HESS-2016-120 Revision report

"A meta-analysis of groundwater contamination by nitrates at the African scale" by Issoufou Ouedraogo and Marnik Vanclooster,(2016)

Dear Dr Editor,

We addressed all technical corrections for Anonymous Referee#2 as requested. We thank Anonymous Referee#2 for his positive and critical appreciation of our manuscript. Dear Anonymous Referee#2, please find below a point-by-point revision report, along with the revised manuscript for your consideration. We have highlighted (blue colour) the sections in the manuscript which have been amended or re-written.

Overall, this is a thorough and well-thought-through evaluation of nitrate contamination of groundwater using a comprehensive modeling and literature review approach. I support its publication with minor revisions, largely focused on minor issues and lack of consistency in grammar use. I think of one of the key strengths of this manuscript is the solid and relatively rare linkage between the developed model and field-based (i.e., easily attainable in the field) data characterising NO3 pollution.

Itemised points:

-there are minor grammatical errors throughout; the manuscript is easily readable but not fully correct. Please have a native English speaker proof-read prior to final submission.

Response: We thank Anonymous Referee#1 for his constructive general comments. The English language was checked, but will further be improved through the HESS editing process (providing systematic language checking for all manuscripts).

- define all acronyms and use consistently.

Response: We present a list of acronyms at the end of the manuscript (see P16 L590-601):

BGS: British Geological Survey
DEWA: Division of Early Warning and Assessment
DRASTIC: Depth, Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, Conductivity
FAO: Food and Agriculture Organization (United Nations)
OECD: Organization for Economic Cooperation and Development
MODFLOW: MOdular finite-Difference Flow model (U.S. Geological Survey)
UNEP: United Nations Environment Programme
UNESCO: United Nations Educational, Scientific and Cultural Organization
US EPA: United States Environmental Protection Agency

-The literature review is admirably thorough, supporting the case. - The authors use fair and logical limitations on the data selected/used. - What does 'risk' describe in Fig. 3? How is 'risk' defined, per reader (and reviewer) understanding?

Response: We defined the "risk" in the text as follows (see P5 L173-178).

The groundwater pollution risk corresponds to the potential of a groundwater body for undergoing groundwater contamination (Farjad et al., 2012). The risk of pollution is determined both by the intrinsic vulnerability of the aquifer, which is relatively static, and the existence of potentially polluting activities at the soil surface. These latter activities are time dynamic and can be controlled (Saidi et al, 2010). We generated the groundwater pollution risk map by combining the intrinsic groundwater vulnerability map with the land use map, using the additive model of Secunda et al. (1998). Details of these procedure are given by Ouedraogo et al. (2016).

– The authors have done an intensive analysis of the data provided via available literature. - Are nitrates naturally more abundant in specific geologic formations? If so, please include detail.

Response: We addressed this remark in P12-13, L458-464.
"Geologic nitrogen" was first recognized by Boyce et al., (1976) as nitrogen associated with certain formations, sedimentary and inorganic in origin. Holloway and al., (1998), investigated the contribution of bedrock nitrogen to high nitrate concentrations in stream water. They conclude that the weathering of nitrogen from rock can potentially affect the chemistry of water and soil. We cited in the revised manuscript the main conclusions of the study of Tredoux and Talma, cited in Xu and Usher, (2006):

- In most cases, the occurrence of high levels of nitrate is due to contamination related to anthropogenic activities.
- Geological formations can only serve as a primary source of nitrogen in exceptional cases where contamination ions are incorporated in rock minerals to be released by weathering and oxidized to nitrate.
- The apparent correlation between the occurrence of high nitrate levels and certain geological formations is due to secondary characteristics of the geological formation and associated factors allowing enrichment with nitrate derived from others sources.

The authors affirms that nitrate originating from anthropogenic sources is the major problem. In this regards, we can conclude that nitrate in specific geologic formations has a relative weak contribution to nitrate in groundwater, but, rather anthropogenic activities. We can classify the question of the Reviewer#2 in the same category of unsaturated zone denitrification process and nitrate accumulation in the unsaturated zone asked by the Reviewer#1. We addressed to this comment to the reply for Reviewer#1.

- p. 14; the range of NO3 goes from 0 to 4625 mg/L for min and max.; this is a large range (as an aside, per the supporting text, max and min definitions need to be reversed). 1) std. dev. Values should be included. 2) with this range of max and min, why is the avg. so low (27 mg/L)? The std. dev. for these data are needed to support.

Response: Maximum and minimum in the text in page 14 were reversed. 1) The standard deviation and the range of minimum and maximum were included in the text. The value 27 mg/L is the median for the mean nitrate concentration category. This was an error in the initial manuscript. We checked and correct this. We added the standard deviations for all data in the text (See P15, L550-555).

"The mean nitrate concentration varies between 1.26 to 648 mg/L. The sample mean of this mean nitrate concentration was 54.85 mg/L, its standard deviation was 89.91 mg/L and its median was 27.58 mg/L. The minimum nitrate concentration varies between 0 to 185 mg/L, while the maximum concentration varies 0.08 to 4625 mg/L), the sample mean of the minimum and maximum concentrations were 8.91 mg/l and 190.05 mg/L, while the sample standard deviations were 23.17 mg/L and 428.69 mg/L and the medians were 0.55 mg/L and 73.64 mg/L respectively."

- There is a general lack of consistency in hyphen use throughout (e.g., Pan-African vs Pan African vs African). Please be consistent.

Response: We checked and we eliminated all terms of "Pan-African", "Pan African". We use "the African scale" only in the revision manuscript.

- The importance of nitrate pollution is solidly presented. Can a brief discussion be included in the conclusion on how this issue can be addressed and/or alleviated?

Response:

The range of literature papers presented in our study illustrates the pollution problem at the continental scale. Our paper does not have the ambition to discuss the remediation problem. In order to keep the focus (the paper is already very lengthy), we propose not to include a discussion on the nitrate remediation problems in our manuscript. However, for the sake of the reviewer, we give some ideas below.

Groundwater protection and alleviation at the pan African scale is not optional. Remediation should be developed at the regional scale. The solutions that can be proposed to mitigate and improve the situation were already partially addressed by Xu and Usher, (2006):

i. Political will: Because, groundwater quality protection is closely related to the government policy towards economic development and the political will for sustainable development and utilisation of resources. Our study may increase awareness of AMCOW (African Ministerial Council on Water) to proceed with groundwater protection programs at the Pan African level.

ii. Capacity building and technical skills: Africa, has little capacity to challenge groundwater degradation and there is a need to boost this capacity through appropriate capacity building programs.
iii. Knowledge dissemination: Awareness of groundwater resources in Africa is low. There is a need to improve the knowledge on groundwater systems for decision makers and for the broader public. Our paper may contribute to the increase of groundwater awareness.

In addition to these 3 points in above, we think that African decision-makers must elaborate groundwater protection programs that are based on groundwater monitoring and data management. Such programs can be boosted through multilateral organisation such as the African Groundwater Commission or SADC, ECOWAS, the Nubian Aquifer Regional Information Systems (NARIS), The North Western Sahara Aquifer System (NWSAS) (better known under the acronym SASS for its French name "Système Aquifère du Sahara Septentrional").

References cited

Boyce, J.S., Muir,J., Edwards, A.P., Seim, E.C., and Olson, R.A., Geologic nitrogen in Pleistocene loess of Nebraska. Journal of Environmental Quality. Vol. 5 No. 1, P. 93-96., 1976.

Farjad, B., Mohamed, T., A., Wijesekara N., Pirasteh, S., Shafri, H. Z. b. M.: Groundwater intrinsic vulnerability and risk mapping. Proceedings of the ICE - Water Management, 165(8), 441-450., 2012.

Holloway, J.M., Dahlgren, R.A., Hansen, B., and Casey, W.H.: Contribution of bedrock nitrogen to high nitrate concentrations in stream water. Nature, Vol.395. P.785-788., 1998.

Ouedraogo, I; Defourny, P; Vanclooster, M.: Mapping the groundwater vulnerability for pollution at the pan African scale. Science of the Total Environment, 544, 939–953,(December 2015).,2016.

Saidi, S., Bouri, S. and Ben Dhia, H.: Groundwater vulnerability and risk mapping of the Hajeb jelma aquifer (Central Tunisia) using a GIS-based DRASTIC model. Environmental Earth Sciences, 59(7), 1579-1588., 2010.

Secunda, S., Collin, M., &Melloul, A. J.:Groundwater vulnerability assessment using a composite model combining DRASTIC with extensive land use in Israel's Sharon region. Journal of Environmental Management, 54, 39–57., 1998.

Xu, Y. and Usher, B.: Groundwater pollution in Africa, Taylor&Francis/Balkema, The Netherlands. 353pp., 2006.