EUROPEAN
COMMISSION

Brussels, 1.8.2014
SWD(2014) 263 final

COMMISSION STAFF WORKING DOCUMENT

Summary of the responses to the Consultative Communication on the Sustainable Use of Phosphorus [COM(2013) 517]

1. INTRODUCTION

The sustainable supply of phosphorus, a key and irreplaceable resource for soil fertilisation, was identified in the 2011 *Roadmap to a Resource Efficient Europe*[1] as an important factor affecting sustainability and long-term global food security. The Roadmap called for further research to identify how improvements in fertiliser use, food production and bio-waste recycling could reduce our dependency on mined phosphate.

Following the publication of the Roadmap, the Commission continued its research on the topic[2]. On 8 July 2013, on the basis of an explicit commitment in the Roadmap, the Commission published a *Consultative Communication on the Sustainable Use of Phosphorus*.[3] Structured around 11 questions to stakeholders, the Communication sought to draw attention to the sustainability of phosphorus use and launch a debate on the state of play and possible areas for action. It was not designed with specific legislation on phosphorus in mind and encompassed several policy areas, looking at the issue of phosphorus sustainability in terms of resource efficiency, waste and a circular economy, food and agricultural production, soil and water quality, etc.

The consultation remained open for contributions from 8 July to 1 December 2013. The Commission received 125 replies from around 150 stakeholders,[4] with around half addressing all 11 questions. The replies included responses from nine Member States administrations (Belgium, the Czech Republic, Estonia, Finland, Germany, Ireland, the Netherlands, Sweden and the United Kingdom) and input from other public authorities, such as government agencies and local authorities. Contributions were also received from a wide range of other stakeholders, including NGOs, industry associations, research bodies, single businesses and private individuals. Respondents represented a variety of sectors, such as phosphorus recycling, water and waste management, agriculture, food, fertilisers, other chemicals, energy and other manufacturers.

On 21 January 2014, the European Economic and Social Committee adopted an opinion[5] on the Communication, commending it overall as presenting a well-informed, balanced and comprehensive picture of the import and use of phosphorus-based products for the production of foodstuffs and other essential applications.

The Communication succeeded in its main aim of launching a debate. Useful contributions were received on all questions posed, and the Commission was invited to consider action in this field. The feedback identified policy options across different areas, gaps as regards data and data sources, and ways to improve the technical terminology. Alternative views were offered on some of the assumptions or statements made in the Communication. The replies

---

1 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions *Roadmap to a Resource Efficient Europe* (COM(2011) 571).

2 In 2012 the JRC published the report EUR 25327 EN "NPK: Will there be enough plant nutrients to feed a world of 9 billion in 2050?" ISBN 978-92-79-24910-5 (pdf); ISBN 978-92-79-24909-9 (print)

3 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions *Consultative Communication on the Sustainable Use of Phosphorus* (COM(2013) 517).

4 Some stakeholders submitted joint replies.

5 http://eescopinions.eesc.europa.eu/EESCopinionDocument.aspx?identifier=ces\nat\nat617\eesc-2013-06363-00-00-ac-tra.doc&language=EN.

demonstrated a clear interest in the topic and a desire that work on it should continue. This report summarises the responses to each of the questions.

2. ANALYSIS OF REPLIES

2.1. General overview

The Commission received 125 replies, around half of which addressed all 11 questions. Questions 4, 5 and 6 (on the risk of soil contamination, technologies for improving sustainable use of phosphorus, and further research and innovation needs) attracted the most responses; fewer respondents addressed question 3 (regarding information on worldwide supply of and demand for phosphate rock and fertiliser), but they still represented nearly two thirds of the total.

Contributions were received from a wide range of stakeholders. Over half (52 %) were submitted by institutions registered in the EU Transparency Register.[6] The distribution across stakeholder categories is presented in Figure 1.

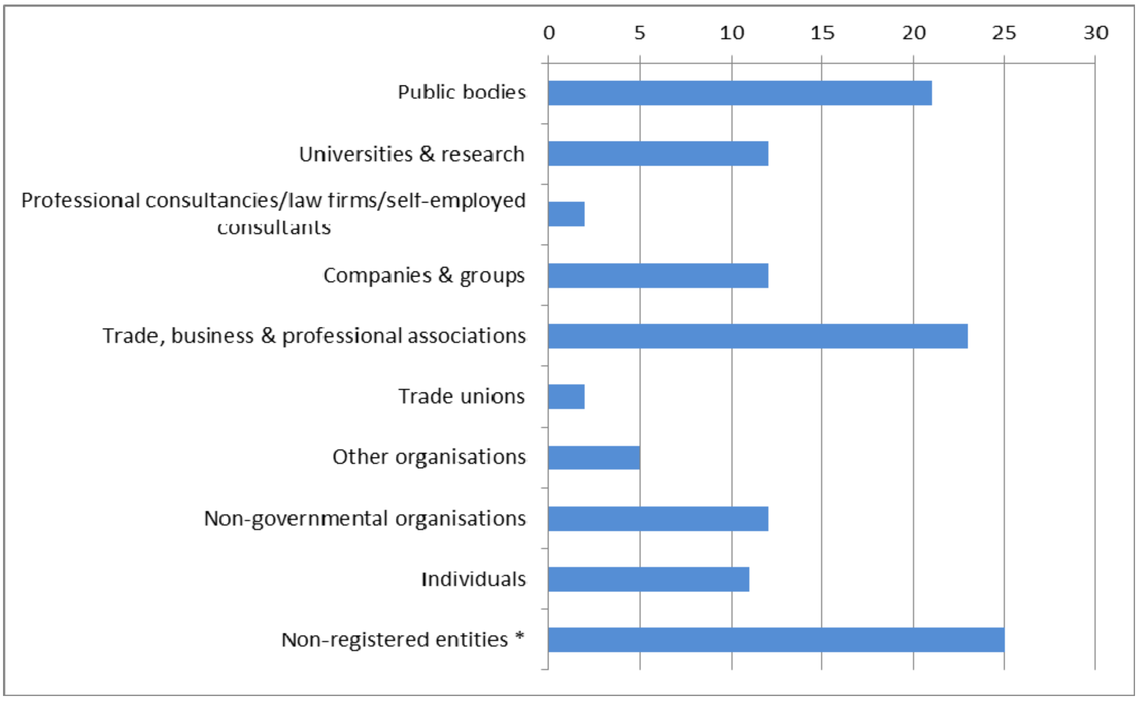

Figure 1: Number of replies received by stakeholder category

(* any entity, excluding individuals, not registered in the EU Transparency Register)

Respondents were from a range of EU Member States (see Figure 2); several European-level organisations and some non-EU or international stakeholders also responded.

6 See http://ec.europa.eu/transparencyregister/. The aim of the register is to make interaction between European institutions and stakeholders more transparent and law-compliant.

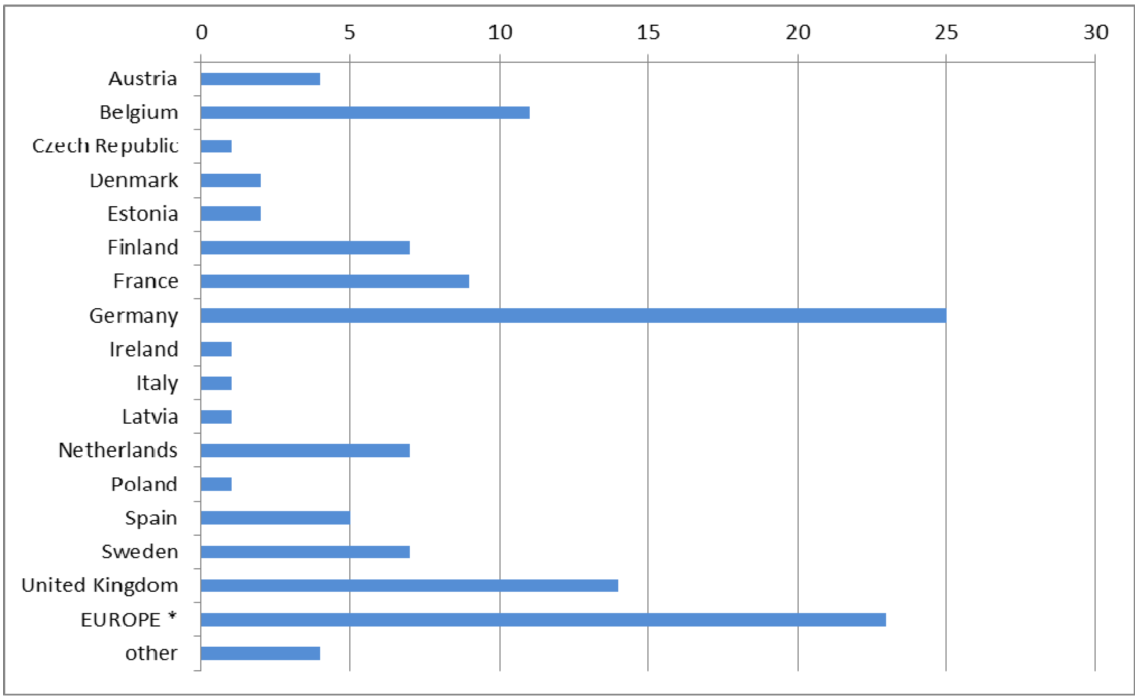

Figure 2: Geographical distribution of replies

(* entities acting at European level)

2.2. Summary of replies

Question 1 — Do you consider that the security-of-supply issues for the EU in relation to the distribution of phosphate rock are a matter of concern? If so, what should be done to engage with producing countries in order to tackle these issues?

Around two thirds of the respondents expressed concern about the security of supply of phosphorus. EU manufacturers' strong dependency on imports and geo-political conditions, and producing countries' pricing and export policies have a major impact. Very few respondents said they were not overly concerned by the supply risk. Some underlined that the EU's influence on the security of supply is quite limited due to its relatively moderate share of global consumption.

Attention was also drawn to a need to include phosphate rock in the list of critical materials in the framework of the Raw Materials Initiative.[7]

Concern also emerged as to access to a high-quality mineral, especially in relation to the issue of contamination, which is addressed under Question 4.

The solutions generally proposed include long-term, mutually fair agreements with the producing countries that would improve the working environment and promote the transfer of expertise on best available technologies, while ensuring a more secure supply of phosphate.

Around half of the respondents considered that, independently of the debate on how long the known resources can last, the EU should consider measures to reduce its dependency on phosphate rock and to secure its agricultural and food production. Along with reduced and targeted use of phosphate, a circular economy for phosphorus was proposed, for instance through more efficient recycling from waste water/sewage sludge, bio-waste, meat and bone

---

[7] The Commission included phosphate rock in a revised list of critical raw materials on 26 May 2014. See *Communication on the review of the list of critical raw materials for the EU and the implementation of the Raw Materials Initiative* (COM(2014) 297).

meal and other organic resources. Innovation, the development of new technologies for the extraction of phosphorus and improvements to existing technologies are important in this respect.

Question 2 — Is the supply and demand picture presented here accurate? What could the EU do to encourage the mitigation of supply risks through, for example, the promotion of sustainable mining or the use of new mining technologies?

While the majority considered that the supply and demand picture presented by the Commission was fairly accurate, it was highlighted that the extreme fluctuations in the estimates of reserves calls for improved methods of analysis; in particular, it was suggested that the EU should conduct its own research into supply and demand issues. Harmonising definitions and preparing internationally applicable sustainability criteria for phosphate rock mining were also mentioned among possible areas for action.

The need was stressed for better technologies to improve extraction efficiency. Some cited specific case studies on the need to improve technology for extraction from phosphogyspsum.

On the other hand, given its limited influence on mining technologies and practices, it was again suggested that the EU should prioritise reducing the use of mined phosphate in favour of recycled phosphates. Particularly those respondents working in the waste, waste water and renewable energy sectors argued that the recycling of organic wastes should be promoted, along with the separate collection of wastes and treatment processes involving the recovery of nutrients.

Other suggestions focused on the importance of better assessing crops’ specific phosphorus requirements and efficient use in agriculture.

Finally, it was suggested, notably by the fertiliser industry, that the EU should promote mining exploration and exploitation within Europe, though this might need more sophisticated infrastructure and better technologies. One suggestion cited seabed harvesting as a possible new form of mining.

Question 3 — Do you consider that the information on the worldwide supply and demand of phosphate rock and fertiliser is sufficiently available, transparent and reliable? If not, what would be the best way to obtain more transparent and reliable information at EU and global level?

Almost half of the respondents openly agreed that information on the worldwide supply of and demand for phosphate rock is not sufficiently available, transparent or reliable, while only few believed that the information is sufficient.

Two reasons were given for the lack of information:

(i) a great deal of it is privately owned or based on reports from individual countries and private companies; and

(ii) the extent of remaining phosphorus resources/reserves is surrounded by uncertainties; to a degree, these are unavoidable, given the dynamic nature of reserves (depending on available technologies). Uncertainties also relate to possible changes in demand in view of the growing population and demand for food, including animal protein.

Among the solutions proposed by the respondents were the following:

1. As the EU currently depends in particular on data from the United States, it would be helpful to establish an independent EU-based geological survey and data-collecting institution, e.g. a European phosphorus research and monitoring centre. Also, phosphorus flows within the EU should be documented and uniform standards should be applied to calculate reserves and resources;

2. At global level, a United Nations mandate for a global survey could be useful. The FAO could also be encouraged to develop suitable mechanisms to collect global data on resources and reserves. The establishment of an International Raw Materials Agency was also suggested;
3. Multi-stakeholder platforms or a consortium of leading national geological surveys and industries (EU or worldwide) or networks could help to improve cooperation and data collection.

Question 4 — How should we handle the risk of soil contamination linked to phosphorus use in the EU?

A clear consensus emerged on the need to protect the environment and human health from the risks associated with unwanted substances. The majority of respondents agreed that this should be handled at EU level.

Cadmium (Cd) was the element mentioned most (in more than half of the replies) and many called for clear standards for Cd levels in phosphates. The revision of the EU Fertiliser Regulation was the legislative instrument referred to most as a means of addressing Cd levels in fertilisers. Uranium, thorium, other radioactive elements and other contaminants that might be a matter of concern for secondary phosphate (copper, zinc, pharmaceuticals, etc.) were also mentioned.

Many respondents called for appropriate and clear standards. Some pointed out that new scientific evidence could allow for higher limits for Cd, while others advocated thresholds lower than those obtained from previous studies. There was consensus on the need for a science-based approach and for continued research. Public awareness of the risk of contamination is also important, as well as continuous data collection. The need for a proportionate approach was highlighted, keeping an eye on any unintended consequences of regulatory options. The need to apply the precautionary principle was also flagged.

It was stressed that the use of phosphorus from sources other than phosphate rock is an effective way of avoiding the introduction of new Cd into the environment. Decadmiation technologies for lowering Cd levels in rock phosphate were also mentioned, though some were deemed not ready for use on an industrial scale. Attention should also be given to technologies for removing other elements (uranium and rare-earth metals).

It was highlighted that Cd limits per unit of fertiliser might not be enough to protect the environment, since soil characteristics and current Cd levels, application rates and local conditions should also be taken into account. Cd input to water bodies also needs to be considered. There was a call for balanced fertilisation and precision agriculture, and other means of increasing phosphorus efficiency, reducing phosphorus excess and preventing its contaminants being discharged into the environment. There was also a reminder that the focus should be not only on contaminants in phosphorus, but also on phosphorus pollution itself (eutrophication), and that it is important to implement existing legislation (Nitrates Directive, Water Framework Directive, Urban Waste Water Treatment Directive, etc.) and new rules in this area.

Some stakeholders also pointed out that fertilisers are not the only channel by which contaminants can enter the food chain. Limits should also apply to feed materials and processes.

The EU Sewage Sludge Directive and its possible revision were mentioned as a way of encouraging phosphorus recycling, possibly through a tightening of the current limits for certain heavy metals. Some Member States already have limits that are stricter than those in the Directive. Upstream management rather than ‘end-of-pipe’ limits was also flagged as an important element. Research on innovative practices and technologies was deemed crucial.

Other specific proposals and examples put forward included: a tax on contaminant levels, focusing on production technologies favouring the separation of heavy metals from rock phosphate rather than recycled phosphorus, other technologies involving separate waste streams, sustainable mining procedures, bio-testing for sewage sludge, improving crop genotypes to avoid Cd accumulation in edible parts, and agricultural decadmiation methods. New specific rules on soil protection at EU level were also mentioned as a way of preventing soil contamination.

Question 5 — Which technologies have the greatest overall potential to improve the sustainable use of phosphorus? What are the costs and benefits?

Several technologies to increase <u>nutrient use efficiency</u> were mentioned, including:

(i) the production of environmentally safe plant-available phosphorus fertilisers from wastes, sewage and manure;

(ii) the use of best practices and precision farming techniques (e.g. evaluation of specific requirements, crop selection, new fertiliser types and new placement methods, soil protection);

(iii) increasing phosphorus uptake through crop modification;

(iv) using inoculants (mycorrhiza) and control of rhizosphere processes; and

(v) the use of precision feeding (e.g. phytase in fodder).

Reference was made to various technologies to increase <u>phosphorus recovery</u> from waste streams (sewage, food, domestic and industrial waste, waste waters), including:

(i) anaerobic digestion;

(ii) composting;

(iii) thermal treatment (e.g. drying, followed by granulation, pelletising or pulverising; incineration, followed by acidic treatment or chemo-thermal treatment at high temperatures; gasification); and

(iv) chemical processes (e.g. struvite precipitation, concentration by membrane technologies) or thermochemical processes (e.g. pyrolysis, hydrothermal carbonisation).

Some specific technologies were cited, such as AshDec (pelletising ash from the incineration of sewage sludge), PEARL (a specific struvite production process) and EcoPhos (soft digestion by hydrochloric or phosphoric acid).

The above technologies for recovering phosphorus from wastes represent only a selection of those covered in the scientific literature. In general, it was argued that, while several such technologies are known, most are still at a laboratory/pilot stage and few are sufficiently developed to be used on an industrial scale. Only few technologies were considered more ready for the market. Some set out the need for a supporting regulatory framework.

Though expensive, anaerobic digestion was often mentioned as the technology with most potential. Composting and incineration were also judged relevant, although the latter is considered expensive and not ready for the market. Struvite precipitation is considered by some to be cost-neutral, but by others as not covering costs. Thermal processes still require development and financial support. Some underlined that coagulants can significantly improve the efficiency of recovery from waste water.

As regards costs and benefits, it was pointed out that the success of a new technology will depend on the existing infrastructure, phosphorus recycling efficiency, environmental impact, the suitability of the resulting phosphorus product for fertilisation or industrial use, cost-effectiveness and marketability. The costs mentioned most frequently were investments in facilities and operational costs. Benefits include phosphorus re-use and thereby the reduced consumption of mined phosphate rock and energy, and greater independence and supply security.

Question 6 — What should the EU promote in terms of further research and innovation into the sustainable use of phosphorus?

In general, over half of the respondents advocated increasing efforts to use phosphorus more sustainably and therefore to recover as much as possible from available wastes, with the various stakeholders possibly involved in a research network. More research was called for in all fields of sustainable phosphorus use, with special attention to the whole life-cycle.

The research areas mentioned most frequently include:

- the production of high quality fertilisers based on recycled streams;
- improving the efficiency of phosphorus use, including:
  - (i) in crop and animal farming, through 'good agricultural practice' and fertiliser management practices (e.g. precision agriculture, integrated crop and nutrient management, field trials, feeding trials, phytase technology) or encouraging conversion to organic farming;
  - (ii) improved application (also through the development of advanced agricultural machinery);
  - (iii) mobilising recalcitrant phosphorus in arable soils (e.g. crop diversity, intercropping, deep rooting crops, phosphorus solubilising microorganisms);
  - (iv) in the industrial use of phosphorus (e.g. food additives, flame retardants, lubricant additives, etc.); and
  - (v) using more sustainable phosphorus substitutes and recovering phosphorus (e.g. from ash from incinerated sewage sludge) for the production of white phosphorus;
- phosphorus recovery, including research programmes on phosphorus flows at EU level, ways to secure greater self-sufficiency in the EU and methods for the proper separate collection of bio-wastes;
- the environmental effects of using and recovering phosphorus. This would involve gaining a better understanding of the behaviour and effects of phosphorus in the environment. The environmental effects of 'co-mining', i.e. recovery of uranium from phosphoric acid plants (particularly in an EU uranium-use scenario) and urban mining of rare earth or platinum group elements from wastes containing phosphorus, should be investigated. The presence of contaminants in wastes (including radioactive waste, i.e. phosphogypsum) should be researched. The need to improve the removal of heavy metals from phosphate rock and to learn more about the Cd cycle in soil-plant systems was also highlighted; and
- economic aspects, in particular the need to support the market uptake of new technologies and to consider economic aspects of environmental issues.

Also pointed out were the possibility of research funding under the Horizon 2020 Programme and the need for the updating, harmonisation and maintenance of data at international and European levels.

It was mentioned that the most promising phosphorus recovery methods should be selected on the based of life-cycle assessment and material flow analysis and that technologies should also undergo economic assessment. Other economic, social and environmental aspects have to be taken into account. Demonstration projects would be useful. The reasons why recycled products are not yet widely used should be analysed.

Other specific topics raised included policy comparison and harmonisation, the need to implement legislation, the labelling of green phosphorus products, the need to support precision agriculture, the effects of regulation on permitted fertiliser inputs, possible levies on phosphorus products, phosphorus recovery obligations, a ban on landfilling and phosphorus use in asphalt and cement, etc.

Question 7 — Do you consider that the available information on the efficiency of phosphorus use and the use of recycled phosphorus in agriculture is adequate? If not, what further statistical information might be necessary?

The prevailing opinion was that there is not enough information on the use of phosphorus, especially the use of recycled phosphorus in agriculture: the available information was considered not adequate, highly variable and incomplete; a need for improvement emerged. A handful of respondents though believed that the information is sufficient and adequate.

The main concern was the lack of information about the agronomic characteristics of phosphorus: nutrient contents of different manure types, their availability to plants and therefore their agronomic efficiency and the presence of contaminants (especially heavy metals) and pathogens and the risk of possible accumulation through the food chain. Also mentioned was a need for more/better information on phosphate flows within Europe (between sectors and countries), the secondary use of phosphate, phosphorus requirements for different crops and plants, and accumulation rates of phosphate in soil as a result of long-term fertilisation. This should also take account of effects on water quality, notably eutrophication. Field trials were proposed in relation to some aspects.

Several respondents stressed that the availability of information varies considerably between EU regions. Information about the location of sources (surpluses) is required at regional level. Parameters to be monitored could differ depending on local circumstances.

Finally, it was also noted that there is not enough information about technologies for the production of recycled phosphates.

Proposals on areas for further development included:

- economic instruments to promote a more efficient use of phosphorus;
- comparative studies on the use of mineral phosphorus and recycled phosphorus in agriculture;
- a common European methodology on data collection and the creation of a publicly available database for recycled phosphorus; and
- the harmonisation and standardisation of European law, so as to provide EU stakeholders with a common language and a level playing-field.

Question 8 — How could the European Innovation Partnership (EIP) on agricultural productivity and sustainability help to take forward the sustainable use of phosphorus?

A proposal that enjoyed broad support (especially, but not only, from industries and their associations) was building comprehensive expertise and developing cross-sectoral and cross-national partnerships (through dedicated focus groups) dealing with issues relating to the sustainable use of phosphorus. The focus should be on innovation and developing technologies (aimed at whole-chain solutions and supported by demonstration projects/cases), with a view to efficiency and cost reduction, the improvement and transfer of knowledge, and raising awareness, including among the public at large.

Practical issues calling for attention and solutions include phosphorus recovery (efficiency and safety of recycling, potential and limitations of various recovery technologies, transport from 'surplus' to 'deficit' areas), the efficient use of phosphorus and (mineral and organic) fertilisers, the prevention of losses (precision farming, crop rotation, erosion control, improvement of soil organic matter), organic farming, decontamination of fertilisers from secondary raw materials, crop requirements and genetic improvement, and phosphorus in fodder (reduction and recycling, livestock requirements, precision feeding).

One message that emerged clearly was the need for an integrated EU policy on phosphorus (to be covered in its sustainability policies) and for agreed best practices. Policy proposals included:

– providing Horizon 2020 and rural development funding for projects that involve farmers, technology providers and researchers;

– carrying out a review of all Member State measures to handle phosphorus surplus and producing recommendations based on the most effective approaches;

– work on a common EU approach to producing secondary phosphates and creating markets, *inter alia* by dismantling market barriers;

– cooperation with relevant organisations and multi-stakeholders platforms; and

– establishing an appropriate incentive system to promote efficiency and discourage abuse.

Question 9 — What could be done to ensure better management and increase processing of manure in areas of over-supply and to encourage better use of processed manure outside of these areas?

In some areas, quantities of phosphorus exceed what can be applied on soil and appropriate solutions need to be adopted to manage the surplus. Manure management in areas of oversupply was recognised as a very significant and sensitive issue. General agreement emerged on the need for a more efficient use of livestock manure and the importance of the balance between livestock farming and crop farming. A more balanced distribution of livestock on land could favour better management of manure, but it was also highlighted that, in some areas of high agricultural pressure, the most effective way of preventing phosphorus surplus at source would be to reduce the number of animals.

Nutrient flows should be properly monitored, with a focus on oversupply areas. The need for balanced fertilisation — avoiding phosphorus applications beyond what can be taken up by crops — was also mentioned. This could translate into phosphate application standards (e.g. in the national action programmes for implementing the Nitrates Directive) or other legislative approaches limiting phosphorus application on land. The common agricultural policy could also help through the cross-compliance arrangements.

Manure processing (e.g. phase separation, drying, thermal processes, chemical processes, etc.) can help in the management of the surplus and result in concentrated products that are easier and cheaper to transport. Around a third of the respondents were in favour of developing and using processing techniques, which could be part of the overall solution. However, some respondents pointed out that manure processing can be effective if coupled with other measures to prevent pollution at source. Cooperation between (livestock and arable) sectors and possible legislative support was also advocated. While market-driven, processing techniques could be made more viable by proper tax measures or other incentives. The quality of the processed product is key to its acceptance. The benefits of standards or labelling systems were evoked by some respondents. The need for a clear legal framework for marketing processed manure across borders was also flagged, especially by the fertiliser industry.

Further analysis of the crop uptake and efficiency of raw and processed manure (also in combination with mineral fertilisers) was generally welcomed and there was agreement that best practices to improve efficiency should be promoted and innovation encouraged in this area.

Question 10 — What could be done to improve the recovery of phosphorus from food waste and other biodegradable waste?

Almost half of the respondents suggested that phosphorus recovery from biodegradable waste be improved, especially through more separate waste collection and appropriate treatment. Some called for the energy recovery of biodegradable wastes, while landfill/incineration without energy recovery was discouraged. Compost and digestate could be used as agricultural fertilisers while recovering energy, thus making the recycling process more economically viable.

A few thought that the re-use of phosphorus from animal meat and bones should also be explored, including through trials aimed at proving the safety of this method. Measures might be needed to gain the acceptance of farmers, the food-processing industry and consumers. Farmers should have access to reliable information on nutrient content and expected availability.

It was suggested that a proper system of incentives/benefits (e.g. for phosphorus recovery in treatment plants or for the use of recycled products in farming) and taxes (e.g. on mineral fertilisers) be established and that the EU impose a programme to reduce phosphorus import dependency by setting mandatory recovery rates and deadlines.

Some respondents stressed the importance of developing end-of-waste criteria, while others were not in favour, arguing that intra-EU trade in compost and compost-like outputs is unlikely to develop (high volumes and low value) and that some countries already have their own established criteria.

Related suggestions concerned the prevention of food waste during processing/distribution and among consumers. Public health policies that would help to reduce phosphate demand (e.g. promoting vegetarian diets) were also suggested.

Question 11 — Should some form of recovery of phosphorus from waste-water treatment be made mandatory or encouraged? What could be done to make sewage sludge and biodegradable waste more available and acceptable to arable farming?

There was no consensus on whether phosphorus recovery should be made mandatory, with equal numbers of respondents coming out in favour or against. Those in favour, especially the recycling industry, some research groups and NGOs, highlighted that the sector is conservative and needs to be legislation-driven, cost barriers should be removed and a mandatory approach (e.g. imposing technologies or recovery quotas or targets) could help the development of the European industry. Those not in favour, including several representatives of the fertiliser and chemical industry, flagged a number of drawbacks, including unproven economic feasibility, the lack of mature technologies, high energy consumption, recovery possibly competing with environmental objectives (e.g. through increased emissions), etc. Some respondents could agree to quotas or targets being set, but not on imposing specific technology. Others would agree with a mandatory approach applying in future years only.

On the other hand, there was broad consensus that phosphorus recovery should be encouraged and developed, creating a market and building market confidence. Incentives, levies and subsidies were suggested. Struvite production was often cited as a success story and a possible growth sector if a phosphorus recovery policy were to be promoted.

Some suggested a step-by-step approach, starting with more studies, research and action to create favourable market conditions. This could then evolve into some form of legislation. Legal obligations on phosphorus recovery would send an important investment signal to industry and could be underpinned by phosphorus recycling targets.

The ‘best available technologies’ (BATs) approach was also suggested, given that waste-water treatments vary and a one-size-fits-all solution is not the best approach. Phosphorus recovery and stewardship could be introduced into existing BATs.

Implementation of environmental legislation was also considered a driver for the recovery of more phosphorus. A number of respondents argued that the top priority should be to implement existing legislation on waste-water collection (e.g. Urban Waste Water Treatment Directive and Water Framework Directive). Phosphorus can be recovered only if waste water is correctly collected and treated.

Some respondents questioned whether technologies such as flocculation with iron coagulants are sustainable, arguing that they do not deliver the best product in terms of potential re-use in agriculture. Others (notably the iron coagulants industry) listed a number of advantages of this technology, not least its effectiveness (as compared with other technologies) in removing phosphorus from water.

Some stakeholders flagged improving practices in the direct application of sewage sludge to land as a way to improve phosphorus recycling on land. Others, notably the phosphorus recycling industry, advised strongly that direct application should be avoided, partly in order to ensure quality and secure farmers’ acceptance. Some proposed that recovery should be made mandatory (or encouraged) only where land spreading is not possible.

Other respondents commented on specific technologies, proposing a ban on some (e.g. co-incineration of sewage sludge, because it is easier to recover phosphorus from ashes from mono-incineration), highlighting the recovery potential of others (e.g. dry toilets), suggesting further work on optimising waste streams, and highlighting the value of approaches creating economies of scale (e.g. central processing rather than single-plant recovery), etc. It was also suggested that organic farming rules could be amended to encourage the use of recycled phosphorus (especially urine).

On the question of acceptability to arable farming, the need to work on quality was one of the main messages that emerged from the replies. Farmers need to know what they are putting on their land and all farm applications (recycled phosphorus products or sewage sludge) should meet environmental and health requirements. All possible side effects of recycling (e.g. the presence in the final product of unwanted substances such as heavy metals, pharmaceuticals and other contaminants) need to be kept under constant monitoring and be subject to risk assessments. Education and communication based on information on quality and risk assessments are needed to make farmers more aware of what they are putting on their land, including the value of nutrients in sewage sludge and other bio-wastes. The role of sewage in conserving soil organic matter was also mentioned as a point that helps to gain farmers’ acceptance.

Several respondents mentioned the EU Fertiliser Regulation as an important instrument to provide more certainty on recycled phosphorus fertilisers. Clear end-of-waste criteria were also flagged as a necessary tool for determining ‘what is a fertiliser and what is a waste’. Some made specific proposals in this respect (e.g. criticising the possible exclusion of sewage sludge from the end-of-waste criteria). Some highlighted the importance of the Sewage Sludge Directive in terms of controlling the risk associated with sludge use and some made other specific comments (e.g. lowering limit values).

A number of examples were given of existing large sewage sludge recycling operations, signalling that in many cases farmers were not opposed to its use in agriculture. Technology and advanced treatment systems with safer products were also flagged as important in increasing farmers' acceptance.

3. CONCLUSIONS

The replies to the Consultative Communication highlighted clearly that closing the phosphorus cycle is both possible and desirable; a need for action was identified in relation to various policies and stages of the cycle.

In terms of **ascertaining the extent of phosphorus supply and demand**, while the Communication represented a good starting point, the replies pointed to a need to increase the knowledge base. Information on flows and reserves should be more transparent and reliable and should cover more sources and geographical areas. It was suggested, for example, that the EU should establish its own research into demand-supply issues or that it should work with the United Nations or other platforms. Definitions need to be harmonised and a common language adopted if the knowledge base is to be improved.

Security of supply is an issue for most stakeholders. There were calls for the EU to secure its agricultural and food production by seeking greater independence of supply, regardless of worldwide reserves. Work on cooperative agreements with producing countries and technology transfers could help bolster security of supply, while enhanced recycling could reduce the need for phosphate rock. The quality of imported phosphate rock is another important issue to be addressed.

Most respondents agreed on the need for EU action to handle the **risk of soil contamination.** Cadmium in phosphate rock was the contaminant referred to most often, but not the only one. Clear standards based on scientific evidence were suggested as a means of addressing this issue. The use of recycled phosphorus can be an effective way of avoiding the introduction of new cadmium into the environment, but attention should also be paid to other unwanted substances that could be contained in the recycled products.

Various opportunities were highlighted for preventing and reducing losses from **food waste and other bio-degradable waste.** Drivers or incentives were called for in order to encourage more phosphorus recovery and loss prevention. While recycling could play a role in various processes and waste streams, many respondents emphasised prevention, highlighting separate waste collection and appropriate treatment as key elements. All approaches involving the re-use of phosphorus from food waste or other biodegradable waste should ensure the quality of the recycled product and the availability of sufficient information on its agronomic characteristics.

As regards **phosphorus recycling from waste water,** a clear wish of many stakeholders is that its potential should be unlocked by creating the appropriate market conditions. Non-mandatory approaches were strongly encouraged; mandatory options would need further analysis. Phosphorus recovery and stewardship standards were also suggested. As regards sewage sludge, while opinions varied as to whether the best approach was direct application on land or the use of processing techniques, quality and information on what is applied on land emerge as the key factors ensuring farmers' acceptance.

As regards the **use of phosphorus in agriculture**, technologies and approaches aimed at ensuring balanced fertilisation are important in view of phosphorus sustainability. In some areas, quantities of phosphorus exceed what can be applied on land and appropriate solutions need to be adopted to manage the surplus. Manure processing can help in this respect and can result in concentrated products that are more efficient and easier and cheaper to transport. However, other measures to prevent pollution at source should also be in place to control environmental pressures. Cooperation between sectors (notably livestock and arable farming) is key.

Innovation was broadly encouraged and the opportunities represented by several new technologies were highlighted. The replies to the Communication offer a wide review of technologies for the extraction, processing, use and recovery of phosphorus, with a clear message that environmental gains can be secured throughout the cycle. As regards phosphorus recycling, several technologies are either at a laboratory/pilot stage or ready for use on an industrial scale, but the market is not sufficiently developed. A supportive regulatory framework could facilitate industry-wide roll-outs and market maturity.

The replies also help in identifying a clear list of **research priorities** covering all aspects of the phosphorus cycle. Key priorities are the enhanced monitoring of phosphorus flows and reserves, a deeper awareness of environmental impacts linked to the phosphorus cycle, more knowledge of phosphorus-use efficiency and agronomic behaviour, and further understanding of phosphorus recovery and recycling processes and products, including environmental and economic aspects.

Horizon 2020 and the European Innovation Partnerships (on agriculture, water and raw materials) were identified as the key **policy instruments** to foster research and innovation. The revision of the Fertiliser Regulation emerges as the preferred instrument to create better market conditions for recycled phosphorus products and address other environmental issues surrounding phosphorus fertilisers. Environmental legislation is recognised as an important driver for a sustainable use of phosphorus and its implementation is crucial in keeping phosphorus losses into the environment under control. Water legislation and its implementation stand out in this respect. Attention was drawn to various other possibilities, ranging from voluntary to mandatory standards or targets in the framework of revised policy and legislative instruments. It was also highlighted that a number of initiatives and policy instruments already exist and further action should start with the ‘mainstreaming’ of phosphorus sustainability in the revision and implementation of existing legislation. Further efforts in this direction and any specific legislation on phosphorus would nevertheless require comprehensive analysis of their implications.

Finally, the consultation demonstrated that more work is needed on **awareness-raising**. The sustainable use of phosphorus is gaining visibility but has yet to attract the attention of the wider public. Likewise, the fact that most replies came from a limited number of Member States indicates the need to widen the geographical scope of activities on the issue. Initiatives such as the first European Sustainable Phosphorus Conference, which took place in March 2013, the national phosphorus and nutrient platforms and the European Sustainable Phosphorus Platform have been commended as contributing to the achievement of this goal and raising public awareness of the need to close the phosphorus cycle.