: We agree with the referee and propose to add this information in this first part of the introduction to highlight the importance of the confining layer in these applications.

1 28-30 First sentence needs revision to ensure it is relevant to content of manuscript –stormwater infiltration is also freshwater storage. Perhaps only include uses of confined aquifer for clarity. ASR is one managed aquifer recharge technique suited to storing fresh water in brackish aquifers. Author's response: It is a bit unclear what the exact point of the referee is here. We propose to replace 'Aquifers' by 'Confined and semi-confined aquifers'. Storm water infiltration is not necessarily storage, but rather 'disposal'. We suggest to combine this with brine disposal.

2 1 Over citation of Bonte – revise. Author's response: We found that the most recent and relevant work in this relatively new field was performed by Bonte, but can imagine to mention only the most relevant 2 of its papers.

2 Introduction Previous research on inter-aquifer leakage and modelling of recovery efficiency has not been adequately reviewed. Author's response: It is unclear to the authors which other literature is exactly meant here, but the authors are willing to extent the review of inter-aquifer leakage and RE.

2 5 Of what wells? All wells globally? Author's response: This concerns all wells worldwide. We suggest to add 'worldwide' after 'wells'

2 7 Soil fractures should be described as fractures (aquifer is not soil zone). Author's response: We propose to amend as such

2 18 Is it necessary to cite 3 Zuurbier papers? Expand review of literature as many others have stored freshwater in confined aquifer, a necessary reference is R.D.G. Pyne's Aquifer Storage Recovery: A Guide to Groundwater Recharge through Wells. Author's response: We propose to diversify the references here, amongst others by mentioning Pyne (2005) here as well (although it was already in line 31 of page 1 as well).

3 3 Suspect error in number, 270,000 not 270,0000. Author's response: Indeed, will be amended as such.

3 Method An overview of the hydrogeology is required. Suggesting moving section 3.1 to methods. Author's response: We have had similar considerations, but decided to put this in Section 3 as the geological characterization contains many newly obtained results. However, we agree that this may better suit in section 3.1.

3 Method A summary of ASR cycles is required. Suggest adding a table with dates, injection and recovery volumes for each ASR well. Author's response: We agree with the referee. Although the operations during the cycles are reported in Section 3, a summary of the ASR-cycles is welcome in section 2.

3 3-13 The reader needs to understand all characteristics of the site, such as aquifer targeted for ASR and for ATES, EC, Cl, SO4 concentrations for each aquifer and for roof runoff. Detail in text is not adequate. Author's response: We feel that we can give the reader the desired detail when we move Section 3.1 to the methods section, with a minor extension.

3 8 Need information about hydrogeology before describing the need for MPPW. Screen intervals for all wells should be given in text or table. Distance from ASR wells should be given for ATES and monitoring wells. 3 8 Give distance of ATES wells from ASR well, clearly identify new and old, suggest giving unique identifier (K3-a and K3-b) Author's response: The authors agree with the referee and are willing to provide this information

3 13 Give the chloride concentrations for each end-member and quantify the amount of mixing < Author's response: We agree with the reviewer and propose to add this information

14 1 The monitoring wells shown in Figure 2 have not been mentioned in the text. Author's response: We propose to add this information in the table requested by the reviewer

4 5 Give sampling frequency. Author's response: We propose to add the exact moments of sampling

4 6 Were stable field parameters also used to indicate adequate purging? Author's response: Yes, upon purging of each well, it was checked if all field parameters were stable. We will add this to information to this section.

4 16 Suggest replacing 'electronic recording' with 'continuous monitoring'. Author's response: We can see an improved clarity by implementing this suggestion and are willing to do so.

4 21 Suggest deleting 'In'. 4 21 Give some explanation of model choice. Author's response: We agree with the referee, this was a typo. We will also elaborate on the choice for SEAWAT (variable density, etc.)

4 21 Sentence requires editing, move 'to' to after Chiang 2012. Author's response: Indeed, a second typo in this sentence. Amended as such.

5 1 Replace 'te' with 'the'. Author's response: Typo, amended as such. 5 8 Justify choice of end-member concentrations; text should be more specific rather than general description. Author's response: We propose to add justification here, as proposed by the referee.

5 Overall The description of the modelling method could be improved by stating a set of clear aims for the modelling. Author's response: The authors agree that the reader should be taken by the hand in this section by elaborating on the modelling aims and

propose to add the following: 'Groundwater transport modelling was executed to validate the added value of the MPPW set-up under the local conditions. In the later stage of the research, the groundwater transport model was used to test potential pathways for deeper groundwater to enter the target aquifer and explore the characteristics of a potential conduit via scenario modelling. Correction for groundwater densities in the flow modelling was vital, due to significant contrast between the aquifer's saltwater and the injected rainwater.'

6 Table 1 Suggest removing VANI heading. Suggest adding more detail to show properties of each layer. Author's response: The authors feel that the table (including VANI) provides the relevant characteristics of the model layers. VANI can be replaced by reporting the Kv in this column

7 Table 2 Suggest replace 'infiltration' with 'injection'. Author's response: For the sake of clarity, we tend to use 'infiltration' instead of 'injection' since the system does not directly pump the water into the aquifer, but to a 4m high standpipe. This standpipe is connected to the ASR wells. The water therefore 'infiltrates' (rather slowly) in to the aquifer. The reader may have a more 'violent' perspective of infiltration

7 26 'close by' is vague, be specific. Author's response: The authors agree and propose to replace 'close by pumping test' by 'a pumping test at approximately 500 m from the ASR wells,'

7 Section 3.1 As mentioned previously, suggest moving to methods. Author's response: The authors agree, as indicated.

9 2 As mentioned previously, give summary of ASR cycles in Table. Author's response: The authors agree, as indicated.

9 Figure 5 Discussion on mixing is based on Cl, but you are showing EC in Figure. Suggest plotting EC, Cl and SO4. Author's response: We thank the reviewer for this suggestion. However, the reason to plot the EC here is the extremely high frequency

of the analyses, which give far more information that the regularly measured

9 Figure 5 Suspect part a y-axis should be volume not EC. Author's response: Indeed, the authors will amend the title on this axis (correct = pumped volume (m3)

9 2-8 Give reader more detail, explain that mixing would be expected on fringe of injected bubble and therefore become evident toward end of recovery cycle. Author's response: The author realize that in this section somewhat more information on what was expected, such that the reader can better understand the deviations and are willing to add this information.

9 2-8 Explain the freshening process in monitoring wells before describing salinisation during recovery. Author's response: The authors agree, this also relates to the previous comment.

10 10 Were any other tracers used to identify leakage? Age tracers? Author's response: As indicated in the Methods Section, only macrochemical analyses were performed. Especially SO4 showed to be a good tracer, followed by HCO3 (which however had a much lower contrast. Na amendments suggested.

17 Table 4 Recovery of 10018 Author's response: It is unclear to the authors what is meant by the reviewer here.

11 Have the authors considered the economic feasibility of such a scheme? Interception of a significant volume of water must lead to significant pumping costs. What is the driver for such a scheme? Author's response: Up to now, an extensive evaluation of the costs of this scheme has not been executed. However, it is known that due to low price of electricity in The Netherlands, this impact will be limited.

23 16 Bonte et al 2014 not cited Author's response: Citation removed. This reference incidentally ended up in the reference section.

References Some editing required, script errors evident for CO2. Author's response: This was due to some problems with Endnote and the desired format of HESS. Will be

corrected.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-343/hess-2016-343-AC2-supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-343, 2016.