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WORKING PAPER
Phosphorus, Human Rights, and Distributive Justice

ABSTRACT: Phosphorus (P) is an important nutrient to humankind. Yet, phosphate-rock resources are finite and non-sustainable P use causes environmental damage including eutrophication of water bodies and soil contamination with heavy metals, thus bearing risks for human health. Based on an analysis of empirical facts, this article discusses normative questions of P use, e.g. how to balance different freedom rights, how to manage a finite and globally unevenly distributed resource, and how to deal with environmental contamination and risks for human health. Furthermore, it is shown that P use is strongly interlinked with other major ecological challenges. From the normative point of view, colliding human rights and balancing rules do not provide a clear yardstick how fast P loss reduction and establishing P cycles (also based on intensified P recycling) have to occur. In any case, various arguments support increased substitution of phosphate rock with secondary raw materials to provide access to P for all people worldwide in the short and long term.

Keywords: phosphorus – distributive justice – human rights – governance – environmental law – economic instruments – fossil fuels – livestock products

1. Introduction

The environmental debate in law and philosophy very often focuses on climate change while the other planetary boundaries tend to get out of sight. For instance, Phosphorus (P) is essential for food production and therefore directly connected to achieving global food security (Asimov 1959; Panagos et al. 2022; Nedelciu 2020; Leinweber et al. 2018; Schoumans et al. 2015). Worldwide, the P supply of soils varies considerably. While in the global south, many soils are undersupplied with P, agricultural soils, e.g., in Western Europe are regularly well-supplied or even oversupplied due to years of stock fertilization or high livestock densities (Panagos et al. 2022; Tóth et al. 2014; Stubenrauch et al. 2018; Kahiluoto et al. 2021). Although peak P is not expected in the near future, the resources of phosphate rock are limited to a few world regions (United States Geological Survey 2022; Jupp et al. 2021; Jama-Rodzeńska 2021) so that most states in the world are highly dependent on P import and face the risk of supply shortages (Nedelciu et al. 2020, Nanda et al. 2020; Vaccari et al. 2019). Currently, as a result of the Russian invasion of Ukraine, the import dependency of the EU from fertilizers and input factors for fertilizer production puts the EU agricultural sector under pressure (European Commission 2022). Apart from that, the remaining, predominantly sedimentary phosphate-rock deposits are increasingly contaminated with (radioactive) heavy metals and thus bear environmental and health risks (Bracher et al. 2021; Gray et al. 2020; Kratz et al. 2016; International Resource

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Panel 2019; Khan et al. 2018). Furthermore, mining and processing phosphate rock to P fertilizers leads to high amounts of greenhouse gases and contamined production residues such as phosphorgypsum (Nedelciu 2020; International Resource Panel 2019). However, there is generally a high substitution potential for rock phosphate with recycled P from waste streams or organic P fertilizers that can be both, animal-derived or plant-based (Mayer/Kaltschmitt 2022; International Resource Panel 2019; Roy 2017).

Thus far, P is predominantly used inefficiently, and global and regional P cycles are disrupted (Jupp et al. 2021; Schoumans et al. 2015; Sharpley et al. 2015). In particular, intensive livestock-farming systems contribute substantially to open P and also nitrogen (N) cycles (Garske/Ekardt 2021; Weishaupt et al. 2020; Lun et al. 2018; Metson et al. 2012). Intensive fodder production requires input of agrochemicals including mineral P fertilizers. At the same time, high livestock densities lead to the accumulation of manure, causing P (and N) hotspots in soils. Local nutrient hotspots promote P losses into water bodies which in turn cause eutrophication of sensitive aquatic ecosystems and thus risks of biodiversity loss and greenhouse gas emissions (Mayer/Kaltschmitt 2022; Bloem et al. 2020; Beaulieu/DelSontro/Downing 2019; Schindler et al. 2016). However, discussions on nutrients often disregard that they are also related to the use of fossil fuels. Inter alia, the aim to phase out fossil fuels in line with the Paris Agreement interconnects strongly with fertilization problems. In particular N production is very energy-intensive, but also the steps of the P fertilizer value chain require energy, i.e., extraction, production, transportation and application of P fertilizers (Sutton et al. 2011; Smith et al. 2020; Kyriakou et al. 2020; Garske/Ekardt 2021; Europeam Commission 2022). In general, fossil fuels and animal husbandry (and the use of pesticides) are the main drivers of manifold global environmental issues (Intergovernmental Panel on Climate Change 2022; Intergovernmental Panel on Climate Change 2019a; Intergovernmental Platform on Biodiversity and Ecosystem Services 2019; Weishaupt et al. 2020; Kachi et al. 2021; Grossi et al. 2021; Garske/Ekardt 2021; Ahlström and Cornell 2018; Leinweber et al. 2018; Rosemarin and Ekane 2016; Iwaniec et al. 2016).

Having said all this, on the one hand there is a source problem with regard to limited and unevenly distributes resources of phosphate rock. On the other hand, there is a sink problem with regard to excess P in water bodies (Panagos et al. 2022; Mayer/Kaltschmitt 2022; Jupp et al. 2021; Jama-Rodzeńska 2021; Haque 2021) and regarding soil contamination by heavy metals from mineral P fertilizers as well as toxic waste resulting from the production process of these fertilizers (Bracher et al. 2021; Nedelciu 2020; International Resource Panel 2019; Kratz et al. 2016). There is thus a clear call for action to close P cycles, to prevent local supply bottlenecks for P, to avoid nutrient hotspots, environmental pollution and health damage (Leinweber et al. 2018). This requires policy instruments which address these challenges effectively (Rosemarin and Ekane 2016; Iwaniec et al. 2016; Stubenrauch et al. 2018; Garske et al. 2020; Garske/Ekardt 2021) as a more sustainable P management is a matter of integrated agricultural concepts and their governance (European Commission 2020; Stamm et al. 2022).

The open question, however, is which goal for P should be pursued at all. This normative yardstick for P management and P governance has hardly been discussed scientifically and politically so far – unlike, for example, in the field of climate or biodiversity. This article asks for P standards by means of a legal interpretation based on an analysis of human rights as universal liberal-democratic basic principles, given that there is a lack of specific and legally-binding P objectives in environmental or agricultural law. To develop these overarching standards, various normative questions have to be addressed, e.g. how to balance different freedom rights, how to manage a finite and globally unevenly distributed resource, and how to deal with environmental contamination and risks for human health. Before that, methodology is explained and the basics of P governance recapitulated to clarify the context of the normative standard sought.

2. Background for Normative Analysis: Phosphorus in Human Sciences – Targets, Anthropology, Governance

The effectiveness of policy instruments can only be assessed against specific policy objectives – otherwise there are no reference values. This is why a normative analysis on P as it is conducted in the present article is needed. As regards environmental governance in general, international environmental law provides overarching, legally binding objectives especially in Art. 2 para. 1 Paris Agreement (PA) that aims at keeping global warming to well below 2 degrees Celsius, or even better 1.5 degrees Celsius, above pre-industrial levels and the Aichi Targets to the Convention on Biological Diversity (CBD) that aim at halting biodiversity loss (in the future – as far as a ratification takes places – further concretized in the Kunminig-Montreal Global Biodiversity Framework). Meeting these targets with a high probability requires zero emissions, zero fossil fuels in all sectors and drastically reduced livestock farming worldwide by 2035 – assuming no technologically unproven, potentially high-risk geoengineering (Ekardt/ Bärenwaldt/ Heyl 2022; Biermann et al. 2022; European Commission 2020; Wieding et al. 2020; Smith et al. 2020; Kyriakou et al. 2020; Intergovernmental Panel on Climate Change 2019b). This implies comprehensive changes for agriculture generally and P management specifically, although a quantifiable international political target for P use in agriculture is missing in environmental and agricultural law and it is difficult to justify such a goal, which is discussed in Chapter 3.

Methodologically, the empirical background on policy instruments is based in a qualitative governance analysis in this article to examine the effectiveness of existing and potential future governance instruments, taking into account human bevaviour and typical governance problems. Primarily, the article focuses on the legal interpretation of human rights with regard to normative standards for P use that may be derived. Legal norms are interpreted grammatically, systematically, teleologically, and historically. This means according to their literal meaning, their relation to other legal norms, their purpose, and their evolution. Regarding the epistemological background, legal interpretation is – like ethics – normative science, not empirical science; law and ethics make statements of ought rather than statements of being. Therefore, legal interpretation as such does not require collecting data or case studies (Ekardt et al. 2022). As regards the underlying P-related facts from natural sciences and governance research, the article builds upon our earlier research (e.g., Garske/Ekardt 2021; Garske et al. 2020; Stubenrauch et al. 2018) and recent international research on P of various disciplines (e.g., Panagos et al. 2022; Mayer/Kaltschmitt 2022; Stamm et al. 2022; Zou et al. 2022; Jupp et al. 2021; Jama-Rodzeńska 2021; Haque, 2021; Bracher et al. 2021).

The effectiveness of policy instruments can to a large extent only be assessed by considering behavioural motivations of humans. In particular, behaviour-related sciences such as economics, sociology, psychology, ethnology, cultural studies and sociobiology (Ekardt 2019; Stoll-Kleemann and O'Riordan 2020) shed light on the question, how far, e.g., politicians, farmers, the fertilizer and food industry and consumers are sincerely interested in avoiding detrimental environmental effects of P use in agriculture. This motivation analysis highlights typical governance problems, which have to be prevented by effective policy instruments (Ekardt 2019; Paul et al. 2019). Importantly, sustainability issues including P use in agriculture are partly (and sometimes even entirely) quantity problems: Optimising individual actions, plants, or products is therefore insufficient. Instead, minimising certain emissions or resource consumption completely is necessary. Before this background, a distinction can be made between command-and-control (CaC) instruments such as threshold values or prohibitions which address individual actions, products or plants, and economic policy instruments (EI) such as cap-and-trade schemes and taxes, which (the most obvious in case of caps) address absolut quantities. Typically occurring governance problems that result from focussing only on individual actions like CaC include enforcement deficits (Kachi et al. 2021; Ekardt 2019; Paul et al. 2019; Kanter et al. 2020), problems of depicting (Paustian et al. 2019; Ekardt et al. 2020), rebound effects (reducing, e.g., the average nutrient input 'per plant' does not prevent increasing the overall input of nutrients, for instance due to an extended agricultural production: Ekardt 2019; Kanter et al. 2020), and shifting effects: Shifting of activities or their consequences can occur from one place/ region/ country to another; from one sector to another, or from one environmental challenge to another, i.e., by addressing only one environmental problem thereby worsening another problem (Ekardt 2019; Ekardt et al. 2020; Weishaupt et al. 2020). For example, governance instruments to reduce fertilizer use locally in one country (or within the EU) might lead to a transfer of agricultural production abroad. A regional or local minimization of fertilizer use is thus prone to shifting effects, without guaranteeing an absolute resource use reduction globally.

In sum, the motivational analysis suggests that voluntary instruments are not very promising (Stubenrauch et al. 2018; Ekardt 2019). Moreover, in contrast to arguments of earlier research (Kanter et al. 2020), intervening at many points in the production chain appears ineffective. Complex CaC regulations tend to intensify enforcement deficits and problems of depicting as well as shifting effects and as such cannot bear the main burden of governance. Instead, it is important to address easy-to-grasp governance units to avoid enforcement deficits and problems of depicting. Two possible overarching control parameters are the main drivers of various environmental challenges: fossil fuels and livestock product. Therefore, policy interventions which directly target these drivers and intervene at the first trading level with a small number of addressees seem very promising. Environmental problems including P-related issues that cannot be solved by regulating fossil fuels and livestock farming, require complementary policy interventions. To avoid shifting effects and enforcement problems, policy instruments should be implemented on a broad geographical and sectoral scale, preferably at the international level, or the transnational level like the European Union (Ekardt 2019). To this end, a cap-and-trade scheme could target the easy-to-grasp governance units such as fossil fuels and livestock farming with absolute caps for all sectors and as many participating countries as possible. Cap-and-trade schemes induce resource scarcity and thus make certain actions more expensive for end consumers. As soon as the cap zero is reached, cap-and-trade schemes have the effect of a total ban. Having a broad sectoral and geographical scale and an absolute cap, cap-and-trade schemes not only avoid spatial and sectoral shifting effects but address various motivational factors such as self-interest and concepts of normality. Furthermore, an absolute cap avoids price elasticity issues of consumer demand.

Fossil fuels could be addressed by a cap-and-trade scheme at the first trade level, i.e., the initial distributing companies, with a cap zero to be met within two decades (Ekardt 2019; Coria and Jaraitė 2019). The EU Emissions Trading Scheme (EU ETS) is such a policy instrument which is already implemented. However, unlike in the EU ETS, *all* fossil fuels have to be included, old certificates have to be removed from the market, and the cap has to be reformulated in accordance with the 1.5-degrees limit based on Art. 2 para. 1 PA – all this is still not fully implemented by the recent EU ETS reform which has been analysed in detail elsewhere (Rath/Ekardt 2022; Ekardt/Rath 2022. Avoiding shifting effects to other countries not participating in the scheme and hence ecological and economic competitive disadvantages, requires border adjustments for imports and exports, e.g., ecological tariffs that will probably put into practice by the EU indeed (Bähr 2015; Ekardt 2019; Will 2019). A cap-and-trade scheme for fossil fuels would primarily lead to N fertilizer shortage, but would also make P fertilizers more expensive since their extraction, processing, transport and application require energy. This stimulates fertilizing efficiency and benefits organic farming, which uses less fossil energy, at least in terms of arable farming (Boone et al. 2019; Smith et al. 2014; Niggli 2014; Stubenrauch et al. 2021). Hence, positive effects on other ecological compartments including soil health could be achieved. Soil health is essential for effective P uptake by plants and for avoiding P losses through, e.g., less erosion (Alewell et al. 2020). Furthermore, P recyclates could be placed in a better competitive position due to higher prices for fertilizers containing rock phosphate – provided that the recyclates are produced energy-efficiently and using renewable energies. Yet, the application of organic fertilizers is pushed which – althought in line with the circular economy – might aggrevate regional nutrient hotspots (Garske/Ekardt 2021). Besides, greenhouse gas emissions from livestock farming would not be regulated by a cap-and-trade scheme for fossil fuels.

Governing *livestock farming* with a cap-and-trade scheme for animal products (involving only a limited number of addressees such as slaughterhouses) would significantly reduce absolute livestock numbers in line with the Paris Agreement (Weishaupt et al. 2020). Even if this cap would not be at zero due to food security and biodiversity advantages of grazing, the instrument would reduce feed demand and thus P demand for fodder cultivation and P imports through feed and feed additives. In contrast, consumer-oriented instruments, such as the often-discussed meat tax (Caro et al. 2017; Säll 2018; Kanter et al. 2020), is unlikely to raise prices sufficiently and is therefore not adequate to achieve, e.g., zero greenhouse gas emissions (always considering that only some remaining emissions could be compensated by natural sinks, for instance by afforestation and wetland management) (Intergovernmental Panel on Climate Change 2019b; Ekardt et al. 2020; Weishaupt et al. 2020). At the same time, strongly reduced livestock numbers imply less P from organic fertilizers, which could increase demand for (Cd- and U-contaminated) phosphate rock (see section IV). In addition, despite reduced livestock numbers, regional nutrient hotspots would not be eliminated. This makes further policy intervention necessary.

Avoiding regional high livestock densities with harmful consequences for water bodies, climate, biodiversity, etc., requires combining the cap-and-trade scheme for livestock products with a CaC *livestock-to-land ratio* on farm level (Weishaupt et al. 2020). The combination of both livestock-related instruments with the overarching cap-and-trade scheme for fossil fuels would drastically reduce environmental pressures including high P demand, high P use and P hotspots. These instruments would render intensive livestock farming impossible, strongly reduce environmental pollution and promote mixed farming systems, i.e., combined livestock farming and crop production, and thus benefit closed nutrient cycles (Garske/Ekardt 2021; Van Zanten et al. 2019). Simultaneously, higher food prices as result of higher energy prices incentivize food waste reduction and thus P losses (Garske et al. 2020; Vaccari et al. 2019; Kummu et al. 2012). Furthermore, price increases for fertilizers containing rock phosphate will stimulate efficiency and increased use of organic and recycled fertilizers. P imports through feed imports will become less attractive as transport costs rise and as declining livestock numbers will reduce feed demand and thus P required for fodder cultivation (Garske/Ekardt 2021). In contrast, to achieve sustainable P management including more supply security and less environmental harm and to promote sustainable agricultural practices in line with the Paris Agreement and the Convention on Biological Diversity, reforming ecologically dysfunctional *subsidies* such as the Common Agricultural Policy (CAP) at EU level (Heyl et al. 2020; Pe'er et al. 2020) is insufficient because the governance effect would be much smaller compared to the options discussed above.

As seen, phasing-out fossil fuels and effectively governing the livestock sector by economic instruments combined with a livestock-to-land ratio on farm level is expected to trigger efficient P use to a large extent. In doing so, the source problem of finite rock phosphate and the sink problem of P as contaminant of water bodies are minimized. Likewise, the problem of toxic waste from processing phosphate rock would be reduced. However, the proposed instruments neither guarantee a complete phasing-out of fertilizers containing *rock phosphate* nor solve the problem of *Cd and U contamination* by these fertilizers (on the following Garske/ Ekardt 2021; Garske et al. 2020). To this end, a cap-and-trade scheme for fertilizers containing rock phosphate, which limits their availability step by step to (near) zero, appears feasible. Exemptions might be allowed in a transitional period or in general to ensure the short-term supply of P to the soils. If policy instruments gradually limit production and marketing of fertilizers containing rock phosphate and favours recycled and organic fertilizers, efficient fertilization in line with circular economy would be incentivised – and no or little Cd and U from phosphate rock would be applied to the soils. Alternatively, threshold values could be established or improved. Supplementary, applied fertilizer legislation might steer good agricultural practices with regard to P use, soil and water protection. However, this issue depends on the normative yardstick, i.e., on the question of whether a complete phasing-out for P rock should be aspired and which distributive criteria has to be applied. This takes us to the major subject of the present article:

3. Phosphorus and Justice

The normative question arises how to deal with a finite natural resource in general and whether the use of fertilizers containing rock phosphate is desired at all. Alongside, questions of distributive justice arise. Another crucial question is how to deal with heavy metal contamination of environmental sinks such as soil and water and with human health from a normative point of view. The following section addresses these challenges. Before this, the issue of balancing different freedom rights with regard to sustainability issues is discussed shortly.

3.1. P Normativity and the Resource Problem

In general, all rights to freedom and preconditions of freedom such as life, health and subsistence are subject to balancing with other freedom rights such as the right of businesses and consumers to extract and consume P resources without being restricted by rising costs due to legal provisions. This normative foundation and the inevitability of trade-offs have been explained in more detail elsewhere (Ekardt et al. 2021; Ekardt 2019). Generally speaking, the liberal-democratic legal system is a system that contains substantive and procedural balancing limits for the collision of different spheres of freedom, based in the very wording of liberal-democratic orders. Within these limits, however, there is democratic decision-making scope.

Since P is a vital element, it needs to be available to all people – globally and permanently – in sufficient quantities. The obligation to provide sufficient P for everyone arises from a number of fundamental rights: Art. 25 Universal Declaration of Human Rights (UDHR) and Art. 11 International Covenant on Economic, Social and Cultural Rights (ICESCR) explicitly enshrine the right to an adequate standard of living including food. Besides, Art. 25 UDHR and Art. 12 ICESCR comprise the right to health while Art. 3 UDHR, Art. 2, 3 and 6 Charter of Fundamental Rights of the European Union (CFR) as well as Art. 2 and 5 European Convention on Human Rights (ECHR) prescribe the rights to live, physical integrity, liberty and security. These rights imply sustainability-related rights such as access to food, water, clean air, a stable climate and intact ecosystems (Office of the United Nations High Commissioner for Human Rights 2008; Ekardt 2019, Ekardt/Hyla 2017). But given that P regulation encroaches freedom rights of consumers and producers, there is a balancing situation that offers leeway for the regulators.

An important balancing in the context of sustainability arises from a balancing rule, which is often been overlooked ethically and legally: As a result of freedom and its preconditions, the political scope for decision-making ends where political action or omission substantially endangers the free democratic system. This is the case if no steps are taken urgently to solve crucial environmental problems. This argument is prominent with regard to climate protection (Ekardt et al. 2022; Wieding et al. 2020). Yet, it is justified for similarly existential ecological topics, but not for environmental protection as a whole. With regard to contaminants of fertilizers, the argument does not work very well since contaminants and their consequences cannot undermine democracy. Yet, the argument seems valid regarding the future availability of P and the stability of water bodies and oceans, which is endangered by P discharges. Today, P is a major factor for exceeding planetary boundaries via eutrophication of freshwater and oceans (Carpenter/Bennett 2011; Steffen et al. 2015)

However, further balancing rules can make it possible to derive at least some normative criteria for dealing with rock phosphate. A crucial balancing rule is that facts underlying legislation have to be collected in an accurate way. The precautionary principle that also applies to human rights furthermore implies that even uncertain, long-term or cumulating damages have to be taken into account (Ekardt et al. 2022). This implies the following: Firstly, it must be clarified with sufficient certainty how much P is basically available – from phophate rock resources on the one hand and from P recyclates and organic fertilizers on the other. The second question is, how much P from rock phosphate could be substituted by recycling and organic fertilizers. Thirdly, the question arises how much P is needed at all to feed the world's population. Further, on what factores does the future P demand depend? Lastly, where are potential savings? Various studies deal with these questions. Some key aspects of the findings of these studies are discussed below.

Current estimations suggest 71 million tons of P reserves globally. These reserves would last for more than 300 years when assuming current production levels of 220 tons per year (United States Geological Survey 2022; Oloo/Asbon 2020; Kauwenbergh et al. 2013; Ulrich/Forssard 2014). World resources of phosphate rock are estimated at more than 300 billion tons, of which frequently new deposits are classified as exploitable, i.e., as reserves. Hence, an imminent short-term global supply crisis is unlikely (United States Geological Survey 2022; Wellmer 2022; Oloo/Asbon 2020; Nedelciu et al. 2020, Kauwenbergh et al. 2013). Nevertheless, phosphate rock deposits are distributed unevenly around the world. The largest sedimentary deposits are located in northern Africa (70 % of global reserves in Marocco/ Western Sahara), the Middle East, China, and the United States. Significant igneouse deposits are located in Brazil, Canada, Finland, Russia, and South Africa (United States Geological Survey 2022). The unequal regional distribution of phosphate rock ressources bears the risk of short-term supply bottlenecks, e.g., due to wars. This entails the risk of short-term price peaks, as in 1974/1975, 2008 and again in 2022 as result of market distortion due to the Russian invasion of Ukraine (European Commission 2022; Nedelciu et al. 2020; Khabarov/Obersteiner 2017; Rosemarin/Ekane 2016; Index Mundi 2022; Daneshgar et al. 2018; Köhn et al. 2017; Cordell and White 2015). Especially regions with P-poor soils and high population density or high population growth, e.g. in Sub Sahara Africa and Latin America, are vulnerable in this respect (Nedelciu 2020; Nanda et al. 2020; Reijnders 2014). But also the European Commission included phosphate rock in the European list of critical raw materials (European Commission 2020; European Commission 2017; European Commission 2014), while currently facing fertilizer shortages (European Commission 2022).

In principle, the right to food can theoretically be fulfilled without fertilizers containing rock phosphate, because P can be provided from organic fertilizers and recycled fertilizers, too. There are several studies on the national, regional and global potential of organic fertilizers and P recyclates to cover the current P demand of agriculture (e.g., Nanda et al. 2020; Vaccari et al. 2019; Powers et al. 2019; Schoumans et al. 2015; Kratz et al. 2014). The outcomes of these studies vary because calculations are based on a number of partly diverging basic assumptions about the required amount of plant and animal food, feed or crops for energetic and material utilization and about possible saving potentials. Yet, most studies takes the current number of animals and thus the high amount of manure as a basis, which cannot be assumed – neither in view of the P-intensity of animal-derived food nor with regard to the international climate and biodiversity targets (Cordell/White 2015; Nedelciu 2020; Lun et al. 2018; Metson et al. 2012; Weishaupt et al. 2020; Intergovernmental Panel on Climate Change 2019a).

At global level, Vaccari et al. state that P from sources other than mining can satisfy P requirements for 14.7 billion people if P use efficiency was improved and P losses reduced significantly, the fraction of animal food in the diet and food waste were mimimized. The authors point out that, without those interventions, P from other sources than mining may satisfy only 2.5 billion people (Vaccari et al. 2020, almost similar Sverdrup/Ragnarsdottir 2011). However, even if all efficiency, consistency and frugality strategies are applied, it cannot be assumed that P demand will fundamentally decrease in the future. Countervailing developments make success in this regard more difficult. Various studies predict that demand for P will increase sharply in future due to population growth, especially if dietary habits remain dominated by animal-based products (Stamm et al. 2022; Nedelciu 2020; International Resource Panel 2019; Vaccari et al. 2019; Lun et al. 2018; Daneshgar et. al 2018; Reijnders 2014; Ragnarsdottir et al. 2011). Yet, dietary patterns are not immutable, but policy and law can influence them. Finally, the world population could start to decline again by the end of the century due to education attainment and access to contraception (Vollset et al. 2020).

Apart from the uncertainties due to population growth and human dietary behaviour, it is hardly possible to estimate the future P demand because it depends on various agricultural factors, e.g. crop and soil characteristics including the existing soil P contents and the ability to mobilize these contents in the soil. The ability of soils to mobilize P depends on natural conditions and management practices. Besides, P fertilization efficiency and P uptake efficiency are no fixed values, but can be influenced, e.g. by precision fertilization or the use of P activators including microorganisms or catch crops (Grafe et al. 2018; Eichler-Löbermann et al. 2008; Zhu et al. 2018; Bergkemper et al. 2016). In contrast, climate change-induced extreme weather events such as droughts can increase P demand. Likewise, heavy precipitation after long periods of drought may trigger erosion and thus higher P losses into water bodies and higher P demand of concerned areas in the following period (Alewell et al. 2020; Schoumans et al. 2015; Sharpley et al. 2015; Zimmer et al. 2016). Lastly, P from mineral, recycled and organic fertilizers is available to plants within different time periods (Roy et al. 2017), making not every fertilizer on every area suitable to replace mineral fertilizers which are available in the short term. In sum, it is almost impossible to accurately quantify future demand of P to produce a sufficient amount of safe (plant-based) food to feed the world population, especially on a global scale with diverse soils, crops, cultivation methods, etc. Yet, the answer to this question would be crucial for a decision on whether a phasing-out of phosphate rock is plausible – globally or in all participating states.

In any case, a long-term reliance on a globally unevenly distributed resource with potential supply risks is not a very convincing option with regard to the balancing obligation on fact accuracy. Instead, other options are needed to ensure P supply for everyone. This conclusion is supported by the facts that P resources are frequently contaminated by harmful substances, which will be discussed in more detail in section 3.2., as well as by the high potential for efficiency gains in P use and the large substitution potential of rock phosphate.

The vital importance of P raises distributive issues, too. For instance, can all people claim an equal per capita supply of P? In contrast to equality of rights, equality of distribution is actually neither a human right nor a basic liberal-democratic balancing rule. The large scope of the balancing limits does not provide such a specified obligation for the legislature (Ekardt 2019). With regard to climate change, we have shown in other texts (Ekardt et al. 2022; Ekardt 2019): A country cannot claim more resource rights than it is entitled to per capita based on its population, because an existential good for whose genesis no one has contributed is endangered. However, this does not rule out the possibility to buy resource rights from other countries – or that, for reasons of capacity and the polluter pays principle that represent further balancing limits (and therefore a higher historical responsibility of Western states), an unequal distribution towards the Global South may even seem mandatory (see also Kahiluoto et al. 2021). All this may imply an at least roughly equal P amount to be available for every person worldwide, respectively a right to a roughly equal P footprint: i.e. the average amount of mined P required to produce the food consumed per capita (Metson et al. 2012). The minimum is the amount of the recommendation for an adequate daily human P intake plus unevitable losses alongside the production chain.

According to dietary recommendations, the adequate daily human P intake should be 700 mg/d (National Institutes of Health 2021; with some deviations, e.g. the European Food Safety Authority suggested 550 mg/cap/d in 2015). Taking eight billion people worldwide as a basis, a global daily P demand could be calculated. However, this would not take into account losses along the entire value chain from mine to fork. Estimates suggest that only 20 % of the mined P is actually used (Sverdrup/Ragnarsdottir 2011; Nature Plants 2022; Cordell/White 2014; Metson et al. 2016; Nedelciu et al. 2020). Such high losses are not compatible with the human right to food and the paradigm of conserving vital resources or protecting the environment. Likewise, P-intensive diets, i.e. especially the high consumption of animal-derived products, counteract the normative derivations presented above (also in view of further resource and environmental problems caused by the consumption of these products) (Cordell/White 2015; Sverdrup/Ragnarsdottir 2011, Nature Plants 2022; Metson et al. 2016, Weishaupt et al. 2020). Especially in developed countries, the consumption of animal products and thus the P footprint, is very high (Metson et al. 2012; on the average per-capita P use see also Vaccari et al. 2019 and Cordell/White 2015).

Therefore, it is reasonable to ensure that the P footprint for all people in the world is not only as equal as possible, but also as small as possible. Losses and inefficient P diets such as strongly animal-based diets are to be avoided. If the daily guaranteed P amount comes from organic, recycles or mined P fertilzers does not matter to fulfil the right to food. If no phasing-out of rock phosphate is envisaged, global ressources have to be depleted in a controlled manner in the long term, taking into account the most equitable global distribution. Nonetheless, even in that case, increased recycling and efficiency are advisable in order to conserve limited resources and to enable their access to as many future generations as possible (Scholz/Wellmer 2019. Intergenerational justice is a basic concept that was agreed upon in the Rio Declaration 1992 (UN 1992; Scholz 2019). P recycling diversifies the number of P suppliers and thus results not only in a larger supply security in the short term, but also in the long term for future generations (Scholz 2019, Withers 2019, European Commission 2022). Another reason in favour of P recycling is the fact that mined P fertilizers are regularly contamined with heavy metals, which is discussed in the next chapter.

3.2. P Normativity and the Sink Problem of Contaminated Fertilizers

The human rights to live, health and physical integrity further provide protection against damage to health caused by heavy metals and further contaminants found in fertilizers, although there is leeway for balancing, as seen. However, once again, the balancing obligation to accurately deal with the underlying facts of regulation becomes relevant. As it is the case with empirical data on the long-term availablity of phosphate rock, the scientific discussion on fertilizer contamination suffers from some uncertainties. This is also true for the most prominent contaminant of P fertilizers, Cadmium, on which we will focus here. For example, it is not investigated conclusively how Cd concentrations in soils develop in the long term depending on fertilization practices (Niño-Savala et al. 2019). Cd neither degrades in the environment nor removes from the soil easily (Schaefer et al. 2020). Soil factors, in particular pH and soil organic matter availability affect Cd solubility, mobilization and uptake (Bracher et al. 2021; Schaefer et al. 2020; Morshedizad/Leinweber 2017; Niño-Savala et al. 2019). Besides, Cd uptake varies by plant species (Schaefer et al. 2020). This makes valid statements on the specific Cd load of certain foods difficult. Yet, the precautionary principle implies action here again to prevent harm for human health and environment. Moreover, it is well known that Cd from fertilizers is transported through the soil, the water and the air. It is taken up by plants and animals and transferred to the human body through the diet, where it accumulates (Niño-Savala et al. 2019; Schaefer et al. 2020; Bracher et al. 2021; Ulrich 2019). Cd in the human body has a half-life about 20 years (Niño-Savala et al. 2019). Cd is toxic and may cause cancer, cardiovascular diseases, dysfunction and damage to the kidney, other organs and to the skeletal system. Further effects of Cd accumlation such as mitochondrial inflammation and damage is being researched. Besides, research focuses on how much Cd is absorbed by humans under which conditions, especially by children, which are more vulnerable to Cd intake (Schaefer et al. 2020; Niño-Savala et al. 2019; Ulrich 2019; Wu et al. 2022).

Nevertheless, as has already been noted, this does not provide a concrete balancing limit regarding a reduction of pollutant loads in P fertilizers. If no balancing limit is violated, the problem remains within the scope of the legislative body in liberal democracies. Notabene, in particular Cd and U input would no longer be an issue if fertilizers containing rock phosphate were completely removed from the market and only using high-quality alternative fertilizers was allowed. In contrast, regulation for contaminants would be required if a complete phase out of the use of rock phosphate is not envisaged or during the transitional period. Likewise, in case of exemption regulations to a ban on rock phosphate, regulation is necessary to ensure the quality of the fertilizers used. In principle, quality assurance cannot be left to the manufacturers of fertilizers, who have a fundamental right to economic freedom.

In any case, the colliding human rights call for distinct rules of public authorities. Purely voluntary solutions will not be sufficient. As indicated in Chapter 2, one option to prevent health and environmental damage through contamined fertilizers – in addition to overall quantity governance on fossil fuels and livestock products – are strict threshold values, in particular for

Cd and U in P fertilizers. In the European Union, threshold values for Cd in P fertilizers are implemented in the in the product-related fertilizer legislation. Unfortunally, during the last reform of the European CE fertilizing product regulation (Regulation (EU) 2019/1009) in 2019, it was not possible to implement an ambitious threshold value for Cd, which is now 60 mg/kg P_2O_5 (for the draft regulation with stricter limit threshold values see European Commission 2016; see also Ulrich 2019). A further reduction is no longer envisaged. Stricter limits would have affected highly contamined rock phosphate from Morocco in particular (Niño-Savala et al. 2019). As a result, an opportunity was wasted to improve the competitive position of P recyclates, which are usually less contaminated und thus provide environmental and health benefits (International Resource Panel 2019; Tonini et al. 2019).

An alternative to threshold values are taxes on contaminant levels in fertilizers as implemented, e.g., in Sweden (European Commission 2002; Watkins et al. 2017). However, the command-and-control approach is more suitable to avoid short-term health hazards and to offer an easily enforceable regulation. Another option is to ban highly contaminated fertilizers completely, as some EU countries did. Besides these options, some strategies to decrease Cd bioavailability exist, e.g., applying lime to incease pH, influence soil parameters such as organic matter and microbial activity or selecting low Cd plant varieties (Schaefer et al. 2020). Further options regarding the use of rock phosphate containing fertililzers are sourcing of low-Cd rock phosphate, blending and decadmiation (Ulrich 2019). But again, the facts are basically in favour of substituting fertilizers containing rock phosphate with organic fertilizers and P fertilizers sourced from secondary raw materials. However, these fertilizers have to be of high quality and free of harmful substances.

4. Discussion and Conclusions

From the normative point of view, colliding human rights and balancing rules do not provide a clear yardstick how fast P loss reduction and establishing P cycles (also based on intensified P recycling) have to occur. In any case, the balancing obligation to accurately deal with facts provides some guidance. Furthermore, the rights to life, health and food makes a right to access to an adequate amount of P for every person worldwide at least plausible. This can be provided on the one hand by organic or recycled P fertilizers, or on the other hand from mined P fertilizers. Based on human rights, it cannot be definitively concluded if a total phase-out of rock phosphate (like inevitably for fossil fuels) is expedient or the adequate answer to the global environmental issues of agricultural P use. Instead, the fulfillment of human rights implies a efficient use of high-quality organic, recycled or mineral P fertilizers so that environmental and health harm is minimized and P is accessible worldwide (Nedelciu 2022; Jupp et al. 2021; Garske/Ekardt 2021; European Commission 2020; Leinweber et al. 2018; Jensen et al. 2017). However, in view of (1) the environmental damages connected with using P from mined fertilizers – i.e. not only P discharges from oversupplied soils, but also Cd and U contamination and toxic waste and greenhouse gas emissions resulting from mining and processing phosphate rock, (2) the high vulnerability of many countries with regard to their P import dependency, (3) the great potential for substituting rock phosphate and (4) the range of possible efficiency measures in P use, the goal of (almost) complete recycling of P is worth striving for. Keys are an optimized P use efficiency including more sustainable soil management to reduce soil erosion, the minimization of P losses throughout the value chain, i.e. from mining to food waste reduction, a strongly reduced P-intensive animal food production, the extensive recovery and recycling of P from all wastewater and waste streams including animal and human excreta, food waste and other organic sources (Vaccari et al. 2020; Cordell/White 2015; Roy 2017; Powers et al. 2019; Metson et al. 2016). All these measures are elements in guaranteeing the human rights to life, health and food worldwide.

These goals can be pursued with the help of governance instruments, which we presented at the beginning. To sum up: To develop a governance for sustainable P use and interrelated environmental problems in the agricultural sector, specific P objectives as well as the more comprehensive, international binding policy objectives, factors of behavioural motivation and governance problems have to be taken into account. These issues and interrelated environmental problems as well as the broader analysis of behavioural factors and governance problems discussed above lead to more specific proposals than the overall call for 'multi-level governance' (Sharpley et al. 2015; Rosemarin/Ekane 2016) or a "One Earth currency" (Kahiluoto et al. 2021). By addressing the major drivers of urgent environmental problems, i.e. fossil fuels and animal husbandry by means of economic instruments, a solution to various P-related problems can be advanced simultaneously. In addition, the livestock-to-land ratio is a crucial supplement to the cap-and-trade system for animal products in order to avoid nutrient hotspots. Cd and U contamination of rock-phosphate-containing fertilizers can be regulated by threshold values if (or as long as) a phase-out of such fertilizers is not (fully) implemented. Additional P instruments such as a cap-and-trade system for phosphate rock depend on normative decisions and open empirical questions and require in parts further discussion. Yet, in terms of avoiding environmental problems through the use of P fertilizers, reducing P-losses, substituting rock phosphate and increasing P-efficiency, research is extremely lively (Panagos et al. 2022; Mayer/Kaltschmitt 2022; Stamm et al. 2022, Zou et al. 2022; Jupp et al. 2021; Jama-Rodzeńska 2021; Haque, 2021; Bracher et al. 2021; Nedelciu et al. 2020; Nanda et al. 2020; Garske/Ekardt 2020; Vaccari et al. 2019; Alewell et al. 2020), so that we might get closer to answers in the near future.

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