www.NanoFASE.eu (EU H2020 Proj. 646002)

NSC WS Basel 10th Feb 2016

Estimating Soil Concentrations of ENP X in agricultural land from sludge application.

Sewage sludge is applied periodically to agricultural soils in some countries. The sludge will contain nano-particles which have been removed during treatment. The aim here is to make a simple calculation of what is the concentration in soils that receives a single sludge application to a soil that had not previously been exposed.

The basic equation for calculating the soil concentration, C(g/kg dry weight) in country Y for ENP X resulting from a single annual application of sludge to a pristine soil is given by Equation 1.

$$C_{X,Y} = \frac{P\_Ld\_inf_X \times Pop_Y \times Con_Y \times R_X}{AAS_Y \times d \times \rho_{soil}}$$ Equation 1

- $P\_Ld\_inf_X$ (g/cap/year) is the European average per capita load of ENP X entering the sewer system
- Pop_Y is the total population of country Y, R_X is the removal efficiency of ENP X in STPs (0-1)
- Con_Y is the fraction of the population connected to sewage treatment in country Y,
- d is the depth of the plough layer (m) into which ENPs are mixed
- ρ_{soil} is the bulk soil density (kg/m^3)
- AAS_Y is the agricultural land area with applied sludge (m^2). The details of how these parameters are calculated and the data sources used are given in the equations below.

The task is simply to derive estimates of the concentrations of nano-Ag or nano-Zn using suitable values for these parameters for a country. Compare the results with PNECs and consider the implications.

The tables below will give you some realistic values for these parameters.

Start with conservative values i.e. values likely to give a worst case PEC.

Assume: everyone is connected to waste water treatment, the treatment removes 100% of the nano-particles, the sludge is applied to only 1% of agricultural land (typical of the UK) in any given year and the plough depth is only 0.12 m (consistent with organic farming).

Consider how this estimate might be refined using other values from the tables below. Looking at how the PEC compares with the PNEC would it need refining?

Useful Information:

Table s1 Parameters used for estimating soils concentrations of nano-particles **(Keller et al in prep)**

Parameters	**Nano Ag**		**Nano ZnO**	
Mass released to Sewer in the EU27 (tonnes/year) [1] – *EU27_Ld_inf*	8.85		1050	
Population of the EU27 Population in EU28 [2]	501,383,000 505,645,000			
Fraction of the population connected to sewage treatment plants [3] - *Con*	The values for each country are given in Table S2			
Scenario	Worst	Expected	Worst	Expected
Fraction captured in Sludge R_X^*	0.99	0.93	0.88	0.85
Soil exposure method EU 28				
National sludge disposal to agricultural land [2, 4] – *AU*	See Figure 1 and Supplemental data for tabulated data.			
Scenario	Worst	Expected	Worst	Expected
% Agricultural land - *%AgrLandSludge*	1	57	1	57
Ploughing Depth (m) – *d*	0.12	0.25	0.12	0.25
Average Soil Bulk Density (kg/m^3) - ρ_{soil}	1,700			

* ENP-Ag: Expected case value was taken as the median of values from 10 studies reported in Dumont *et al.*, 2014[5]. The worst case was taken from the result of an un-published batch experiment conducted in the NanoFATE project. ENP-ZnO: Expected case value is the median of three published documents[1, 6, 7]. The worst case value was the maximum of these studies[1].

Table S2: Country specific data used to calculate soil concentrations nanoparticles resulting from applications of sewage sludge (Keller et al in prep).

Country	**Total Area Km^2**	**% Arable land**	**% Total Agricultural land**	**Population (millions)**	**% of the Population Connected to Sewage Works**	**% of total sludge used in Agriculture**
Austria	83858	13.1	32.7	8.45	90	16.9
Belgium	30528	21.9	57.6	11.16	85	9.8
Bosnia and Herzegovina	51197	2.2	37.4	3.90	56	0.0
Bulgaria	110912	35.3	51.7	7.28	69	33.9

Croatia	56538	6.9	44.0	4.26	68	0.0
Cyprus	9251	28.7	48.0	0.87	28	82.1
Czech Republic	78866	41.4	57.8	10.52	78	49.7
Denmark	43094	65.3	77.5	5.60	89	52.5
Estonia	45100	14.7	32.7	1.32	73	4.4
Finland	338145	4.8	8.7	5.43	80	5.6
France	551500	28.0	59.9	65.58	82	75.2
Germany	357022	38.2	59.8	80.52	96	29.1
Greece	131957	16.8	40.2	11.06	85	4.1
Hungary	93032	53.3	67.9	9.91	65	46.3
Ireland	70273	7.8	67.2	4.56	95	67.4
Italy	301318	27.6	52.0	59.69	94	28.6
Latvia	64600	14.2	43.9	2.02	67	35.0
Lithuania	65300	34.2	61.7	2.97	69	20.1
Luxembourg	2586	8.7	54.9	0.54	100	53.0
Malta	316	0.6	50.4	0.42	100	0.0
Netherlands	41528	21.7	70.8	16.78	99	0.0
Norway	385155	4.0	6.5	5.05	83	62.0
Poland	312685	44.8	64.4	38.53	60	22.4
Portugal	91182	15.1	47.9	10.49	57	65.7
Romania	238391	34.2	56.6	20.02	42	1.6
Slovakia	49033	34.0	49.7	5.41	57	0.6
Slovenia	20256	5.6	35.0	2.06	54	0.0
Spain	505992	24.6	50.7	46.73	100	82.6
Sweden	449964	6.7	8.8	9.56	86	24.8
Switzerland	41284	12.7	27.6	8.04	97	9.4

United Kingdom	242900	25.0	58.6	63.91	99	78.8

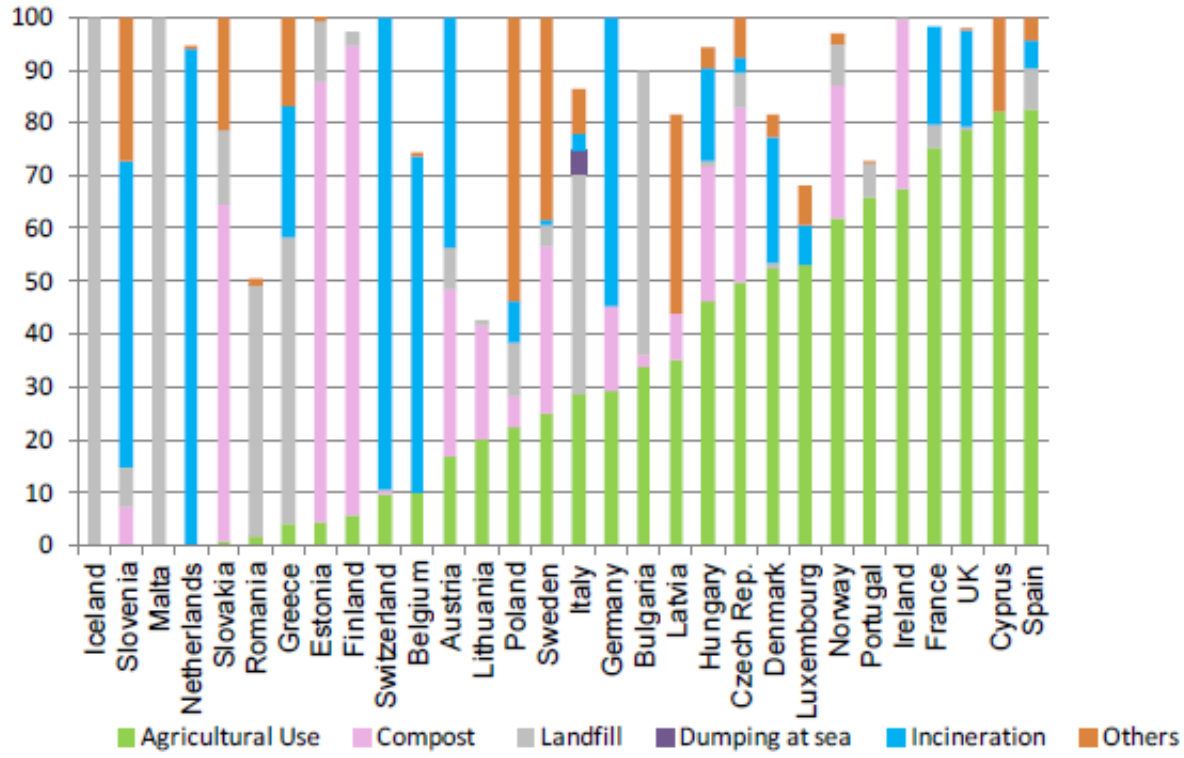
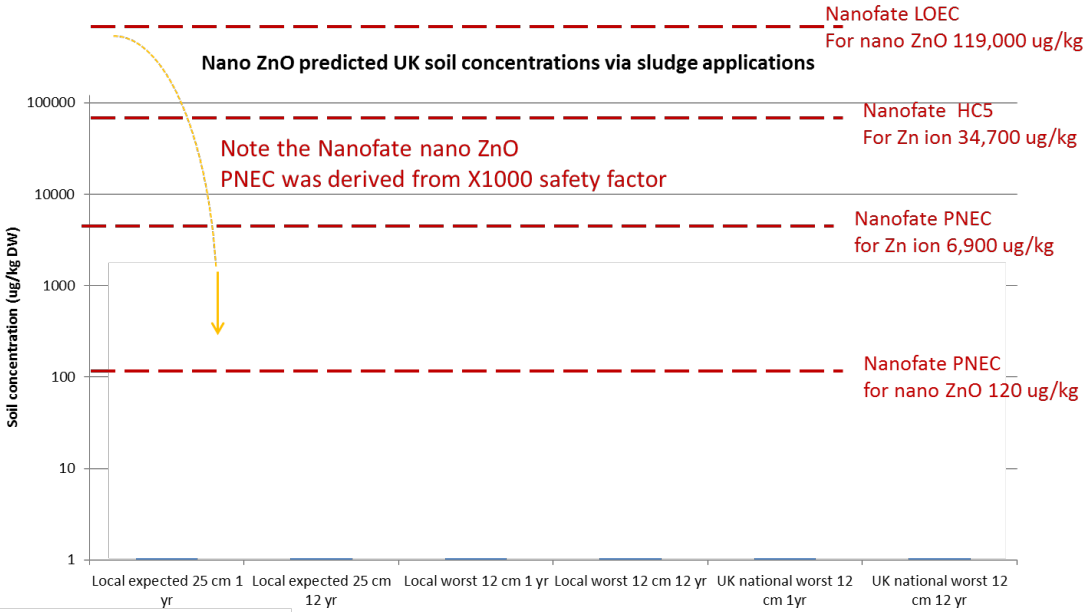


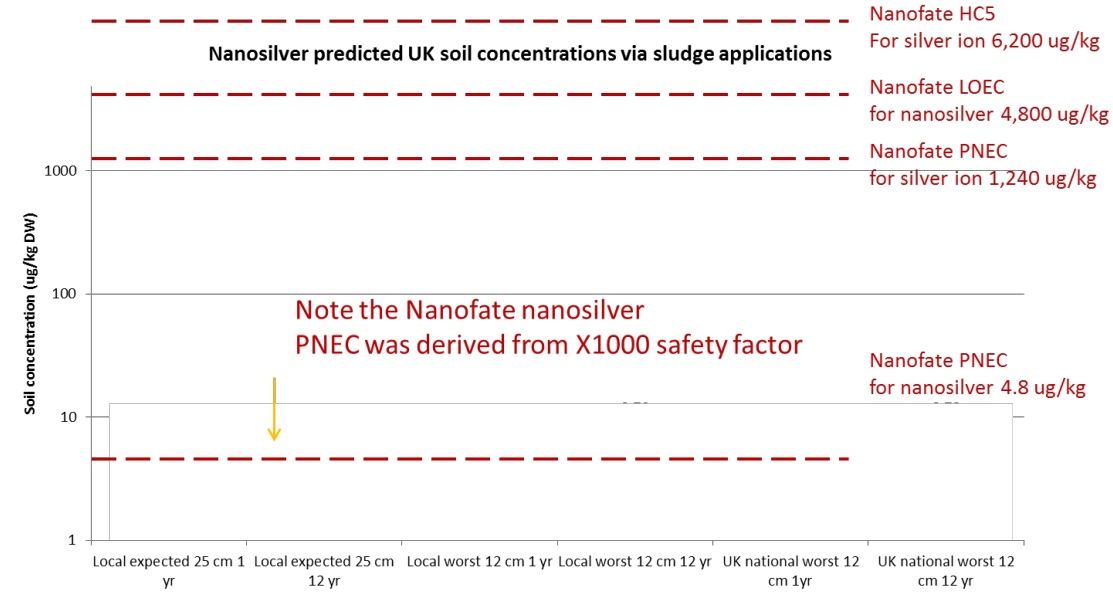
Figure 1 Sludge disposal strategies (% by each route) used by European countries.

(From Keller et al in prep)

Predicted nano ZnO in UK soils and risks



Predicted nanosilver in UK soils and risks



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6. E. Lombi, E. Donner, E. Tavakkoli, T. W. Turney, R. Naidu, B. W. Miller and K. G. Scheckel, *Environmental Science & Technology*, 2012, **46**, 9089-9096.
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