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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Global Phosphorus Recovery for Agricultural Reuse" *by* Dirk-Jan D. Kok et al.

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That authors would like to thank Dr. Yuan for his insightful messages on how to improve on the article. In the below, we would like to share our thoughts with regards to some of the presented concerns.

1. The referee remarks that the manuscript lacks an essential definition of what is understood as 'phosphorus wastes' in section 1.1.

In this study, we investigate the potential in partially meeting the agricultural phosphorus demand by recovering the phosphorus: i) discharged by humans through wastewater, and ii) excreted by animals through manure/liquid wastes. 'Phosphorus waste' by that definition is limited to only that which is produced by humans as accumulated in

wastewater streams, and that which is excreted by animals. The referee has made a very valid remark that this essential definition is missing. A more refined definition will be added in revised version of the article.

2. The referee claims to be confused about the methods used in determining global market price of phosphorus - as resulting largely from a lack of definition in the manuscript on exactly what product prices are evaluated for.

In the study, all prices (unless mentioned otherwise) are in U.S. dollars per tonne of elemental phosphorus: [$ t-1] P. We tried to avoid presenting the prices in terms of [$ t-1] phosphate rock, chemical fertilizer, struvite, or other forms of phosphorus (e.g. phosphate (PO4)), so as not to confuse the reader and to make price estimates between the different products comparable. Even though, therefore, there are different products acting in the same phosphorus market, the model and actors judge the value of these products based only on the amount of absolute P in their contents, i.e. as [$ t-1] P.

3. The referee remarks that 'phosphorus throughput rate' is not well defined with regards to formula (1) and that the recovery efficiency depends on the treatment technologies and collected rates (and other factors). The referee recommends to define and explain the production density definition and formula more clearly.

The authors recognize that, indeed, 'phosphorus throughput rate' is not well defined. In the study, 'phosphorus throughput rate' is presented as the kilograms of phosphorus per head, per year [kg h-1a-1] each organism of group O (human, cattle, poultry, swine), 'produce'. Since phosphorus is not 'produced' by organism, only consumed and excreted, the yearly amount of phosphorus excreted per head ([kg h-1a-1] P), is defined as the phosphorus throughput rate. This, or at least similar, definition will be included in the revised version of the article.

Furthermore, the recoverable amount indeed varies significantly with the composition of wastewater and manure. It is one of the major generalisations made in this study

that, for example, only 20% of phosphorus inflow into wastewater treatment facilities can be recovered via struvite precipitation. We will ensure that these and other related assumptions are presented in a comprehensive overview, e.g. in a table, and that these definitions are well explained in the revised version of the manuscript.

4. The referee remarks another issue with regards to a lack of definition for the 'phosphorus demand density'.

In the study, the phosphorus demand density is defined as the phosphorus which a crop patch requires in a year, and is expressed as tonnes per square kilometer [t km-2]. It further assumes no change in soil stored P. Therefore the total phosphorus demand per area is largely defined by the crop harvested area and how much phosphorus the crop requires per harvest as defined by FAO fertilizer manual. Furthermore, it does not include the phosphorus demand of any grazing animals or such. We will make sure to adequately define and describe these terms in the revised version of the article.

5. The referee remarks that in the section 2.2 phosphorus content is treated as only that which is found in wastewater and therefore does not include that found in solid wastes.

This study only focuses on the recovery of phosphorus from wastewater and therefore disregards any recovery potential of phosphorus from solid wastes. This is never explicitly defined as such, and therefore the confusion is understandable. In the revised version, we will be sure to define phosphorus waste in the introduction, as in accordance to point 1.

6. The author remarks to be totally confused about the trade model, and emphasizes that, to his best knowledge, phosphorus wastes are more suitably recycled locally and cannot be traded at global scale.

Firstly, we regret that we have not been able to explain the model adequately and will review our explanation of the model setup in the revised version of the manuscript.

Secondly, we believe our work shows that international trade in recovered phosphorus is feasible, just as international trade in chemical phosphatic fertilizers is feasible. In many ways, recovered phosphorus is similar to mined phosphorus. They both incur extraction costs, processing costs, and transportation costs. These costs determine the scale at which trade is feasible. Recovered products have a competitive advantage over mined products, as wastewater is almost everywhere where people are, while natural reserves are concentrated in few areas of the world (see Figure 1). Additionally, recovering phosphorus from wastewater can (depending on the wastewater treatment facility) lead to reduced operational costs (regardless of the sale of the product) thereby allowing these facilities to offer recovered products practically for free (as in The Netherlands). Indeed, however, because transportation cost plays an important role, our model also shows that most trade does occur locally/regionally, confirming the referee's intuition.

7. The author states that resolving the issues mentioned above will change the results entirely, requiring a new analysis and discussion of the implications.

We intend to review and revise the article in response to the comments of the referee. However, since most of the issues identified by Dr. Yuan pertain to (a lack of) definitions, we do not expect that it will change the results significantly.

8. The referee recommends to delete figure 1 (we assume, as the figure number is not specified) from the manuscript considering it presents basic data. Furthermore the referee regards Figure 2 to be confusing, wondering what is meant by phosphate rock; the production, the use or consumption, theoretic demand, or supply capacity? The referee further suggests to move the figure 3 and figure 4 to supporting information.

We thank the referee for the comment. Figures 1 and 2 were included in the introduction of the manuscript to contextualize the phosphorus market by highlighting and illustrating some of the important spatial (figure 1) and temporal (figure 2) aspects of the market. Figures 3 and 4 are integral model results for those interested in the market

potential of recovered phosphorus. We therefore intend to keep the figures as such.

9. The referee concludes that 'the english expressions need to be polished so as to make it more understandable with scientific basis'.

The authors recognize that the language can be adapted into a more scientific form and will polish the English in the revised version of the manuscript.

We would like to thank the referee for the feedback. We hope to adequately address the issues identified by Dr. Yuan to improve the manuscript and the study as a whole. We would be grateful to receive additional feedback, when and if it comes to mind.

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