Evaluation and management of arsenic contamination in agricultural soil and water - AgriAs

Framework for management for compliance to the guidelines

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Summary

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This summary defines the framework that will be used in the AgriAs Project Task 5.3 to define recommendations D5.3 'Report on recommendations for sustainable management of the risks linked to the land and aquatic environments in a generic perspective'. The framework is based on the work of the previous WPs and the recognized pathways, risks and criteria.

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1 Introduction

The objective of AgriAs Task 5.2 was to prepare a framework for management for compliance to the guidelines with respect to the developed methodologies for ensuring: sustainability of agricultural soils with respect to the guideline values and the natural background concentrations; protection of groundwater resources, and predicting the uncertainties of risk mitigation (based on the results of the previous WPs).

Recommendations for the formulation of management guidelines will be based on the outcomes of previous WP´s. The formulated framework of recommendations were based on the recognized pathways, risks and criteria that were discussed in the AgriAs workshop on recommendation in Orleans, France, on 27th September 2018. This deliverable is short because it is just the justification of the framework that will be developed in the Task 5.3. The outcome is almost the same as the structure of the final deliverable D5.3.

2 Arsenic pathways in agriculture

This chapter will introduce the pathways of arsenic (As) in agroecosystem. Pathways were already discussed in the D4.1 (Jones et al. 2017) and in the D5.1 report of the AgriAs project (Ahmad et al. 2018) and an updated version of the pathway figure is presented in Fig. 1.

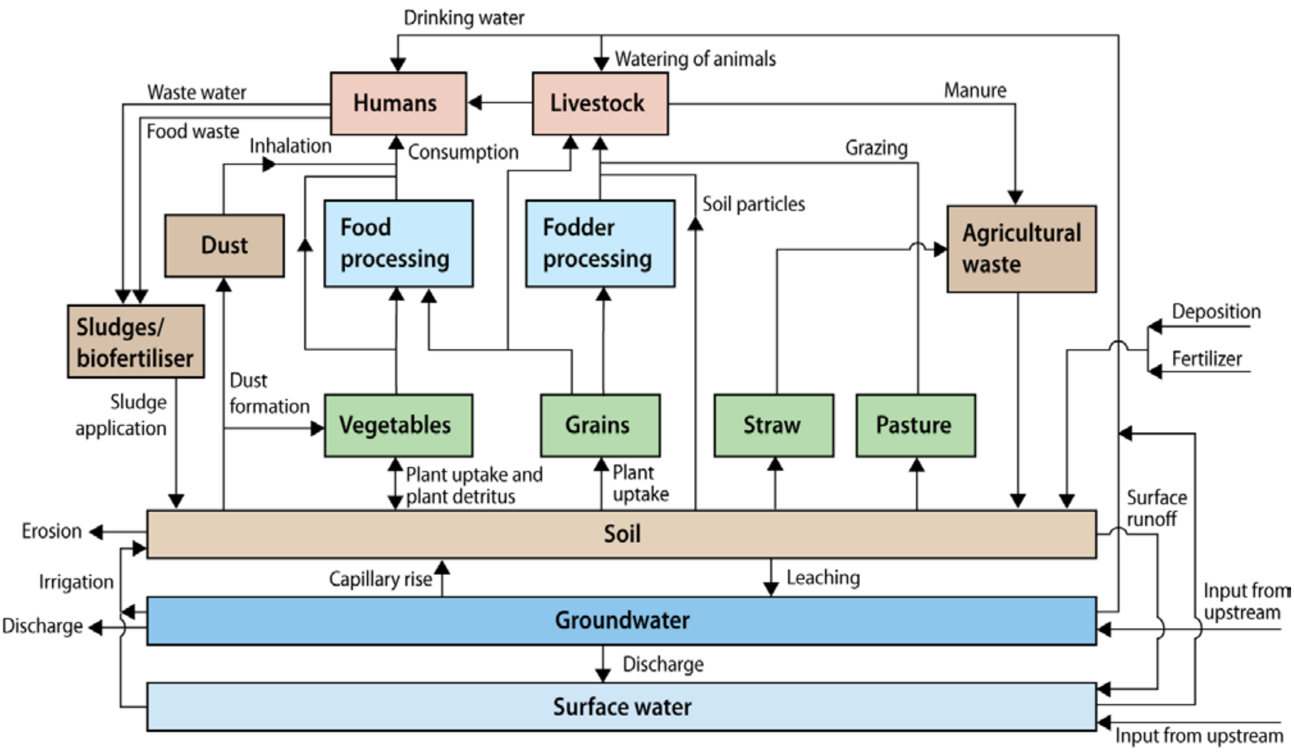

Figure 1. A preliminary model for the pathways and exposure of people to arsenic in agricultural soils (Jones et al. 2017).

Natural concentration of As in agricultural and pasture soils vary in different parts of Europe. According to Tarvainen et al. (2013), the median As concentration in the agricultural soils of southern Europe was found to be more than 3-fold higher than in those of northern Europe (median values of aqua regia extractable concentrations: 2.5 mg/kg vs. 8.0 mg/kg; median values of total As concentrations: 3 mg/kg vs. 10 mg/kg). Most of the As anomalies on the maps can be directly linked to geology (ore occurrences, As-rich rock types). However, some features have an anthropogenic origin (Tarvainen et al. 2015). Weathering of minerals in soil and sediments can enhance the mobility of arsenic. One special example of chemical weathering is the oxidation of arsenic containing acid suphidic soils in the coastal areas of the Baltic Sea.

Atmospheric deposition and applications of arsenic containing fertilizers, sludge, biofertilizers, lime or other soil amendments are additional arsenic sources. Historical sources include arsenic-based herbicides and pesticides. Long-range transported atmospheric deposition can be derived from mining and smelting activities or from coal combustion for energy. Agricultural waste such as manure and straws can add As to the soil as well. Capillary rise of groundwater or irrigation using arsenic containing surface or groundwater can lead to accumulation of arsenic in agricultural soil. When plants have taken arsenic from soil, decaying plant detritus can return part of the uptaken arsenic back to soil.

Soil amendments were mentioned as potential sources of arsenic. However, soil amendments have shown potential in reducing arsenic uptake by plants. Such amendments are iron-based and silica-based additives (Punshon et al. 2017).

Outputs of arsenic from soil include leaching to the groundwater, transport with surface runoff to the streams and lakes, soil erosion, dust and plant uptake.

Punshon and others (2017) summarized in their literature review that below toxic concentrations, the higher the total soil arsenic concentration, the higher the crop uptake of arsenic. Thus, when most of the soil arsenic data are based on total or semi-total arsenic concentrations rather than an estimate of bio-accessible concentration, this total As data is useful in the prediction of As uptake for conventional aerobic agriculture, for aerobic agronomic systems and for anaerobic cultivation systems such as rice.

In addition to plant uptake, As can enter to vegetables with dust. Punshon and others (2017) mention also biovolatilization as a potential output of As. Volatile As species can be formed either biotically by fungi, bacteria or algae – or abiotically. Vegetables and grains are used in food and fodder production and thus enter to humans and to animals. Application of As containing drinking water and inhalation of As bearing dust are other pathways to humans. Arsenic bearing fodder, grazing in As bearing pasture land and watering with As containing water are pathways to livestock.

Among various cultivated soil types, peat soils especially in higher altitudes can be sinks of As. These soils can later become sources of As if the peat is mineralized or eroded (Punshon et al. 2017).

3 Arsenic risks in agriculture

This chapter will summarize risks to human health and ecological risks related to the amount and mobility of As in agricultural soils and related surface and groundwater bodies as well as in the products. Risks are highlighted in Fig. 2.

The main health risks are connected to the consumption of As bearing food products or As-bearing drinking water. In some cases, inhalation of As containing dust can be an additional risk.

ECHA (2017) has published the Opinion of the Committee for Risk Assessment on the Evaluation of the Occupational Exposure Limits (OEL) for arsenic acids and its inorganic salts. Inhalation is the primary route of occupational exposure for arsenic while non-occupational exposure occurs mainly through food and through the drinking water in areas with high levels of arsenic in drinking water resources. Absorption by the dermal route is considered to be low compared to the other routes. The critical endpoint for establishing an OEL is carcinogenicity. However, health-based OELs cannot be established for arsenic acid and its salts because the available data do not allow the identification of a threshold for the genotoxic and carcinogenic effects of arsenic.

Arsenic can also be toxic to livestock through consumption of As containing fodder or water. As-rich soil particles can enter the fodder. Grazing in As rich pasture soil can lead to As input as well.

Arsenic can cause toxicity to plants when plants uptake As from soil. Plants vary in their tolerance to As (see Punshon et al. 2017 for examples). Ecological risks can be linked to soil ecosystem or to aquatic ecosystem.

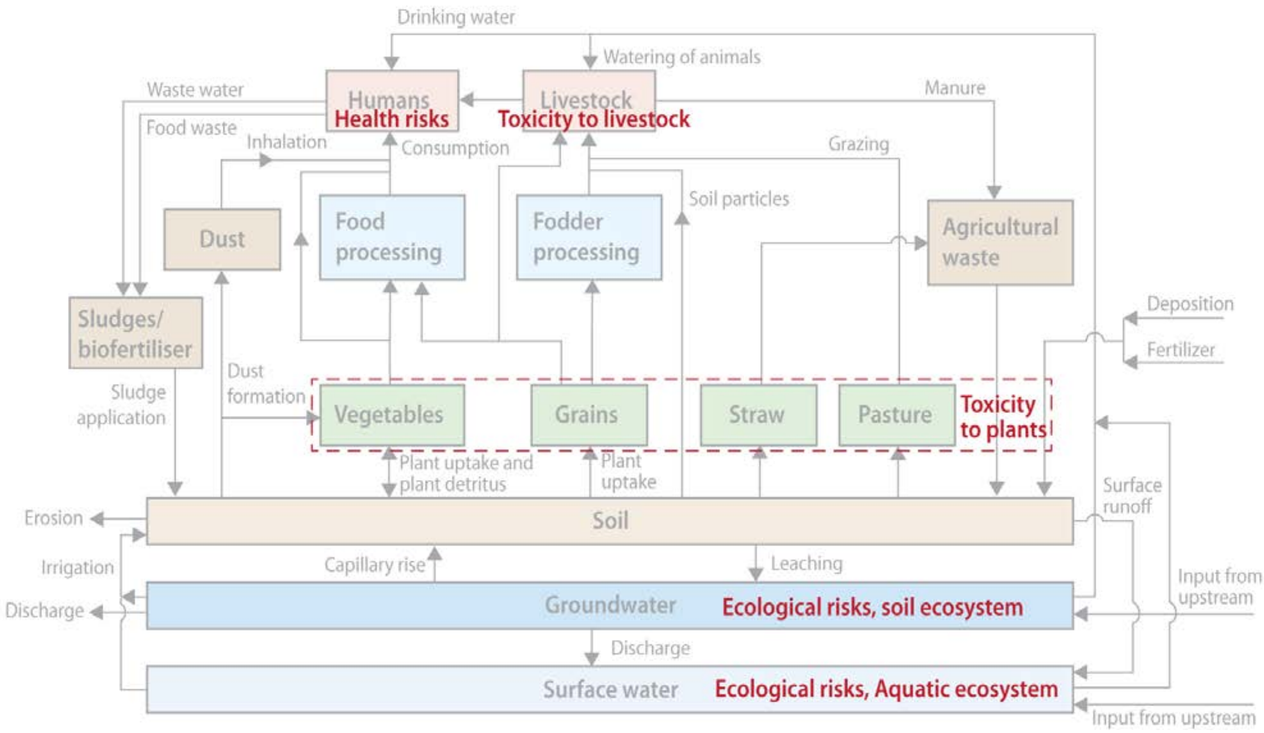

Fig. 2. Risks to human health and ecological risks related to the amount and mobility of As in agricultural soils shown in red. Background: As pathways in agroecosystem.

4 Criteria for soil, water and products and remediation possibilities

This chapter will give a summary of existing criteria for soil, surface water, groundwater, air, dust, foodstuff and fodder taken into account the natural background values in various parts of Europe. In addition to that, the possibilities of good agricultural practices and remediation methods will be discussed. The criteria and remediation options are summarized in Fig. 3.

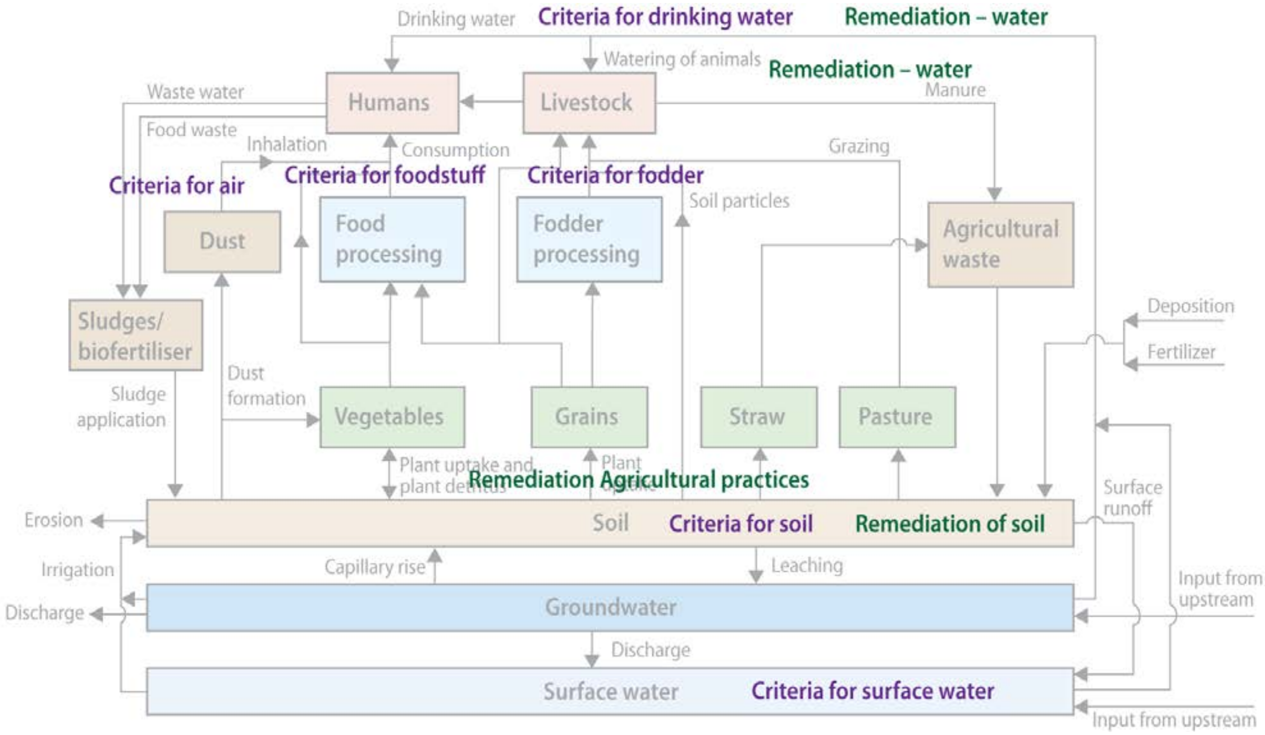

Fig.3. Criteria for soil, water and products and remediation possibilities in agricultural soils, adjacent water bodies and related systems in areas with elevated As concentration.

Criteria can be or have been defined for agricultural soil, for surface water, for drinking water, for air quality, for foodstuff and for fodder As concentrations. Good agricultural practices can reduce mobility of As. Remediation options have been developed both for soil and water.

Punshon and others (2017) made a review on As in agronomic ecosystems and tried to cover processes that influence the entry of As into the human food chain. One of their highlights was that 'understanding the sources of As to crop plants and influence the dynamics of the agronomic As cycle are key to reducing crop uptake of As now, and preventing exposure in future.'

5 The framework

Finally, the key points will lead to the formulated structure of recommendations that will be developed in the Task 5.3. The outcome is almost the same as the structure of the final deliverable D5.3. The proposed structure of recommendations was developed in the AgriAs recommendations workshop in Orleans, France, on 26 September 2018 and presented in Table 1. The workshop was lead by Ingo Müller from the Advisory Board and all partner organizations and subcontractors were present in the workshop.

Table 1. Headlines of recommendations.

1. Sources of arsenic and pathways in agroecosystem
2. European legislation (water framework directive, drinking water directive, soil thematic strategy, food safety)
3. Background values and guideline values (discussion on existing values)
4. Recommendations for site characterisation
5. Recommendations for risk assessment
6. Recommendations for water management
7. Recommendations for agricultural practices (effect on food and fodder)
8. Health risk due to dust and direct contact in rural areas
9. Ecological risks
10. Recommendations for risk management, soil remediation, management and reuse
11. Recommendations for further research and development (Addressing Research and data gaps)
12. Recommendations for policy (implication and outreach)

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