PHOSPHORUS DILEMMA

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Résumé : Phosphorus is an essential element for the support of life; it makes make of DNA, bones, and is an essential element for the transference of energy at cellular level
To maintain the high agricultural yields to guarantee food security it is essential to apply phosphate fertilizers. Phosphorus is the limiting plant growth nutrient.
Although, phosphate rock reserves, the raw material for phosphate fertilizers, are located only in a small handful of countries, such as, Morocco (which is occupying Western Sahara since the 70's), Algeria, China, Syria. Many of these countries have very unstable governance, making the supply and price very volatile.
Europe has almost no reserves, besides a small one in Finland. To ensure food security and avoid environmental phosphorus related impacts it is fundamental to achieve a sustainable use and management of phosphorus.
Mots clés (5 maxi) : Phoshorus, flows, fertilizer, phosphate rock, food

1 SUSTAINABLE PHOSPHORUS USE

The world population is increasing and it is expected to reach 9.8 billions by 2050, along with it is expected to substantially increase the need for the use of phosphorus (P).
Therefore, currently, it is the right time to manage the P cycle as a whole, and let behind the old fashioned approach of looking at the cycle as single pieces that are poorly interconnected.
To assure that the coming generations will be able to use P, it is necessary to use it more efficiently, minimizing the losses and wastes disseminating viable economic recycling technologies.

P is not lost as it dissipates through geochemical processes, although it reaches such low concentrations, which makes it too difficult and/or expensive to recover [1]. Losses of P and transport to the oceans sediments is an unavoidable process. Nonetheless, human activities, such as, phosphate rock mining and beneficiation, soil tillage, food production, and industrial activities, have significantly speeded this process. It is widely known that P is responsible for several environmental problems, being eutrophication the main one. Eutrophication is responsible for the reduction of water quality, and due to the big load of nutrients a shift in the native species can happen.
Improvement of use and recycling of P whilst diminishing negative environmental impacts are the fundamental immediate targets, although in a long term it is essential to develop more measures to achieve a holistic management of this finite resource.

2 PHOSPHORUS AND HUMAN FOOD

To enhance the P use efficiency in the human food chain the cooperation is necessary between various stakeholders, such as, P mining industry, fertilizer industry, agriculture and forestry production, food-processing industry, industrial P users, wastewater sector, and individual consumers. World Health Organization recommends a daily intake of 1g P (for an adult) to keep a 'good' health level, which means that worldwide are required only for nutrition over 2.5 Mt of P a year. Currently, on the other hand, the average intake is about 3 g P daily. Because the conversion of phosphate rock into human food is very low (around 20%) it means that is a wide opportunity to improve the efficiency [2].

3 USE OF CHEMICAL FERTILIZERS

Almost all the mined phosphate rock (around 80 %) is beneficiated into phosphate fertilizers for agricultural use.
It is a sequential process where the insoluble phosphate rock reacts with a strong acid to form water-soluble compounds that will be available for plant uptake. With the discovery of acid treatment process in the 1840s was started modern P fertilizer industry, also allowing a better understanding of plant nutrition. During the 20th century P fertilizers were fundamental for the global food production. As the demand for food increases to satisfy the needs of the population the need for more P fertilizers also increases.
Several studies have shown that P is the limiting nutrient for plant growth, but only a small fraction of the added P to soils actually ends up in the harvested crops. Depending on the soil's pH the quantity of excess P remaining in the soil can react with Ca and Mg carbonates. These reactions result in the conversion of soluble P into less soluble forms that will not be available for plant uptake.
The desired high crops yield necessary for food security, economic profit, and farm sustainability put a considerable demand on soil nutrient profile.
Modern crops remove between 15 and 35 kg P/ha for cereals, 15-12 kg P/ha for legumes and roots crops, and 5-15 kg P/ha for vegetables and fruits. Although, many regions worldwide have P deficient soils, such as Sub Saharan Africa, South East Asia and are many small farms where the lack of access to P fertilizers has led to land degradation and food insecurity. The unsustainable agro ecosystem management in these areas, like burning or feeding of crops residues and switching to more nutrient demanding crops has resulted in serious erosion and drains on soil nutrient profile. On contrary, in many regions of North and South America, Europe and Asian floodplains have a record of repeated P use leading to a P soil buildup. When the soils are too rich in P it can lead to important environmental problems, eutrophication, of the receiving water bodies
Computing of P balances is an effective way to estimate if the soil is getting enriched or depleted over time. All the nutrients added to a field, are compared to the outputs in the harvested production, lost through erosion, and surface runoff [3].

3.1 OPPORTUNITIES TO IMPROVE:

Integrated nutrient management (INM) is an approach to improve the nutrient use efficiency by crops and animals whilst decreasing the nutrient losses to the environment. INM considers all the components involved in the nutrient cycling (weather conditions, soil, fauna, flora, and all the inorganic and organic nutrient sources) and also relevant socioeconomic factors.

3.1.1 SOIL TESTING AND P RECOMMENDATIONS

It was shown that crops growth is limited by the concentration of plant available P in soils. To overcome this limitation farmers have adopted strategies, such as use of mineral fertilizers, animal wastes, compost and several recycled materials.
The main issue is how to determine the right amount of P to add to achieve the production goals. Insufficient P fertilization leads to risk of low crop yields, on contrary over fertilization can lead to environmental problems due to runoff and economic inefficiency.
In developed countries it is widely accepted to use chemical analysis of soils to assess the need to P fertilizers adapted to specific crops and soils properties. Although, the costs associated with soil sampling, and access to laboratories restricts the use of this technique in many parts of the world. When farmers have no access to this kind of accurate information they have to do fertilization based on historic fertilization practices, general soil fertility recommendations to the region, and on P fertilizers market prices. Modern fertilization should be based on site-specific information as much as possible.
Soil testing is essential to estimate the amount of P that will be available for plant uptake in the coming growing season, but is not as helpful as a predictor of the long term P in relatively insoluble soil compounds.

3.1.2 ADDITION OF FERTILIZERS AND RESIDUAL P

Enhancing P fertilizers application can improve short-term P recovery by plants. Because P is fairly immobile in most soils, the fertilizer should be placed as close to the roots as possible. Special equipment allows the fertilizer to be injected to the roots area increasing P plant recovery. If the P fertilizer is added to the soil surface separates it from the active root area and makes it vulnerable to losses with water by runoff. Tiling the soil to deeper incorporate P into the root area brings a risk along of erosion of the sediments are carried off the field.
When the fertilizers are applied onto the soil's surface it creates a stratified zone of nutrients that might not be available for the deeper roots, representing a runoff risk. After fertilizer application the remaining part that was not uptake by plants associates with mineral and organic fractions of the soil, mostly unavailable for short-term plant uptake.
On the year of application, plants just recover about 15-25 % of the P the remaining fraction (85-75 %) stays in the soil where it is slowly released over time. When P accumulated in soils reaches appropriate levels, high agricultural yields can be maintained for many years without needing further P fertilizers application.

3.1.3 REDUCING P LOSS FROM SOIL

The biggest source of P loss from cropped soils is through erosion while grassland soils mainly loose P by water runoff. To limit the loss of P sediments good management practices can help to avoid P triggered water quality impacts. There are several measures to avoid this situation, such as retention of crop residues in the soil surface, reduced tillage practices, improvement of water infiltration by subsoil tillage, terracing and counter tillage, use of cover crops, and conversion of perennial crops. Use of additives that bind soil particles have shown to be effective reducing sediments mobility. Several management measures, like planting vegetative buffer strips (riparian or grassland) are effective to reduce P losses from agricultural fields.

4 PHOSPHORUS IN THE FOOD CHAIN

In the whole global food chain, P losses occur during and after the production process. These inefficiencies include accumulation in the soil, erosion, crops losses (due to diseases, natural causes, and pests); post harvest losses, and losses at the distribution, retail and household level.
Crops losses due to diseases, natural causes and pests are higher in developing countries, it accounts for 20% of the food, in some regions it can reach up to 40 %. A close assessment of P recovery of post harvest losses is essential to improve overall efficiency.
At retail and household level, food losses account for 10% of total production in developing countries, whereas in developing countries it can reach up to 20-30%.

4.1 OPPORTUNITIES TO IMPROVE

In developed countries usually, the food processing is contained in a closed process making P recovery easier. I less developed countries, it might be harder to recover P residues from food processing and use them. Nevertheless, there are multiple opportunities to reduce nutrient losses during food processing, storage and transportation in both cases.
Following harvest, the crops are processed into final products for food, fuel, feed, and fiber. The losses that take place during storage because of pests and disease can be reduced by better management practices. If parts of food that are rejected during the processing are not returned to the fields are considered P losses. To improve this situation it might be needed an additional infrastructure, better management of the processing plant, and more considerate food handling by consumers.
The challenged faced currently with the waste from the global food chain could be minimized by producing food closely as possible to where it is consumed, and then returning the wastes to the agricultural fields. Yet, exist important economic, technological, social and logistic aspects that have to be solved before employing such an ideal. Unnecessary food waste at retail level can be avoided if a balance between excessive disposal and food quality and safety is sustained [4].
In some countries the losses of food and nutrients can reach very high levels. The reasons behind this fact are: poor shopping planning, not understanding the 'use by date' and 'best before date', food not stored correctly, poor skills combining left overs and fresh food. Therefore, it is essential to create awareness among the consumers, and the best way to start is with educational programs in school.
It is expected that the global population will largely increase much of this increase will take place in peri-urban areas of developing countries where P recycling can be improved. It is easier to recycle nutrients where a large number of people are living. Decreasing the amount of food and nutrients to landfills and the sewer system gives us a chance to develop compost and other organic products to reuse this important resource.
The recovery of P at household level is not an easy task. Food wastes have to be separately collected and processed at a collection area. Special toilets have been developed to separate human excreta (liquid from solid) and recover the P present before entering the sewer system, but this technology is not widely available/ accepted. The biosolids from WTPs can be used to pally in soils to recover the nutrients, but risks from health and safety rise because of the presence of heavy metals. To avoid this risk exist technologies developed to recover P from sludge ash monoincineration.
The ideal P cycle contains removal of soil nutrients with the harvesting of the crops and returning of nutrients back to the soil without losses. Though, the closed P cycle never existed and there will always be an inevitable loss. Nevertheless, our actual system of mining large amounts of phosphate rock to compensate the big quantities of P that are transported from the farms to the cities it is inefficient and unsustainable. Restoring this link is essential to achieve progress in improving P use.

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