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Clearing the fog on phosphate rock data – Uncertainties, fuzziness, and misunderstandings

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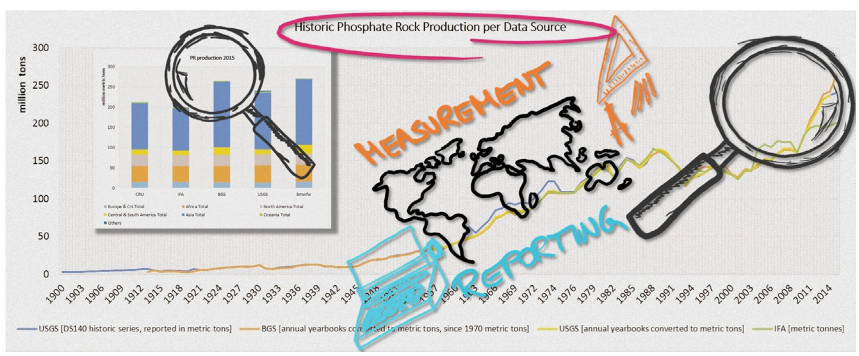
HIGHLIGHTS

- There are massive data discrepancies in global-production data for recent years.
- Conversion of all phosphate figures to a common base like 100% P_2O_5 reduces errors.
- Important policy-making processes must be aware of the present data discrepancies.
- We call for a global, independent agency to collect and monitor phosphorus data.

GRAPHICAL ABSTRACT



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ABSTRACT

Big Data, *blockchains*, and *cloud computing* have become ubiquitous in today's mass media and are universally known terms used in everyday speech. If we look behind these often misused buzzwords, we find at least one common element, namely data. Although we hardly use these terms in the “classic discipline” of mineral economics, we find various similarities. The case of phosphate data bears numerous challenges in multiple forms such as uncertainties, fuzziness, or misunderstandings. Often simulation models are used to support decision-making processes. For all these models, reliable and accurate sets of data are an essential premise. A significant number of data series relating to the phosphorus supply chain, including resource inventory or production, consumption, and trade data ranging from phosphate rock to intermediates like marketable concentrate to final phosphate fertilizers, is available. Data analysts and modelers must often choose from various sources, and they also depend on data access. Based on a transdisciplinary orientation, we aim to help colleagues in all fields by illustrating quantitative differences among the reported data, taking a somewhat engineering approach. We use common descriptive statistics to measure and causally explain discrepancies in global phosphate-rock production data issued by the US Geological Survey, the British Geological Survey, Austrian World Mining Data, the International Fertilizer Association, and CRU International over time, with a focus on the most recent years. Furthermore, we provide two snapshots of global-trade flows for phosphate-rock concentrate, in 2015 and 1985, and compare these to an approach using total-nutrient data. We find discrepancies of up to 30% in reported global production volume, whereby the major share could be assigned directly to China and Peru. Consequently, we call for a global,

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independent agency to collect and monitor phosphate data in order to reduce uncertainties or fuzziness and, thereby, ultimately support policy-making processes.

1. Introduction

The essentiality of phosphorus (P) is known and beyond doubt (e.g., Mew et al., 2018; Scholz and Wellmer, 2018). Phosphate rock (PR) is almost exclusively the primary source for modern-day chemical phosphate fertilizers (PF). It is produced practically entirely by mining considerable, igneous and higher concentrated sedimentary phosphate rock deposits. Given that these deposits are finite, we face the challenge of utilizing this unsubstitutable resource in a way that encourages sustainable development as well as intra- and intergenerational fairness.

Short-, mid-, and long-term strategies for sustainable phosphorus management often rely on quantitative models to support decision-making. Therefore, policy-makers repeatedly seek support from experts and consultants from science and/or practice. Independent of the type of model or approach, a reliable and accurate set of data is an essential premise. In particular, this has often proven to be the crux of the problem, especially in regard to global data such as production, consumption, or trade. Whereas private consulting firms often rely on their own primary data, scientists usually depend on access to (fee-based) databases provided through their universities or publicly available data from national geological surveys. Depending on the type of data required, data analysts and modelers must often choose from various available sources. Particularly if data outside their scope of expertise is needed, precise data selection might present a difficult and challenging task. One of the most prominent examples of using a wrong set of data in P research is that of the proclaimed "peak phosphorus" (see Box 1), which was based on a scientific misconception of the Hubbert Curve (e.g., see Scholz and Wellmer, 2013a, 2013b; Steiner et al., 2015; Wellmer and Scholz, 2016), where reserve data was used as a wrong proxy for the unknown URR (ultimate recoverable resources) data that was actually needed.

A significant number of data series relating to the phosphate supply chain are available (e.g., reserve/resource levels, capacity for production, production, imports, exports, and consumption of phosphate rock, phosphoric acid, phosphate fertilizers, and non-fertilizer products). Some of the data are in the public domain; some are held by companies for internal use; and other data are held by member-only organizations. In several cases, a degree of communication exists between these various data-collecting groups, but at the same time, there are often significant differences between data from various sources.

With this manuscript, based on a transdisciplinary orientation that focuses not only on science but also on practice, we aim to help peers from all fields by illustrating quantitative differences between reported data. Furthermore, we analyze and point out differences and inconsistencies from different publically available and subscription-based data sources in accordance with our guiding question:

What challenges (e.g., uncertainties, fuzziness, misunderstandings…) do we face when working with phosphate supply chain data?

To elucidate the question above, we derive the following three sub-questions:

- What is the magnitude of discrepancies (i.e., differences) in global marketable phosphate-rock data across major data sources/suppliers over time and particularly in the most recent times, and why do these occur?
- How can we address the complexity of the overall P supply chain when working with phosphate data?
- What are the potential implications of misuse or misunderstanding when working with phosphate supply chain data?

Section 1.1 provides a brief theoretical background on measurement in general, followed by a comprehensive overview of fundamental knowledge on mineral data and especially phosphate data. Sources/publishers for the latter are encompassed to a certain degree within the second section. The centerpiece of the work is addressed in the analysis section, where differences in global marketable PR concentrate (PR-M) production data are analyzed beginning in 1900, with an emphasis on the most recent data (2015 is the latest year for which we could retrieve complete production data sets). A further section on global grade distributions highlights the vast differences of ore characteristics. An additional sub-section provides a comparison of global phosphate trade for the years 1985 and 2015. The paper is concluded with an extensive discussion and outlook for further research.

Box 1
The myth of "peak phosphorus".

The Myth of Peak Phosphorus (potential price implications)

Déry and Anderson (2007) were the first to introduce the peak theory in relation to the commodity phosphate rock, coining the phrase "peak phosphorus." Based on two examples (the US and Nauru Island), they argued that the application of a Hubbert curve would also work for the global PR market. Their main conclusions were that i) peak phosphorus had already taken place in 1989; ii) the production of PR was declining at the time of their writing; and iii) the global URR was estimated at 8,000 MMT.

Thus, we can see that there are fundamental misconceptions within the model, given that i) the alleged peak in the late 1980s was followed by a decline due to the dissolution of the Soviet Union. Production capacities today (257.9 MMT, CRU International, 2013) are well above the levels of 200.5 MMT in 1989 (Stowasser, 1989), and this also holds true for ii). Their final estimation iii) of a URR of 8,000 MMT is also a fundamentally incorrect assumption; up to the present time, we may have consumed somewhere in the region of 7,000 MMT of phosphate rock reserves (Mew, 2011). The most recent USGS data show remaining reserves of 70,000 MMT, and resources are quoted at "more than 300 billion tons" (Jasinski, 2018, p.123).

Based on great practical experience in the field, Mew (2011) proposed a different theory, namely "Plateau Phosphorus." In short, he agrees with the concept of increased production up to the middle of the century, but instead of a peak with a decrease in production, he argues for a more or less constant plateau. His theory is based on slowing population growth, as well as a slowdown in demand for per capita meat consumption as the developing countries will have met a fairly high level of caloric consumption by then. This slow increase will be compensated by efficiency improvements in phosphate production and agriculture.

The necessity to incorporate the dynamics as well as the overall life cycle of raw materials, increasing globalization leads to the observation that, most of the time, value-producing processes and uses take place in developed countries, whereas potentially hazardous impact processes in the form of mining and disposal take place in developing countries. At least for the case of PR, we see an increasing trend toward downstream facilities close to mining sites (Mew, 2016).