

SUPPLEMENTARY MATERIAL

Table S1. Explanation of flows: assumptions made, references, entered and reconciled values, including uncertainties (coefficients of variation (CV)).

Flow	Description	Assumptions and calculations	References	Reconciled values		Values entered in STAN	
				Amount, t P/year	CV, %	Estimated amount, t P/year	CV, %
F1 Phosphate ore	P in imported phosphate ore	Statistical data on import of 2510 Natural calcium phosphates, natural aluminium calcium phosphates and phosphatic chalk, and in particular 25102000 (Ground) was used to estimate amount of phosphate ore. P content in ore as P_2O_5 was taken 38% and 32% (from Russia other countries, respectively).	[1-4]	214,718	11.35	216,871	21.21
F2 Phosphogypsum waste	P in phosphogypsum from phosphate ore processing	Amount of the generated phosphogypsum waste was retrieved from Waste accounting at Lithuanian Environmental Protection Agency (EPA). Average total P concentration as P_2O_5 was taken 1.66%.	[5,6]	14,776	21.16	14,766	21.21
F3 Fertilizer & feed additives	P in fertilizer & feed additives produced at the local phosphate ore processing company	Company data was used on produced amount of fertilizers and feed additives, as well as on P content in these various products. Diammonium phosphate dominated among the products (46% P_2O_5). The other major production, although varying in different years, included monocalcium phosphate (22.7% P_2O_5), monoammonium phosphate (61% P_2O_5), carbamide phosphate (44% P_2O_5), and NP(S)+Zn+B complex fertilizers (40% P_2O_5).	[7]	199,942	12.14	202,135	21.21

F4 Fertilizers	P in imported ready P fertilizers	Amount of the imported fertilizers was taken from statistical data (expressed as kg of P ₂ O ₅ or in kg of fertilizer and then re-calculated based on potential amount of P ₂ O ₅). The imported amount was then adjusted based on balance calculations to include only fertilizers that were used within the country and exclude re-export.	[1]	12,053	33.53	12,089	33.54
F5 Food & fodder	P in imported food and feed (crops, animal products, processed food)	<p>Amounts of imported major plant and animal products were retrieved from statistical data on Supply Balance Sheets for Agricultural Products. Amounts of imported processed food and feed were taken from statistical data (Detailed international trade in goods indicators): numerous product codes of combined nomenclature under Prepared foodstuffs; beverages, spirits and vinegar.</p> <p>Flow of each product was multiplied by P concentration in that particular type of product. P concentrations: from literature.</p>	[1, 8-14]	6167	42.47	6182	42.43
F6 Others	P in imported non-food commodities such as detergents, chemicals, also plants and livestock	<p>Flows of various commodities containing P were taken from statistical data (Detailed international trade in goods indicators): detergents, chemicals, live animals, plants. P concentrations in these flows were taken from literature or estimated based on chemical formula (for chemicals).</p> <p>For detergents, it was assumed that majority of them is P-free (0.01 g P/g). Detergents and chemicals dominate among the import of Others.</p>	[1,15-17]	1696	42.45	1697	42.43

		For imported plants/ flowers, P concentration was assumed 0.25% (According to [15], P concentration in plants ranges from 0.05 to 0.5% of the dry weight.)					
F7 Fertilizers	P in exported P fertilizers	Export of P fertilizers produced in the country was based on company data. About 93% of production is exported. P concentrations in products see under F3.	[7]	147,896	16.33	145,783	21.21
F8 Food & fodder	P in exported food and feed (crops, animal products, processed food)	<p>Amounts of exported major plant and animal products were retrieved from statistical data on Supply Balance Sheets for Agricultural Products. Amounts of exported processed food and feed were retrieved from statistical data: numerous product codes of combined nomenclature under Prepared foodstuffs; beverages, spirits and vinegar.</p> <p>Flow of each product was multiplied by P concentration in that particular type of product. P concentrations: from literature.</p>	[1,8-14]	22,184	41.31	21,992	42.43
F9 Others	P in exported non-food commodities such as detergents, chemicals, also plants and livestock	<p>Flows of various commodities containing P were retrieved from statistical data (Detailed international trade in goods indicators). P concentrations in these flows were retrieved from literature. See details under F6.</p> <p>The export of Others is dominated by feed phosphates (monocalcium phosphate).</p>	[1,7,15-17]	43,226	38.86	42,507	42.43
F10 Fertilizers used	P in fertilizer applied to arable and grassland	Amount of the used fertilizers was retrieved from statistical data (expressed as kg of P ₂ O ₅).	[1]	23,088	14.95	23,062	15

F11 Seeds & planting material	P in seed and planting material used in agriculture	This comprises a share of imported plants (assumed 10%), and locally grown seeds and planting materials (removed from and returned to Agricultural land). Flow of the latter was retrieved from statistical data on Supply Balance Sheets for Agricultural Products. P concentrations: from literature.	[1, 10-14, 17]	992	33.53	992	33.54
F12 Fodder input	P in feed phosphates and in imported animal fodder	Feed phosphates used in animal husbandry in the country were calculated as a difference of produced (company data) and exported (statistical data) amount. P ₂ O ₅ concentration: 22.7%. Imported fodder was retrieved from statistical data.	[1,7]	3406	31.39	3405	33.54
F13 Live animals from import	P in livestock imported to the country	Amounts were calculated from statistical data on number and weight of imported/ exported animals; literature sources were used for P concentration in various animals.	[1, 16]	11	21.21	11	21.21
F14 Live animals to export	P in livestock exported from the country			4	21.21	4	21.21
F15 Plant products	P removed from agricultural land in crops	Flow of plant products from agricultural land to Industry Trade Commerce was based on statistical data on Supply Balance Sheets for Agricultural Products. Flows include total harvest minus losses and amount used for fodder. P concentrations in various plants: from literature.	[1,8, 10-14]	22,776	33.32	22,906	33.54
F16 Milk & eggs	P removed from agriculture in produced milk and eggs	Flow of milk and eggs going to Industry Trade Commerce was based on statistical data on Supply Balance Sheets for Agricultural Products. Flows include total amount minus internal use in agriculture	[1,12, 18]	1497	21.11	1497	21.21

		for fodder and hatching: these stay within the process Animal husbandry.					
F17 Meat	P removed from agriculture in produced meat	Flow of meat going to Industry Trade Commerce was based on statistical data on Supply Balance Sheets for Agricultural Products. P concentrations in various meat: from literature.	[1,18]	486	21.2	486	21.21
F18 Fodder	P removed from agricultural land in produced fodder and taken up during animal grazing	Flow of fodder was taken from statistical data on the harvest of plant products. P concentrations in various plants were retrieved from literature.	[1, 10, 11, 16, 18]	7201	22.48	7210	33.54
F19 Livestock manure	P in animal manure applied to agricultural land	<p>P in livestock manure was calculated based on numbers of cattle and poultry, and P excretion norm (P/yr for an animal). All manure was assumed to reach agricultural fields.</p> <p>Numbers of cattle and poultry were taken from statistical data. Excretion norms were retrieved from a legal document on manure and sewage management: dairy cows 13-18 kgP/yr; heifers 6 kgP/yr; calves 3 kgP/yr; cattle for slaughter 6 kgP/yr; breeding sows 10 kgP/yr; pigs for fattening 2 kgP/yr; laying hens (1000) 140 kgP/yr; other poultry (1000) 50 kgP/yr; horses 12 kgP/yr, sheep 1 kgP/yr.</p>	[1,19, 20, 21]	8612	17.55	8607	21.21
F20 Food	P in food for consumption	<p>Food flow for consumption was taken from statistical data on Supply Balance Sheets for Agricultural Products.</p> <p>For ready products, a difference between P in import and export was calculated.</p>	[1, 8-14]	2968	42.37	2965	42.43

		P concentrations: from literature (see under F5 and F8).					
F21 Others	P in non-food commodities such as detergents, flowers, straw (e.g. construction), etc.	Non-food commodities comprise detergents (a difference between import and export; assumptions on P concentration see under F6), a share of imported plants/ flowers (90%), a share of P in chemicals (10% from import-export difference; assumed to be included into various products), a share (30%) of straw delivered to other users.	[1, 10, 15, 17]	464	42.42	464	42.43
F22 Domestic wastewater	P in wastewater from domestic sources (collected via networks and cesspits)	P in domestic wastewater was retrieved from Eurostat data.	[22]	2056	15.28	2061	33.54
F23 Industrial wastewater	P in wastewater from industrial sources (both treated on site and diverted to municipal treatment)	P in industrial wastewater was retrieved from Eurostat data.	[22]	283	41.94	283	42.43
F24 Effluent	P in wastewater discharged from wastewater treatment plants to water bodies	P in effluents from wastewater treatment was retrieved from data of Lithuanian EPA (143-157 t), and cross-checked with Eurostat data (131-146 t).	[22,23]	150	33.46	150	33.54
F25 Pit drainage and discharges	P in effluents from individual wastewater treatment, pit drainage	Based on expert judgement. The total connection to the centralized collecting systems in 2019 was 76.45%. Majority of those using individual treatment were in rural areas small agglomerations.	[24]	100	60	100	60

F26 Sewage sludge	P in sewage sludge to waste treatment operations (incineration, composting, landfilling)	P in sewage sludge was calculated as a difference of P in inflow to waste water treatment and in waste water treatment effluents (calculation shows treatment efficiency to be about 93%).	[22,23]	2189	13.57	2195	33.54
F27 Waste	P in biowaste fraction of municipal waste, both mixed and source-separated	P in the total generated municipal solid biowaste (BW) fraction was calculated by summing up P in source separated biowaste that goes to home composting or green waste composting sites, and P in biowaste fraction of mixed municipal waste (MMW) that goes to centralized sorting facilities. Flow volumes were retrieved from Lithuanian EPA and Regional Waste Management Centers, and multiplied by respective P concentrations. P concentration was taken 0.15% in BW of MMW, 0.4% in home composting, and 0.14% in green waste composting flow.	[5,25-29]	780	20.44	781	42.43
F28 Industrial waste	P in industrial waste, mainly food processing	P in biowaste from industries include wastes under the waste codes from 02 02, 02 03, 02 04, 02 05, 02 06, and 02 07 in waste code chapter 02(Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing). Data on these flows was retrieved from Lithuanian EPA Waste accounting based on waste codes. P average concentration in industrial waste flows was taken 0.2%.	[5, 29]	100	26.94	110	42.43
F29 Crop farming waste	P in waste from crop farming that is not utilized/ recycled in the farms themselves	Flows were retrieved from statistical data, P concentrations (0.35% P in grain cleaning residues, 0.1% in straw, 0.04% in horticulture waste)): from literature.	[1,10,13]	26	33.6	26	33.54

F30 Animal husbandry waste	P in waste from animal husbandry that is not utilized/ recycled in the farms themselves, e.g. fallen animals	Flows were retrieved from statistical data, P concentrations (0.2% in animal tissue waste and fallen animals): from literature.	[1,16,18]	19	33.66	19	33.54
F31 Sewage sludge to agriculture	P in sewage sludge directly applied to agricultural land	P in sewage sludge that was diverted to agriculture was calculated based on the total amount of P in generated sludge (see F26) and a share of sludge that was diverted to agriculture. According to Lithuanian EPA and Eurostat, 30-38% (or 12,289-15,892 t) of sewage sludge generated in municipal wastewater treatments plants per year went to agricultural use.	[5,22,23,30,31]	759	30.59	758	33.54
F32 Compost	P in compost produced from sewage sludge and/ or green waste. In this analysis it is all added to agricultural land, although in fact a part of it is used for other types of land. Home-composting compost not included.	Compost production from sewage sludge and separately collected biowaste and green waste were the sources of the compost. P concentration in green waste compost (0.14%), and in compost from other sources (0.4%): from literature.	[5,25-28,30,31]	803	26.06	785	42.43
F33 Compost to gardens	P in home-composted compost to gardening	Amount of BW going to home composting was retrieved from Regional Waste Management Centres. It was taken that a yield of the finished compost is 40% of the original weight, with P concentration 0.4%.	[25-28]	194	33.04	193	33.54

F34 Digestate	P in digestate from biogas production to agriculture			34	21.11	34	42.43
F35 Leaching & erosion	P lost to water bodies from agricultural land	According to Helcom NIC (National Input Ceiling) 2020 assessment results with country per basin, discharges from Lithuania were 1165 t P/yr. When P from point sources is subtracted (150 t and 100 t), this results in 915 t from diffuse sources.	[32]	900	45	900	45
F36 Leachate	P in leachate from landfills, sludge polygons, composting sites	Expert judgement. Leaching from landfills or other waste treatment operations is expected not to be substantial as good practice is largely followed.	-	0.3	34.64	0.3	60
F37 Sewage sludge (SS) to composting	P in sewage sludge from waste water treatment to composting	P in sewage sludge that went to composting was calculated based on the total amount of P in generated sludge (see F26) and a share of sludge that was diverted to composting. According to Lithuanian EPA and Eurostat, 21-42% of sewage sludge generated in municipal wastewater treatments plants per year went to composting.	[5,22,23,30, 31]	740	26.28	749	33.54
F38 Sewage sludge (SS) to incineration	P in sewage sludge from waste water treatment to incineration	P in sewage sludge that went to incineration was calculated based on the total amount of P in generated sludge (see F26) and a share of sludge that was diverted to incineration. According to Lithuanian EPA and Eurostat, 4.3-35% of sewage sludge generated in municipal wastewater treatments plants per year went to incineration.	[5,22,23,30, 31]	323	33.01	323	33.54
F39 Sewage sludge (SS) to landfill	P in sewage sludge from waste water treatment to landfilling	P in sewage sludge that went to landfilling and other storage operations was calculated based on the total amount of P in generated sludge (see F26) and a share of sludge that was went to these operations. According to Lithuanian EPA and Eurostat, 14-21% of sewage	[5,22,23,30, 31]	365	32.86	365	33.54

		sludge generated in municipal wastewater treatments plants per year went to landfilling or storage.					
F40 Biowaste (BW) in mixed municipal waste (MMW)	P in biowaste fraction of mixed municipal waste	Flow volume of BW going to centralized sorting facilities (364,445 t) was calculated from data at Lithuanian EPA. P concentration in BW of MMW was taken from literature (0.15%).	[5,29]	546	23.08	547	42.43
F41 Technical compost	P in technical compost produced during aerobic or anaerobic treatment of biowaste separated from mixed municipal waste in mechanical biological treatment (MBT) facilities	Flow volume of BW undergoing aerobic or anaerobic treatment was calculated from data at Lithuanian EPA. P concentration was taken from literature (0.15%). Technical compost is not used for agricultural purposes due to quality issues.	[5,29]	318	35.98	318	42.43
F42 Biofuel	P in granules or other biofuel produced at MBT facilities	Flow volume of BW going incineration was calculated from data at Lithuanian EPA. P concentration was taken from literature (0.15%).	[5,29]	228	39.24	228	42.43
F43 Source separated biowaste (BW) to composting	P in source separated biowaste which then goes either to composting sites or home composting	Amount of BW going to green waste composting sites and to home composting was retrieved from Regional Waste Management Centres. See also F32 and F33.	[25-28]	234	49.4	236	54.08

F44 Biowaste (BW) to composting	P in agricultural and industrial biowaste that is composted	Industrial (food processing) waste flows that go to particular treatment method were retrieved from Lithuanian EPA Waste accounting based on waste codes (see also under F28). P average concentration in industrial waste flows was taken 0.2%. Agricultural waste flows that go to particular treatment method were retrieved from statistical data. P concentrations were taken from literature (see under F28, F29 and F30).	[1,5,8,10,14,16,18,29]	22	41.13	22	42.43
F45 Biowaste (BW) to biogas	P in agricultural and industrial biowaste that is used to produce biogas			34	29.11	34	42.43
F46 Biowaste (BW) to incineration	P in agricultural and industrial biowaste that goes to incineration			19	41.36	19	42.43
F47 Biowaste (BW) to other treatment	P in agricultural and industrial biowaste that is diverted to other treatment or usage (not particularly specified)			66	35.64	63	42.43
F48 Biowaste (BW) to landfill	P in industrial biowaste goes to landfill			2	42.36	2	42.43
F49 Ash & slag	P in incineration ash & slag to landfilling	Calculated from the balance	-	571	24.46	-	-
F50 Leaching from composting	P in leachate composting sites	Expert judgement. See F36.	-	0.15	54.77	0.15	60

F51 Leaching from landfills	P in leachate from landfills, sludge polygons	Expert judgement. See F36.	-	0.15	54.77	0.15	60
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