Arsenic, lead, cadmium and mercury in animal feed and feed materials

Trend analysis of monitoring results collected in the Netherlands

P. Adamse, H.J. Van der Fels-Klerx, J. de Jong

WAGENINGEN
UNIVERSITY & RESEARCH

Arsenic, lead, cadmium and mercury in animal feed and feed materials

Trend analysis of monitoring results collected in the Netherlands

P. Adamse, H.J. Van der Fels-Klerx, J. de Jong

This research has been carried out by RIKILT Wageningen University & Research, institute within the legal entity Wageningen Research Foundation funded by the Dutch Ministry of Economic Affairs
(project number WOT-02-004-012).

Wageningen, October 2017

RIKILT report 2017.006

Adamse, P., H.J. Van der Fels-Klerx, J. de Jong, 2017. *Arsenic, lead, cadmium and mercury in animal feed and feed materials; Trend analysis of monitoring results collected in the Netherlands.* Wageningen, RIKILT Wageningen University & Research, RIKILT report 2017.006. 124 pp.; 107 fig.; 64 tab.; 29 ref.

Project number: 122.7225001
BAS-code: WOT-02-004-012
Project title: Statistische onderbouwing Nationaal Plan Diervoeders
Project leader: Ine van der Fels-Klerx

This report can be downloaded for free at https://doi.org/10.18174/416680 or at www.wur.eu/rikilt (under RIKILT publications).

P.O. Box 230, 6700 AA Wageningen, The Netherlands, T +31 (0)317 48 02 56, E info.RIKILT@wur.nl, www.wur.eu/rikilt. RIKILT is part of Wageningen University & Research.

RIKILT report 2017.006

Distribution list:
- Netherlands Food and Consumer Product Safety Authority, Utrecht, the Netherlands (NVWA): M.L.H. Pelk, R.D. van Buuren, M.W. van Brakel, Karen Zwaagstra, H.A. van der Schee, E. Oldeheuvel, J. Schans, R.C.M. Theelen, J.A. van Rhijn, H.J. Hagen-Lenselink, S. van der Meijs, S. Ljubijankic;
- Netherlands Ministry of Economic Affairs, Department of Agro Plant Supply Chain and Food Quality, The Hague, the Netherlands (EZ-PAV); F. Leijdekkers, S.J. Beukema
- Netherlands Ministry of Economic Affairs, Department of Agro Knowledge, The Hague, the Netherlands (EZ-AK): G.J. Greutink
- Wageningen University and Research, Livestock Research: W. Hendriks
- Netherlands National Institute for Public Health and the Environment, Bilthoven, the Netherlands (RIVM): G. van Donkersgoed, A. Bulder
- European Commission, Directorate General for Health and Consumers (EC, DG SANCO E-1): F. Verstraete
- Secure Feed: F. Gort, Y. Yntema, G. van Heerikhuize
- Comité van Graanhandelaren: P. van de Graaff
- GMP+ International: J. den Hartog

Contents

Summary

This study aimed to obtain insights into the presence of arsenic, lead, cadmium and mercury in feed materials and feed over time, for the purpose of guiding national monitoring. Data from the Dutch feed monitoring programme and from representatives of the feed industry during the period 2007-2013 were used. Data covered the concentrations of arsenic, lead, cadmium and mercury in a variety of feed materials and compound feeds in The Netherlands. Trends in the percentage of samples that exceeds the maximum limits (ML) set by the European Commission, and trends in average, median and 90th percentile concentrations of each of these elements per feed material or compound feed were investigated.

Based on the results, monitoring for arsenic, lead, cadmium and mercury should focus on feed material of mineral origin, feed material of marine origin, especially fish meal, seaweed and algae, and feed additives belonging to the functional groups of (1) trace elements (notably cupric sulphate, zinc oxide and manganese oxide for arsenic) and (2) binders and anti-caking agents. Mycotoxin binders are a new group of feed additives that need attention. For complementary feed it is important to make a proper distinction between mineral and non-mineral feed because the ML in the latter group is usually lower. In seaweed/algae products a relatively large number of samples contained arsenic concentrations that exceeded the ML. Forage crops in general do not need high priority in monitoring programmes, although arsenic in grass meal still needs attention.

Keywords: heavy metals, element, cadmium, lead, mercury, arsenic, trends, feed, feed material, compound feed, chemical contaminant, monitoring program.

1 Introduction

Animal feed and feed materials can be contaminated with undesirable substances, which may originate from the environment and/or the production process. When production animals consume such contaminated feed, the contaminants may transfer to food of animal origin, such as liver, meat and milk. In the European Union (and most of the rest of the world) legislation is in place to manage feed and feed material contamination. Official limits and guidelines indicate maximum permitted levels of each contaminant, often per feed (material) group. Also procedures for control of the presence of the contaminant are prescribed, e.g., the number of samples to be taken for certain contaminants. Within the European Union (EU) Regulation (EC) No 882/2004 describes rules for the official controls that have to be performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules (EC, 2004). In accordance with this regulation each EU Member State draws up a multi-annual control programme for feed and feed materials. The programme indicates feed materials - contaminant combinations to be checked as well as the frequency with which the controls will be implemented. Next to European or national monitoring of feed and feed materials, feed producing companies have their own control programmes for contaminants. To establish such control programmes on a risk-based approach it is necessary to have insight into the presence and level of the contaminants in each of the feed materials and animal feeds.

One group of relevant contaminants in feed materials and animals feeds are certain heavy metals and elements. The heavy metals mercury, cadmium and lead and the metalloid arsenic are of concern because they are readily transferred through food chains, have toxic properties and are not known to serve any essential biological function (Lopez-Alonso, 2012; NRC, 2005). Industrial and agricultural developments have been largely responsible for pollution of the environment, although natural geological sources also have contributed to contamination (Lopez-Alonso, 2012; Rajaganapathy et al., 2011). Within the European Commission (EC), the maximum presence of cadmium, lead, mercury and arsenic in feed and feed materials have been regulated in Directive 2002/32/EC, last amended for heavy metals by Regulation (EU) 2015/186.

The aim of the current study was to gain insight into the contamination of feed materials and compound feed used in the Netherlands with arsenic, lead, cadmium and mercury. The emphasis is on compliance with the maximum limits (MLs) set in the European Union, on background concentrations and on possible trends over time. The results can be used to define priorities for national monitoring plans.

Part of this report has been published in Food Additives & Contaminants (Adamse et al, 2017). The annexes present additional and more detailed results (tables and figures) of contamination of feeds and feed ingredients.

2 Materials and methods

Data collection
For the aims of this study, data from the National Feed monitoring programme (NP) of the Netherlands Food and Consumer Product Safety Authority (NVWA) and monitoring data from representatives from the Dutch feed industry (IND) were obtained. Data cover monitoring results, i.e. the presence of the four elements in feed materials and feed used in the Netherlands, between 2007 and 2013. Data do not contain results from targeted samples taken as a follow-up on incidents. However, the monitoring programmes do have a risk-based design to some extent. In most samples all four elements were analysed at the same time. The analysis of mercury, cadmium, arsenic and lead concentrations in the samples was performed as described in Adamse et al (2009) using validated and accredited methods (Table 1). Data from RASFF were used for comparison. These data, covering the same time period, were subtracted from the RASFF portal with search criteria product type ”feed” and hazard category ”heavy metals” (RASFF, 2014). The RASFF data include all notifications from the EU. Usually, the feed materials that are notified in RASFF are also used in the Netherlands. This means that the warnings from other European countries are relevant for the Dutch situation as well.

Table 1 *Detection methods used. For IND samples LOQs vary between matrices and laboratories that performed the analyses.*

Element	Data source	Analysis method	LOQ (mg/kg)
mercury	NP	Flow Injection Mercury System (FIMS)	0.01
	IND	Cold Vapour-Atomic Absorption (CVAAS)	0.02
	IND	Atomic Absorption Spectrometry (AAS)	0.005 – 10
cadmium	NP	Multi-element Electro thermal Atomic Absorption Spectrometry (ETAAS)	0.02
	IND	Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)	0.01 or 0.02
	IND	Inductively Coupled Plasma Mass Spectrometry (ICP-MS)	0.01 – 0.1
lead	NP	ETAAS	0.1
	IND	ICP-AES	0.1
	IND	ICP-MS	0.005-0.5
arsenic	NP	ETAAS	0.1
	IND	ICP-AES	0.002-2
	IND	ICP-MS	0.01 – 2

Data analysis
Product names were harmonized to enable combining them into one dataset. The products were grouped according to feed groups defined in Regulation (EC) No 767/2009 (EC, 2009) and according to the groups used for defining the ML for cadmium, mercury, lead and arsenic in animal feed and feed materials according to Directive 2002/32/EC (EC, 2002), last amended for heavy metals by Regulation (EU) 2015/186 (EU, 2015). This enables grouping products with the same ML. Where applicable, subgroups were used to highlight specific feed materials that differ from the rest of the group.

Because the data originate from different suppliers the limits of quantification (LOQs) varied, but in general (most records) the LOQs for mercury, cadmium, lead and arsenic were 0.01, 0.02, 0.1 and 0.1 mg/kg, respectively. Values reported as < LOQ were replaced by zero for the statistical analysis. Apparent outliers, i.e. samples with an exceptionally high concentration, were examined individually and excluded from the dataset when they appeared to be the result of targeted sampling (Adamse, 2014).
Descriptive analysis was used to calculate averages (avg), medians (P50), 90^{th} (P90) percentiles and percentages of samples exceeding the ML per feed group (% > ML). The Pearson Correlation Coefficient (MS Excel®) was used to evaluate the significance of potential trends in the presence of the

element over the time period considered. Trends with R^2 values exceeding 0.30 were considered significant. In some trend analyses (Van der Fels-Klerx et al. 2012) 20 observations per year were considered a minimum, but in the current analysis every number of measurements per year is taken into account. Trendlines were always calculated, however, sometimes the number of samples was too low to consider any trend to be significant, often indicated by a R^2 value of 1 (or close to 1) or #N/A. This will be addressed where applicable.

Interpreting the results
The monitoring results were studied per contaminant and feed material product (sub)group. Each contaminant/product(sub)group combination was studied in detail with separate trend analyses using the average, median, P90 or % > ML. The result of those analyses are summarised in separate tables for each contaminant. Results are evaluated and colours in the trend tables are added to indicate the level of priority this feed of feed material should have in the national monitoring plan. The priority was considered high (I) when two or more of the following criteria were fulfilled: average concentration higher than 20% of ML, more than 3% of the samples exceeded the ML, a significant increase of the average concentration between 2007 and 2013, and/or more than five RASFF notifications (*from all of Europe*). The priority was also considered high when 10% or more of the samples exceeded the ML. The priority was considered medium (II) when only one of the criteria was fulfilled. With low priority (III) none of the criteria was fulfilled.

3 Results and discussion

In general the percentage of samples of all feeds and feed materials that exceed the ML was low for each of arsenic, lead, cadmium and mercury, and did not increase or decrease significantly over the time period considered (Table 2, 5, 6 and 8). However, there were some exceptions, which are discussed below.

Arsenic
Arsenic in feed and feed material originates from natural geological sources, from pollution by industrial activities or from specific feed additives (EFSA, 2005). There are many different MLs for arsenic in the various feed materials (Table 2). The highest ML is for zinc oxide (100 mg/kg) and the lowest (2 mg/kg) is for complete feed and feed materials (with some exceptions). Between 2007 and 2013 in total 14 samples (out of 2701 with an ML) exceeded the ML. For another 828 samples (feed additives and pre-mixtures) no ML for arsenic was applicable.

Table 2 *Summary of the evaluation of the presence of arsenic in animal feed and feed materials between 2007 and 2013.*

Products intended for animal feed	ML (mg/kg)	N (2007-2013)	Average (% of ML)	% > ML	Trend average (R^2)	RASFF (2007-2013)	Priority
Feed materials, with the exception of:	2	1188	3	0	0 (0.00)	6	II
— meal made from grass, from dried lucerne and from dried clover, and dried sugar beet pulp and dried molasses sugar beet pulp;	4	122	14	0	0 (0.25)	0	III
— palm kernel expeller;	4	64	11	0	- (0.85)	4	III
— phosphates and calcareous marine algae;	10	91	21	0	0 (0.15)	1	II
— calcium carbonate; calcium and magnesium carbonate [(10)];	15	106	11	0	0 (0.12)	0	III
— magnesium oxide; magnesium carbonate;	20	41	8	0	0 (0.01)	1	III
— fish, other aquatic animals and products derived thereof;	25	232	12	0.4	0 (0.05)	2	III
— seaweed meal and feed materials derived from seaweed.	40	64	24	11	-[c]	1	I
Complementary feed, with the exception of:	4	6	9	0	-[c]	1	III
— mineral feed;	12	438	8	0	+ (0.84)	1	II
— complementary feed for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed;	10	0	n.a.	n.a.	n.a.	0	III
Complete feed, with the exception of:	2	189	8	1.1	0 (0.01)	0	III
— complete feed for fish and fur animals;	10	3	1	0	0[c]	1	III
— complete feed for pet animal	2	48[d]	7	2	0 [c]	9	II
— complete feed for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed.	10	8	0	0	0[c]	3	III

Products intended for animal feed	ML (mg/kg)	N (2007-2013)	Average (% of ML)	% > ML	Trend average (R^2)	RASFF (2007-2013)	Priority
Feed additives belonging to the functional group of compounds of trace elements, with the exception of:	30	69	11	1.4	0 (0.01)	0	III
— cupric sulphate pentahydrate; cupric carbonate; di copper chloride trihydroxide; ferrous carbonate;	50	37	45	5.4	0 (0.20)	1	I
— zinc oxide [e]	100	45	32	0	0[c]	1	II
Feed additives belonging to the functional groups of binders and anti-caking agents	no ML	209	n.a.	n.a.	+[a] (0.80)	0	II
Feed additives belonging to the category vitamins and pro-vitamins	no ML	80	n.a.	n.a.	0 (0.01)	0	III
Other feed additives	no ML	72	n.a.	n.a.	0 (0.11)	0	III
Pre-mixtures	no ML	466	n.a.	n.a.	0 (0.00)	0	III

Notes: [a] Median and/or [b] P90 increased significantly. [c] Not enough years for reliable trend analysis. [d] Not always sure if it contained fish.
[e] Category includes manganous oxide and cupric oxide, but no samples were available from those product in the current study.

Two product (sub)categories were ranked with a high priority. One is seaweed meal and feed materials derived from seaweed (average concentration 24% of the ML, 11% exceeding the ML, Figure 1). Seaweeds tend to accumulate arsenic; especially the brown algae *S. fusiforme* (Harvey) Setchell (synonym Hizikia fusiformis (Harvey) Okamura) is known for its high concentration of arsenic (Makkar et al., 2016). Since most of the samples of seaweed meal (50 out of 64) were taken in 2009 no trend could be determined. The other high priority category concerns the feed additives cupric sulphate pentahydrate, cupric carbonate, di copper chloride trihydroxide and ferrous carbonate (only cupric sulphate in this study, average concentration 45% of the ML, 5.4% exceeding the ML). Cupric sulphate is produced from industrial by-products, with a high probability of having impurities such as arsenic (Wang, 2014). For cupric sulphate no significant trend was observed.

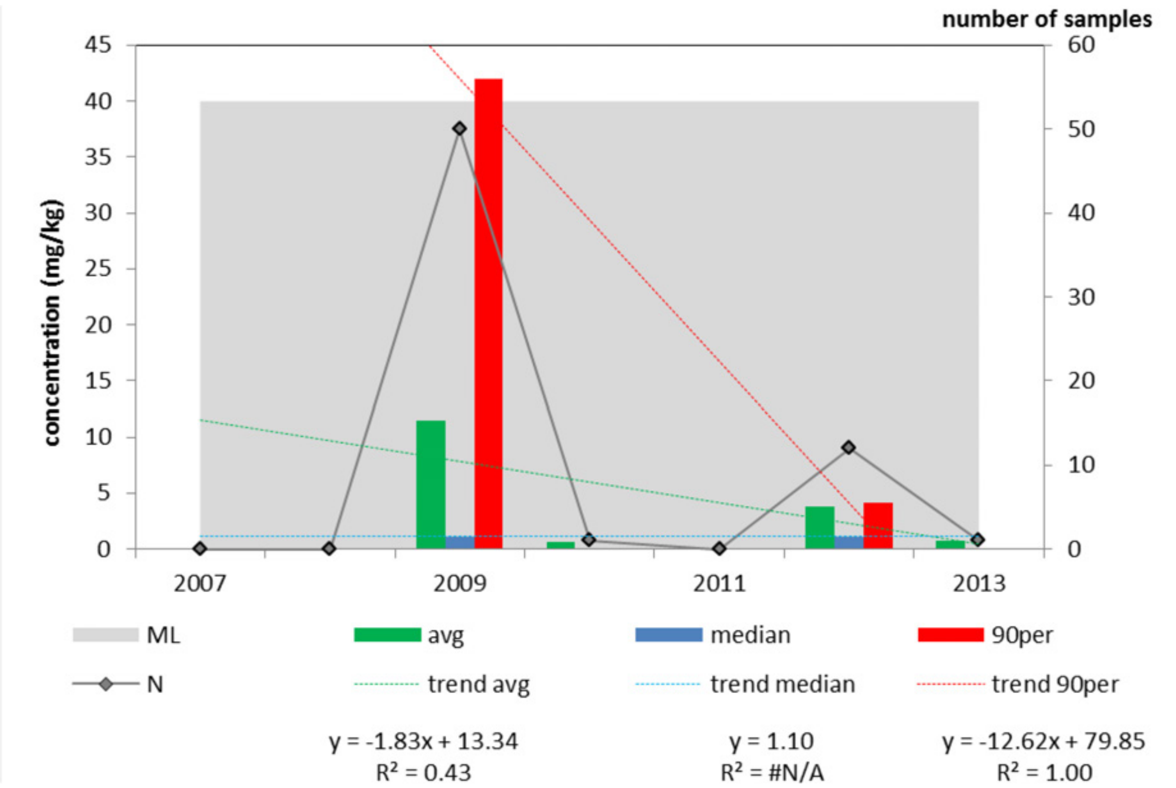

Figure 1 *Average, median and 90th percentile concentration of arsenic in seaweed meal and feed materials derived from seaweed; 2007– 2013, N = 64; ML = 40 mg/kg.*

Several product categories were ranked as medium priority (Table 2). Some because there were five or more RASFF notifications for this product group, namely feed materials with an ML of 2 mg/kg (6 notifications) and complete feed for pet animal (nine notifications). Others because the average arsenic concentration was higher than 20% of the ML, viz. phosphates and calcareous marine algae (average concentration 21% of the ML) and zinc oxide (32% of ML). A third group showed a significant increase of the average arsenic concentration between 2007 and 2013, namely mineral feed and binders (Fig. 2). For binders (i.e. feed additives belonging to the functional groups of binders and anti-caking agents) there is no ML.

In feed materials with an ML of 2 mg/kg the highest reported concentrations were 1.6 mg/kg in vegetable feeding stuff (2009) and 1.4 mg/kg in green maize (2007). The average concentration was low, namely 0.1 mg/kg, i.e. 3% of the ML. RASFF reported notifications for dried apples, sugar beet pulp, sunflower seed meal and yeast (Table 3). This category appears to have some incidents but does not show to be a structural problem.

For the category samples of complete feed for pet animals it was not always clear if the feed contained fish, sea animals or seaweed. The ML for pet feed without fish, sea animals or seaweed is 2 mg/kg whereas the ML for pet feed with fish, sea animals or seaweed is 10 mg/kg. RASFF reported nine notifications related to arsenic in pet feed, most of them having concentrations below 10 mg/kg. As with the pet food samples containing mercury most notifications involve pet food from Thailand in 2011 and 2012, and three were related to fish (RASFF, 2011; RASFF, 2012). Only five samples in the current dataset contained arsenic concentrations above the LOQ, and four of them were below 2 mg/kg. One sample from 2013 contained 4.7 mg/kg and thus would exceed the ML of 2 mg/kg (the product description did not indicate the presence of fish or seaweed). It was not possible to determine trends since most samples were from one year.

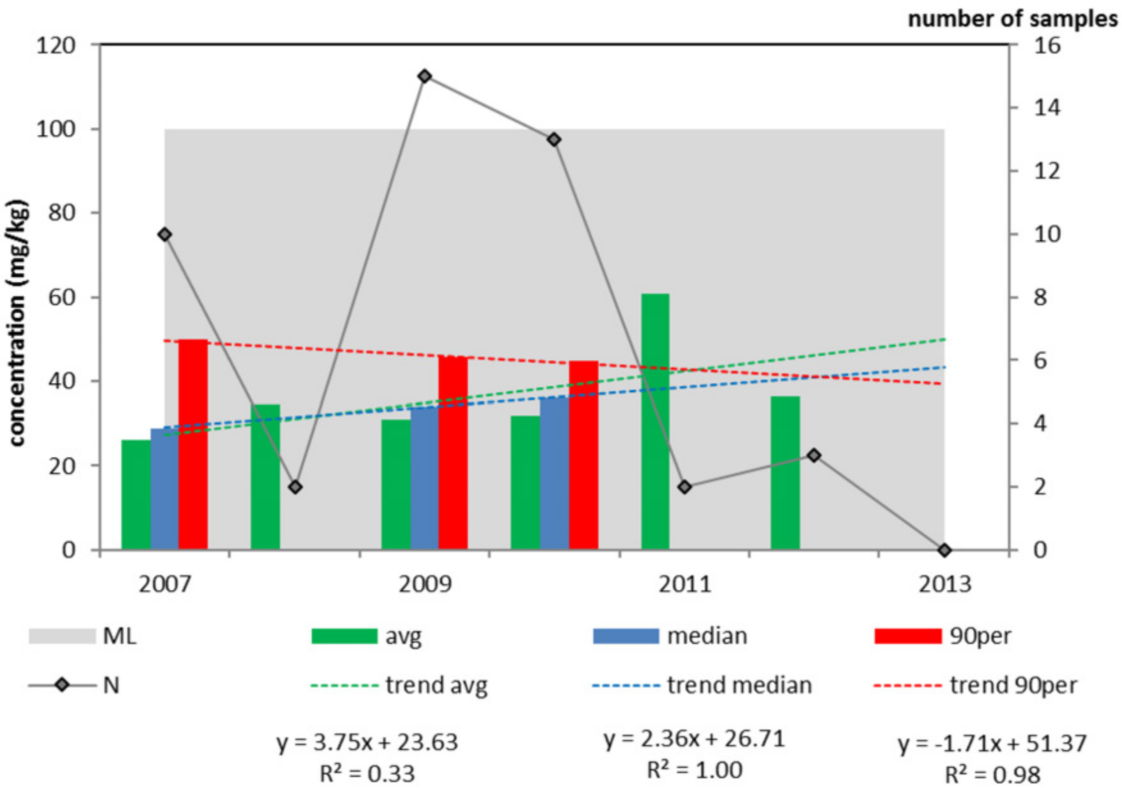

Figure 2 *Average, median and 90th percentile concentration of arsenic in zinc oxide; 2007– 2013, N = 77; ML = 100 mg/kg.*

According to a study performed by EFSA in 2005 in which data from several member states was used, the highest levels of arsenic were found in fishmeal and fish oils. This is reflected in the levels of arsenic in compound feeds for fish, for which these are major feed ingredients (EFSA, 2005). Based on the results of the current study, arsenic in fish meal does not seem to be a problem: average concentrations were 12% of the ML and only one sample exceeded the ML. For fish feed, no samples have been tested for the presence of arsenic in this period.

In the feed material category phosphates and calcareous marine algae the average arsenic concentration was 21% of the ML (of 10 mg/kg). The average and median arsenic concentration increased significantly between 2009 and 2013. For a large part this was caused by monocalcium phosphate (highest concentration was 6.41 mg/kg in 2011) but the three samples of calcareous marine algae with concentrations around 4 mg/kg also contributed to this increase.

No samples of zinc oxide (Figure 2) or manganese oxide exceeded the ML of 100 mg/kg, but the average concentration was relatively high (32% of the ML). The highest value was 74.4 mg/kg in zinc oxide. The number of samples dropped to zero in 2013 therefore no trend could be determined between 2007 and 2013.

The average arsenic concentration in complementary feed was rather low (9% of the ML) and no samples exceeded the ML (12 mg/kg). In mineral feed no samples exceeded the ML either. A few samples (2.5%) contained concentrations of more than 50% of the ML. This corresponds to the statement of EFSA that mineral supplements are generally not considered a major source of arsenic (EFSA, 2005). However, the average concentration of arsenic in mineral feed increased during the time period considered (Figure 3).

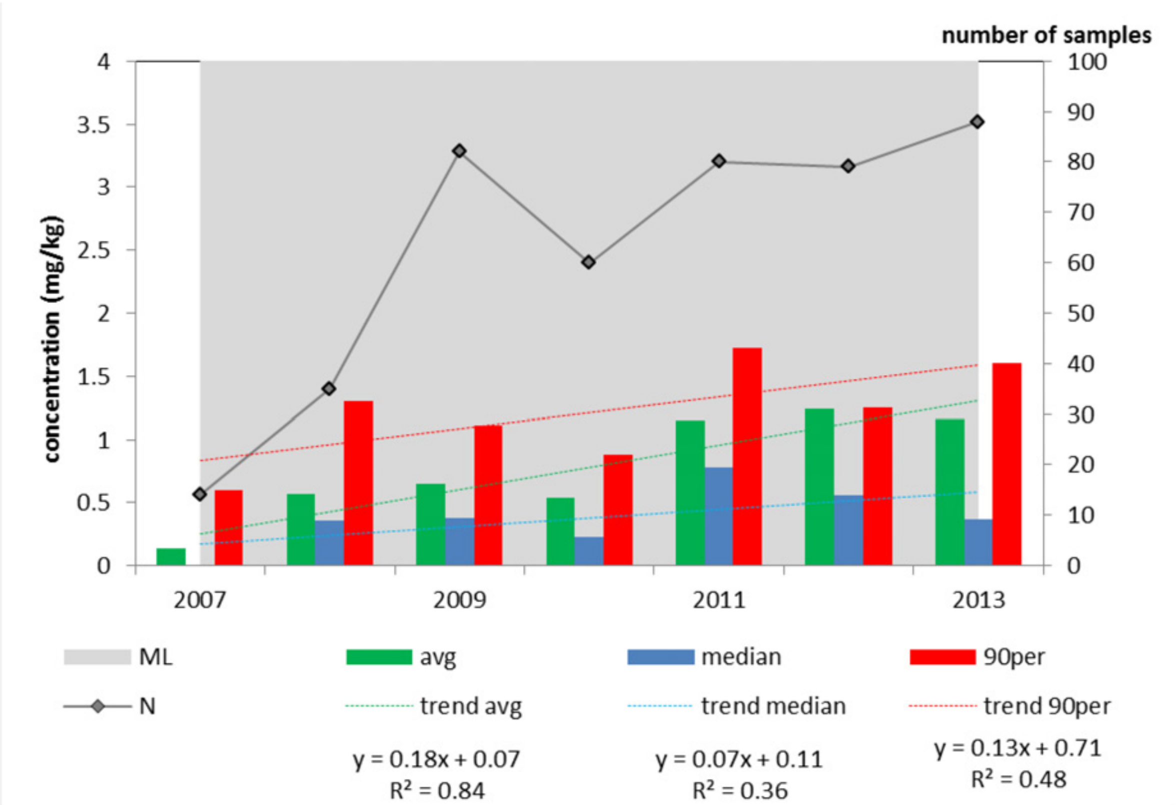

Figure 3 *Average, median and 90th percentile concentration of arsenic in mineral feed; 2007–2013, N = 438; ML = 12 mg/kg.*

There was no ML for the feed additives belonging to the functional group of binders and anti-caking agents. The highest concentration reported was 31 mg/kg in zeolite. Both the average and the median concentration increased significantly. This increase was mainly caused by sepiolite (116 of the

209 samples) with an average concentration of 6 mg/kg. Analysis of the subset sepiolite also showed a significant increase (R^2 = 0.65) of the average arsenic concentration over the time period considered. RASFF contained 42 alerts and notifications regarding arsenic (Table 3); most of these concerned pet food (12 notifications), of which eleven from Thailand and one from Vietnam.

Table 3 *RASFF alerts and notifications related to arsenic (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
algae	1	80	80	40
apple, dried	2	23.2	24	2
cat feed	5	5.79	7.1	2
copper sulphate	2	52	126	50
di-calcium phosphate	1	12.9	12.9	10
dog food	2	7.1	8.5	2
horse feed, complementary	2	6.7	8.7	4
fish feed	1	6.9	6.9	10
fish meal	1	7.1	7.1	25
magnesium oxide	2	8.5	56.5	20
manganese oxide	1	110	110	100
mineral mix, general	3	5.9	37	12
mono-calcium phosphate	1	12	12	10
mussel grist	1	24	24	25
oyster shells	1	22	22	25
palm kernel expeller	4	7.2	220	4
pet food	5	7	11	2
pig feed, complementary	1	12.4	12.4	4
shrimp feed	2	7.4	11	10
sugar beet pulp	1	6	6	4
sunflower seed meal	1	1.8	23.7	2
yeast	2	3.2	23.1	2

(More details in Table Sup5-1).

Lead

Most RASFF alerts and notifications for lead (Table 4) concerned complementary mineral feeds (mineral mixes) or zinc oxide. Other studies also reported high lead concentrations in minerals (e.g., Lopez-Alonso, 2012; Dai et a., 2016). In the current study (Table 5) the highest percentage of samples with lead concentrations exceeding the ML (of 30 mg/kg) were observed in feed additives belonging to the functional groups of binders and anti-caking agents, especially in the subgroup unspecified clay minerals (5.6% of 18 samples). The average lead concentrations in the entire group of binders were relatively high (approximately 25% of the ML) and 1.1% of the samples exceeded the ML, although contamination was less than before 2007 (Adamse et al., 2009). The priority was considered medium for the entire group, but high for the subset of unspecified clay minerals. Since 2012 mycotoxin binders are allowed to be used in animal feed as a new category of feed additives. Until now, no ML has been established in the EU. Those materials often have a clay-like background. Currently they are sometimes (wrongly) classified as complementary feed (ML = 10 mg/kg) or as mineral mix (ML = 15 mg/kg). The highest lead concentrations found were around 30 mg/kg. It is important to monitor those products in the coming years and to classify them in the appropriate category.

Table 4 *RASFF alerts and notifications related to lead (2002-2013).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
bone meal	1	46.3	46.3	10
copper sulphate	1	196	196	100
dicalcium phosphate	1	39.5	39.5	15
horse feed, complementary	1	52	52	10
poultry feed	1	14.95	14.95	5
iron oxide	1	339	339	100
manganese oxide	1	292	292	200
mineral mix, general	4	15	306	15
mono-calcium phosphate	1	23.7	23.7	15
palm kernel expeller	1	1.7	15	10
pet food	1	15.7	15.7	5
pig feed, complementary	1	165.3	281.4	10
pig feed, complete	1	10	10	5
premix, general	1	92.5	92.5	200
rice protein	1	22	22	10
sepiolite	1	105.8	105.8	30
sugar beet pulp	1	383	383	10
sunflower seed meal	1	1.5	43.5	10
zinc oxide	4	571	134000	400

(More details in Table Sup5-2).

Table 5 *Summary of the evaluation of lead in animal feed and feed materials between 2007 and 2013.*

Products intended for animal feed	ML (mg/kg)	N (2007-2013)	Average (% of ML)	% > ML	Trend average (R^2)	RASFF (2007-2013)	Priority
Complementary feed (excluding mineral feed)	10	5	5	0	0^c	0	III
subset: complementary feed (ruminants)	10	3	11	0	0^c	0	III
Complementary mineral feed	15	434	14	1.4	+ $_{(0.64)}$	2	II
subset: complementary mineral feed (ruminants)	15	319	12	0.7	+ $_{(0.59)}$	0	II
Pre-mixtures	200	455	1	0	+ $_{(0.36)}$	0	II
Complete feed	5	114	2	0	0 $_{(0.02)}$	1	III
Feed materials (excluding forage, phosphates, calcium carbonate and yeasts)	10	646	4	0.2	$0^{a,b}$ $_{(0.21)}$	5	III
subset: feed materials of vegetable origin (excluding forage)	10	368	4	0.1	0^a $_{(0.00)}$	4	III
subset: feed materials of non-vegetable origin	10	279	5	0	$0^{a,b}$ $_{(0.23)}$	1	III
- subsubset: fish meal	10	145	1	0	$+^{(0.62)}$	0	II
Forage	30	280	2	0	0 $_{(0.01)}$	0	III
Phosphates and calcareous marine algae	15	73	9	0	0 $_{(0.01)}$	1	III
Calcium carbonate; calcium and magnesium carbonate	20	78	16	0	0 $_{(0.01)}$	0	III
Yeasts	5	2	0	0	n.a.	0	III
Feed additives belonging to the functional group of compounds of trace elements (excl. zinc oxide and manganous oxide)	100	99	6	0	0 $_{(0.06)}$	2	III
Zinc oxide	400	29	19	0	0 $_{(0.10)}$	2	III
Manganous oxide	200	13	17	0	+ $_{(0.74)}$	0	II

Products intended for animal feed	ML (mg/kg)	N (2007-2013)	Average (% of ML)	% > ML	Trend average (R^2)	RASFF (2007-2013)	Priority
Feed additives belonging to the functional groups of binders and anti-caking agents (excluding clinoptilolite of volcanic origin; natrolite-phonolite)	30	186	25	1.1	0^a (0.03)	1	II
subset: sepiolite	30	116	23	0	0 (0.03)	1	II
subset: clay minerals (unspecified)	30	18	42	5.6	0 (0.00)	0	I
Clinoptilolite of volcanic origin; natrolite-phonolite	60	20	18	0	0 (0.00)	1	III
Other feed additives	no ML	143	n.a.	n.a.	+ (0.39)	1	II

Notes: [a] Median and/or [b] P90 increased significantly.

In the products assigned to the medium priority group, the average lead concentration was between 1% and 17% of the ML, but their concentration increased significantly between 2007 and 2013. The concerned products were complementary mineral feeds, pre-mixtures, fish meal, manganous oxide and "other feed additives". For the other feed categories the priority was considered low, with average concentrations well below (viz. < 10% of) the corresponding MLs.

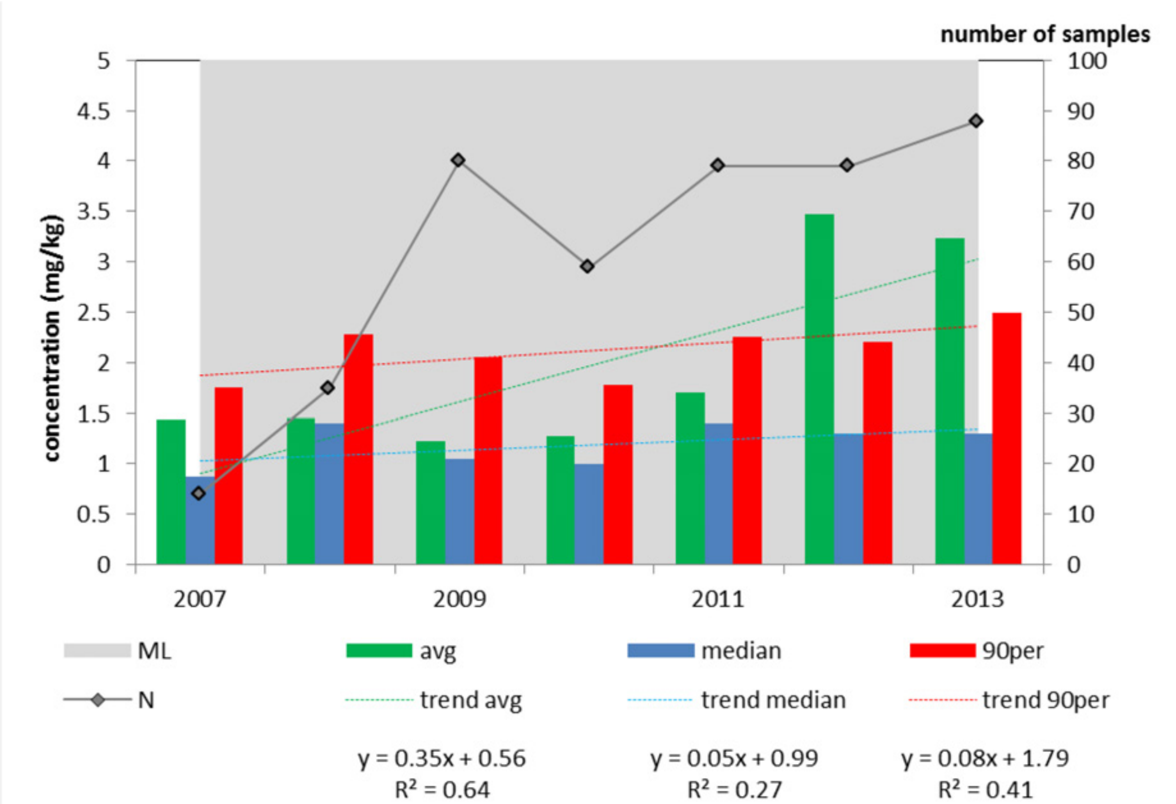

Figure 4 *Average, median and 90th percentile concentration of lead in complementary mineral feeds; N = 434; ML = 15 mg/kg.*

Complementary mineral feeds have a relatively high percentage of samples exceeding the ML (1.4%, 6 of 434 samples). There was a significant increase in both average and 90 percentile concentrations of lead in complementary mineral feeds (Figure 4). The average lead concentrations was approx. 14% of the ML. In the largest subgroup, i.e. complementary mineral feeds for ruminants, the average, median and 90 percentile lead concentrations also increased significantly. The reason for the upward trend for complementary mineral feeds is as yet unexplained.

In three other products which were ranked as medium priority, being pre-mixtures, fish meal (Figure 5) and manganous oxide, an increasing trend of the average concentration was observed. However, no samples exceeded the ML and average concentrations were well below the ML. The average concentrations of lead in fishmeal were quite close to the limits of quantification, so this upward trend should be considered with some precautions.

For “other feed additives” there is no ML. In most samples the concentration was below 3 mg/kg (14 samples) or below the LOQ (89 samples), except for Myco-AD (a feed additive to bind mycotoxins; 2011 26 mg/kg), choline chloride (2011, 33 mg/kg) and calcium propionate (2013, 34 mg/kg). The upward trend in the average concentration is probably caused by these samples that were taken in the second half of the time period studied.

The highest ML for feed materials was set for forage (30 mg/kg). As with cadmium, contamination with lead, especially in forage crops, is often caused by contaminated soil or dust that is deposited on plants (EFSA, 2004a). However, in the current study no forage samples have been reported with lead concentrations exceeding the ML and the average concentration was only 2% of the ML. The average lead concentration in forage decreased significantly for the period 2000-2006 (Adamse et al, 2009). This decrease is in line with the decreased use of leaded fuel. With the introduction of unleaded fuel in the mid 1980’s, lead has considerably decreased in the environment all over Europe (EFSA, 2013; Alldrick, 2014). In the current study, the number of samples taken from forage products has decreased. Since the average and individual concentrations were well below the ML this seems justified.

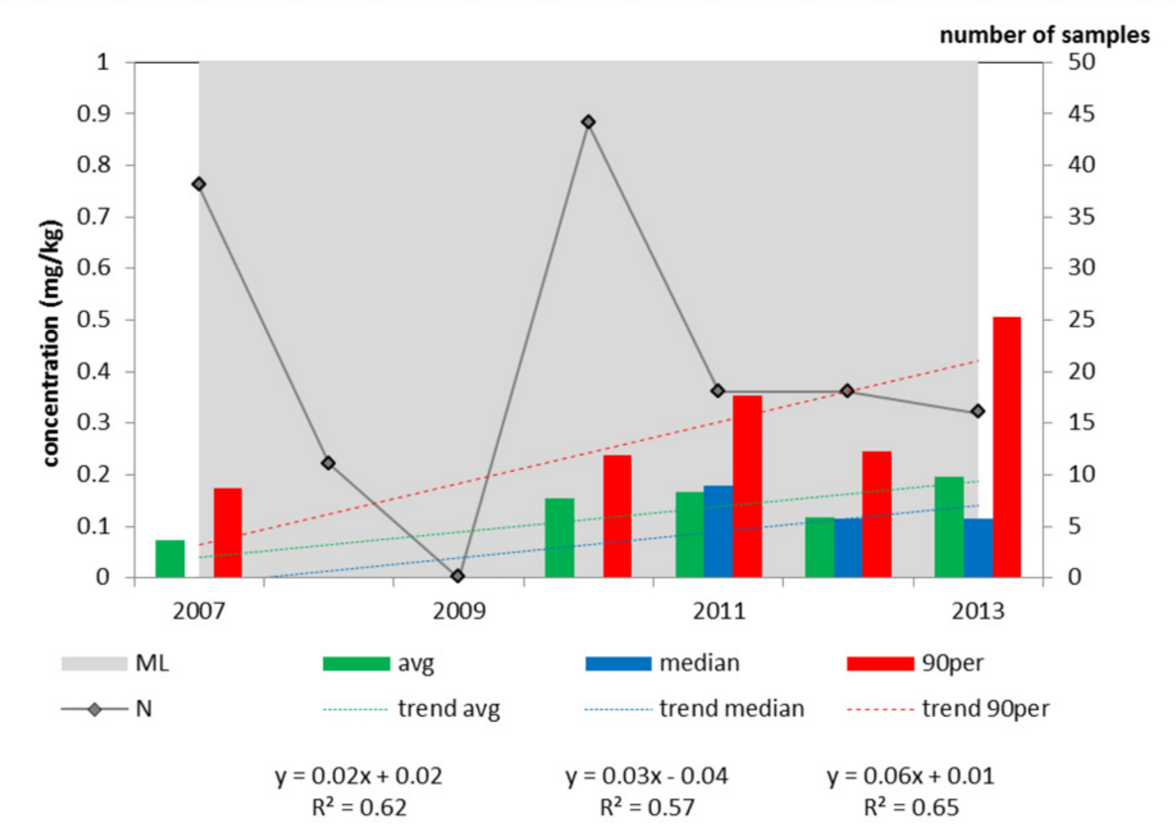

Figure 5 *Average, median and 90th percentile concentration of lead in fish meal; N = 145; ML = 10 mg/kg.*

Cadmium

Most RASFF alerts and notifications for cadmium concerned feed additives belonging to the functional group of compounds of trace elements and sea animal related feed materials. This coincides with the results of the current study. In this study feed materials of marine origin (especially fish meal with an average concentration of 34% of the ML, 2.9% exceeding the ML) was ranked in the high priority class (Table 6). Complementary feed (average concentration 41% of the ML), feed materials of vegetable origin (average concentration 7% of the ML, but increasing significantly between 2007 and 2013) and phosphates (average concentration 29% of ML) were considered medium priority. For the majority of the feed categories the priority was considered low, since they had average cadmium concentrations well below (namely < 10% of) the corresponding MLs. Further monitoring for cadmium should focus mainly on feed material of mineral origin (notably phosphates), fish meal and products containing fish meal. For complementary feed, excluding mineral feeds and pet food, only five samples were taken and so it is not possible to draw conclusions about the importance of cadmium in these feeds.

Table 6 *Summary of the evaluation of cadmium in animal feed and feed materials between 2007 and 2013.*

Products intended for animal feed	ML (mg/kg)	N (2007-2013)	Average (% of ML)	% > ML	Trend average (R^2)	RASFF (2007-2013)	Priority
Complementary feed, with the exception of mineral feed and pet feed)	0.5	5	41	0	0[c]	2	II
subset: complementary feed for ruminants	0.5	3	20	0	0[c]	1	III
Complementary mineral feed	5	436	6	0	- (0.49)	1	III
subset: complementary mineral feed for ruminants	5	320	6	0	- (0.49), +[a,b] (0.67/0.43)	0	III
Complementary feed for pet animals.	2	0	n.a.	n.a.	n.a.	0	III
Complete feed, with the exception of:	0.5	57	8	4	0 (0.05)	0	II
- complete feed for cattle (except calves), sheep (except lambs), goats (except kids) and fish	1	1	4	0	- (1.00)	0	III
- complete feed for pet animals	2	56	2	0	0 (0.00)	3	III
Feed materials of marine origin	2	183	28	2	0 (0.01)	7	I
subset: fish meal	2	139	34	2.9	+[b] (0.74)	5	I
Feed materials of vegetable origin	1	668	7	0	+[a,b] (0.40)	1	II
Feed materials of mineral origin, with the exception of phosphates:	2	203	9	1	0 (0.07)	2	III
subset: calcium carbonate	2	96	14	0	- (0.52)	1	III
Phosphates	10	73	29	0	0 (0.00)	3	II
Pre-mixtures	15	454	2	0	0 (0.01)	1	III
Feed additives belonging to the functional groups of binders and anti-caking agents	2	204	10	0.5	0 (0.01)	0	III
subset: sepiolite	2	116	13	1	0 (0.15)	0	III
Feed additives belonging to the functional group of compounds of trace elements with the exception of:	10	100	12	0	0 (0.22)	5	III
- cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate	30	41	3	0	0 (0.04)	3	III
Feed additives belonging to the functional group of vitamins and pro-vitamins	no ML	80	n.a.	n.a.	0 (0.05)	0	III
Other feed additives	no ML	66	n.a.	n.a.	0 (0.06)	0	III

Notes: [a] Median and/or [b] P90 increased significantly. [c] Not enough years for reliable trend analysis.

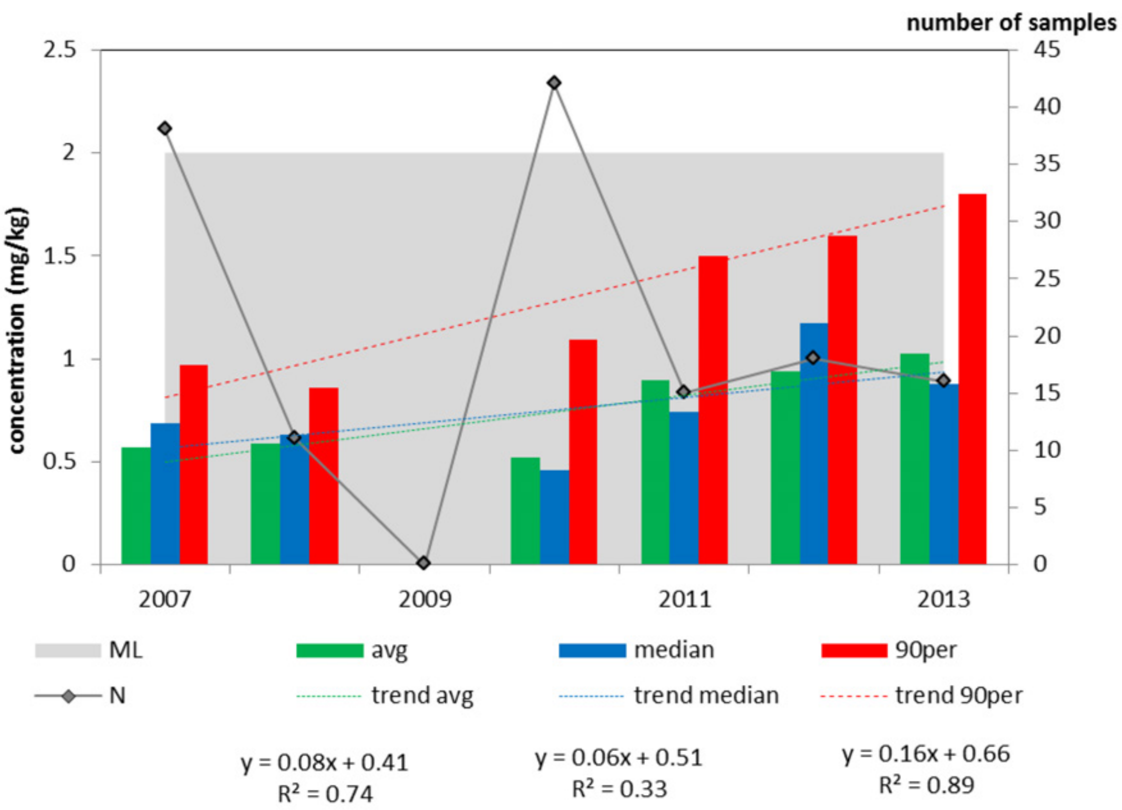

Figure 6 *Average, median and 90th percentile concentration of cadmium in fish meal; N = 141; ML = 2 mg/kg.*

The high priority group was feed material of marine origin, especially fish meal. The presence of elements like cadmium in the aquatic environment originates from natural (volcanic activity, weathering of bedrocks) or from anthropogenic sources such as mining activities, incineration of waste and agricultural use (Amlund et al., 2012; Lopez-Alonso, 2012; Rajaganapathy et al., 2011). Transfer of cadmium to fish is generally low (Amlund et al., 2012). However, RASFF reported five incidents with cadmium in fish meal and also the current study and previous studies (MIK, 1985; Adamse et al., 2009) showed that cadmium in feed materials of marine origin should have a high priority. In the current study both the average and the P90 cadmium concentration increased over the years (Figure 6) and the average concentration is around 34% of the ML. A considerable number of fish meal samples originated from Peru (37 out of 141 in total). Out of the 32 samples with cadmium levels of 1 mg/kg or higher, 10 samples were from Peru. This justifies the relatively high number of samples taken from fish meal from this country. However, none of the samples from Peru exceeded the ML of 2 mg/kg and no significant trends over time were observed. The increase in concentration over time was mainly caused by samples with relatively high cadmium concentrations collected from several European countries in the last few years. However, it is likely that (part of the) samples classified as originating from Germany are actually from Peru since there is a large throughput of fishmeal from Peru in the harbour of Hamburg (personal communication). For insights into the influence of country of origin of the feed material on contaminant levels it is very important that the original country of origin is registered correctly during sampling.

Many feed materials of vegetable origin have been analysed for their cadmium content. Feed materials of plant origin generally have low levels of elements. However, when the plants grow in a strongly contaminated environment (industrial emissions, traffic etc.) the heavy metal concentration in feed materials of plant origin can increase due to either uptake of the plant or by adhering soil particles, which may cause elevated levels in forage (Lopez-Alonso, 2012). Cadmium is very widespread in the soil (in certain areas) and can be taken up by the plant (EFSA, 2004b). The cadmium concentration of only one sample exceeded the ML: grass meal, with 2.4 mg/kg in 2012. The average, median and P90 cadmium concentration increased between 2007 and 2013 (Figure 7). However, the average concentration remains well below the ML (1 mg/kg); moreover, the average concentration is quite close to the LOQ and so these upward trends should be considered with some precautions. Important contributors to feed of vegetable origin were grass (including meal), alfalfa, soya bean expeller/extracted. No significant increase or decrease in cadmium concentrations could be observed in those product groups and the average concentration remains well below the ML (1 mg/kg). Based on the current results it is recommended to include grass meal in the monitoring programme because of elevated levels in part of the samples and since one ML exceedance was found recently.

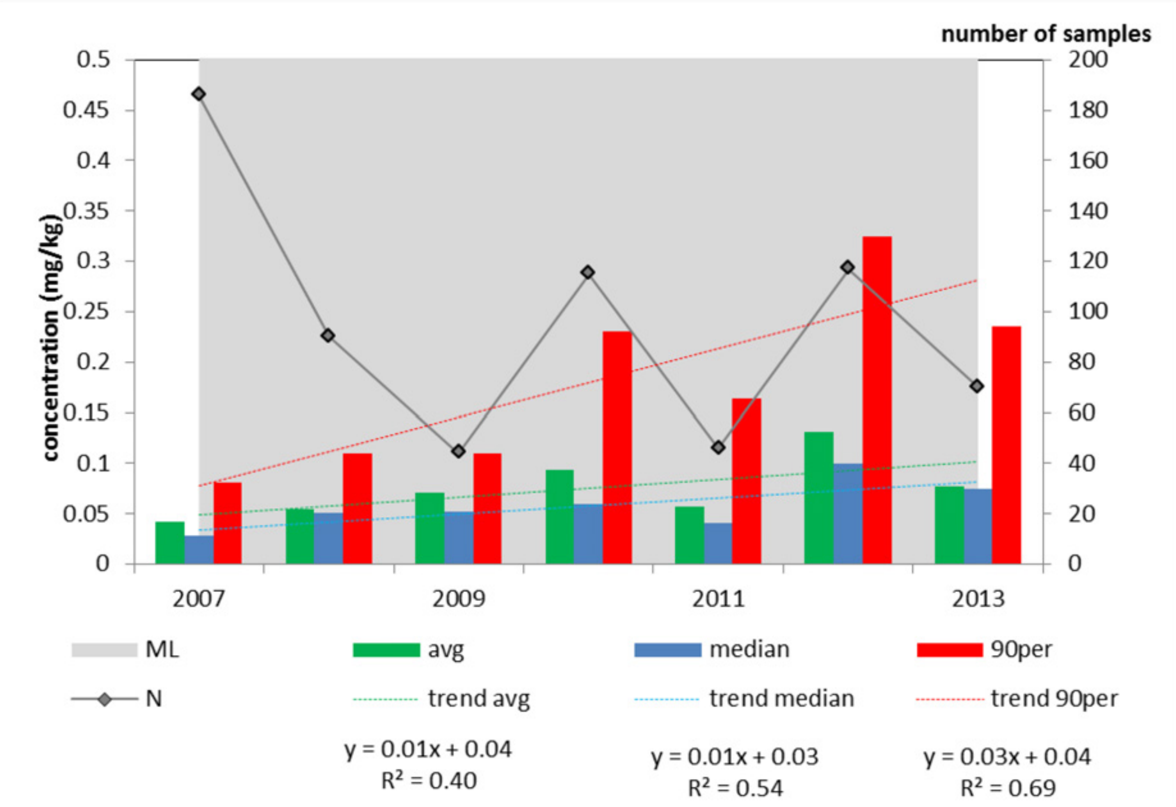

Figure 7 *Average, median and 90th percentile concentration of cadmium in feed materials of vegetable origin; N = 668; ML = 1 mg/kg.*

In feed materials of mineral origin, including phosphates, significant quantities of cadmium can be present resulting in elevated levels in mineral supplements and pre-mixtures (Lopez-Alonso, 2012; Dai et al., 2016). In a previous study (Adamse et al., 2009) covering the period 2000-2006 the highest percentage of samples with cadmium concentrations exceeding the ML were from complementary feeds, excluding mineral feeds. In the current study no samples of this product group were reported with cadmium concentrations above the ML. After 2006 the product descriptions have improved with a better distinction between complementary feed from mineral origin and other complementary feeds. As a result, only few samples have been taken from the latter category. The ML for complementary mineral feed (5 mg/kg) is high compared to the ML of 0.5 mg/kg for complementary feeds, excluding mineral feeds and pet feed.

For phosphates no samples exceeded the ML of 10 mg/kg. However, the average cadmium concentration was 29% of the ML. This justifies continuation of monitoring, also because RASFF reported three incidents regarding phosphates. Most alerts and notifications in RASFF concerned feed additives (notably trace elements), minerals or feeds with a high mineral content and sea animal related feed materials (Table 7).

Table 7 *RASFF alerts and notifications related to cadmium (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
zinc sulphate	8	3.7	966	10
di-calcium phosphate	3	12.4	16.7	10
zinc oxide	3	52	480	30
calcium carbonate	2	6.3	20.6	2
manganese oxide	2	41	45	30
mono-calcium phosphate	1	19.5	19.5	10
mineral mix, general	1	25	25	5
pre-mixture, fish	1	500	11500	15
pre-mixture, poultry	1	160	160	15
fish meal	5	2.81	6.1	2
squid	2	2.5	13.8	2
lobster shell powder	1	4.3	4.95	2
complementary feed, general	1	1.1	1.1	0.5
bovine feed, complementary	1	1.4	1.4	0.5
celery	1	2.7	2.7	1

(More details in Table Sup5-3).

Mercury

The origin of mercury in feeds and feed materials can be natural (volcanic activity) as well as from industrial pollution. In this study, only four samples out of in total 1497 samples exceeded the ML; two in feed material and two in compound feed (Table 8). For another 906 samples (feed additives and pre-mixtures) no ML was set for mercury. No feeds and feed materials where ranked at high priority and only one product (pre-mixtures) was ranked as medium (Table 8). For pre-mixtures there was no ML, but the concentration increased significantly over the years. Of the 441 samples of pre-mixtures that were analysed, three samples had a mercury concentration between 0.2 and 0.9 mg/kg, much lower than the alert reported by RASFF (17.8 mg/kg). All others samples had a concentration below 0.1 mg/kg (the lowest ML for mercury in feed and feed materials).

Table 8 *Summary of the evaluation of mercury in animal feed and feed materials between 2007 and 2013.*

Products intended for animal feed	ML (mg/kg)	N (2007-2013)	Average (% of ML)	% > ML	Trend average (R^2)	RASFF (2007-2013)	Priority
Feed materials, not including:	0.1	686	4	0.1	0 (0.17)	1	III
— fish, other aquatic animals and products derived thereof	0.5	198	16	0	0 (0.00)	4	III
subset: fish meal	0.5	166	17	0	0 (0.22)	3	III
— calcium carbonate; calcium and magnesium carbonate	0.3	65	3	0	0 (0.14)	0	III
Compound feed, not including:	0.1	59	8	2	0 (0.00)	1	III
— mineral feed	0.2	434	2	0	0 (0.16)	1	III
— compound feed for fish	0.2	0	n.a.	n.a.	0 (-)	1	III
— compound feed for dogs, cats and fur animals	0.3	56	5	2	0 (-)	4	III
Feed additives -> no ML	no ML	465	n.a.	n.a.	0 (0.17)	1	III
subset: clay minerals	no ML	192	n.a.	n.a.	0 (0.27)	0	III
Pre-mixtures -> no ML	no ML	441	n.a.	n.a.	+ (0.39)	1	II

There were different MLs for feed materials: 0.5 mg/kg for fish, other aquatic animals and products derived thereof, 0.3 mg/kg for calcium carbonate and calcium and magnesium carbonate, and 0.1 mg/kg for the other feed materials. For fish, other aquatic animals and products derived thereof no samples exceeded the ML. In a similar study covering 2000-2006 (Adamse et al, 2009), a decrease of the average mercury concentration was observed after 2003. Between 2007 and 2013 this decrease was not significant anymore.

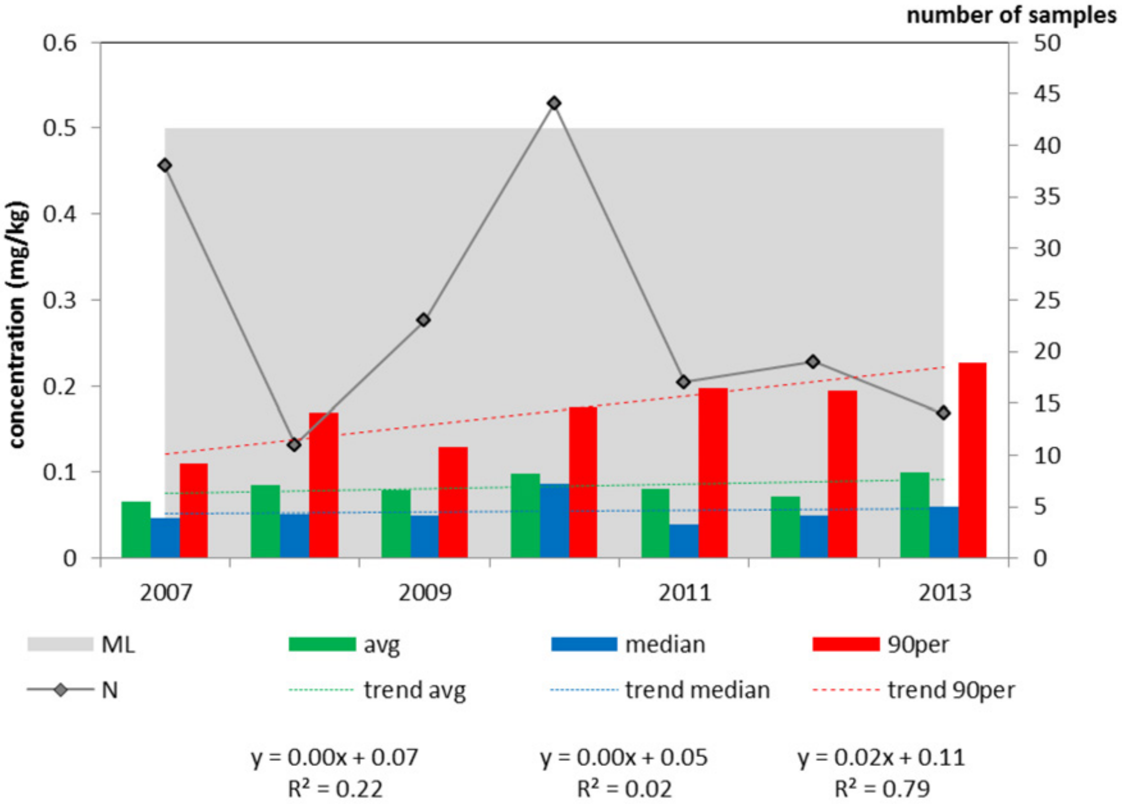

Figure 8 *Average, median and 90th percentile concentration of mercury in fish meal; N = 166; ML = 0.5 mg/kg.*

In the subcategory fish meal the 90th percentile concentration increased between 2007 and 2013 (Figure 8) indicating an increase of the higher concentrations to around 50% of the ML. When the country of origin was taken into account, the highest concentrations were reported for fish meal from Peru, comparable with the 2009 report (Adamse et al, 2009). The average concentration in fish meal from Peru tended to increase between 2007 and 2013 (R^2=0.29). In fish meal from Denmark and Norway the average concentration decreased but in fish meal from the EU (specific countries not specified) the average concentration increased significantly (R^2=0.41). Monitoring fish meal and products containing fish meal, e.g. fish feed, will thus be necessary, especially since mercury accumulates in fish tissues. EFSA reported that 8.2% of complete feed for fish (often containing fish) in their study (280 samples between 2003 and 2006) contained mercury levels above the ML (EFSA, 2008).

One sample of pet food (without target animal specified) from 2013 exceeded the ML with a mercury concentration of 0.46 mg/ml. In general, only a few samples of pet food were collected per year. However, in 2013 50 samples were taken (out of 56 in total). In 2012 RASFF reported four incidents with mercury in pet feed from Thailand (Table 9), also referred to in their annual report (RASFF, 2012). This, in combination with notifications on high arsenic concentrations in the same product, probably triggered the large number of samples collected in the course of the national monitoring programme in the Netherlands in 2013. Only three samples of cat feed (out of 32) contained mercury levels above the LOQ, none of them exceeded the ML of 0.3 mg/ml. Due to the low number of samples it was not possible to perform a trend analysis.

Table 9 *RASFF alerts and notifications related to mercury (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
cat feed	3	0.43	2.11	0.3
complete feed, general	1	0.24	0.24	0.1
fish meal	3	0.73	1.14	0.5
mineral mix, poultry	1	0.34	0.34	0.2
pet food	1	0.43	0.43	0.3
pig feed, complete	1	0.22	0.22	0.1
premix	1	17.8	17.8	0.1
shark cartilage powder	1	0.87	0.87	0.5
shrimp feed	1	0.21	0.21	0.1
vitamin	1	0.38	0.38	-
yeast	1	0.14	0.16	-

(More details in Table Sup5-4).

Usefulness of monitoring data for trend analysis

Knowledge about contaminant levels in feed is often gathered in controlled studies where prearranged amounts of samples are taken from more or less controlled environments during a limited period (e.g. Nicholson, 1999; Nicholson et al. 2003; Li, 2005; Granados-Chinchilla et al.; 2015; Dai et al, 2016). This approach ensures that statistically relevant amounts of samples are taken and enables researchers to study trends over time of contaminant levels in certain feeds or feed from certain producers. The current study shows that monitoring data, spanning a long period and multiple sources of data, can be used to obtain insight into the levels and trends of heavy metals in feed and feed materials for the purpose of setting monitoring priorities. Due to the variation in the number of samples collected per year it is important to always pay attention to the number of collected samples before determining whether a trend really is significant, even when the statistical test indicates that it is. It is also important to harmonise the names of the products sampled by different parties in order to classify them properly. The uncertainty whether a feed is a mineral feed or not is an important example of this. Animal feed containing fish or seaweed is another example. Finally, for imported feed materials that contain elevated levels of heavy metals, e.g. fish meal, it is important that the country of origin is known.

4 Conclusions and recommendations

Based on the results, monitoring for arsenic, lead, cadmium and mercury should focus on feed material of mineral origin, feed material of marine origin, especially fish meal, seaweed and algae as well as feed additives belonging to the functional groups of (1) trace elements (notably cupric sulphate, zinc oxide and manganese oxide for arsenic) and (2) binders and anti-caking agents. Mycotoxin binders are a new group of feed additives that also need attention. For complementary feed it is important to make a proper distinction between mineral and non-mineral feed because the ML in the latter group is usually lower. In seaweed/algae products a relatively large number of samples contained arsenic concentrations that exceeded the ML. Forage crops in general do not need high priority in monitoring programmes, although arsenic in grass meal still needs attention.

Taking into account that heavy metals are analysed with multi-methods in which all four heavy metals/elements are analysed with one method at the same time(run), the following general recommendations can be made:

In the following products relatively high average concentrations and/or exceedances of MLs were found but currently few samples are taken and, hence, monitoring should be intensified:

- Seaweed meal, feed materials derived from seaweed and algae (arsenic)
- Several feed additives belonging to the functional group of compounds of trace elements, viz. cupric sulphate (arsenic), zinc oxide (lead and arsenic), manganese oxide (arsenic and lead)

For fish feed monitoring should be started in fish meal (mercury) because fish meal is a main ingredient of fish feed.

For the following products, in which relatively high average concentrations and/or exceedances of MLs were found, monitoring should be maintained:

- Fish meal (lead, cadmium and mercury)
- Complementary feed, incl. mineral feed (arsenic, cadmium, lead)
- Pre-mixtures (lead, mercury)
- Phosphates and calcareous marine algae (arsenic)
- Calcium and magnesium carbonate (lead)
- Feed additives belonging to the functional groups of binders and anti-caking agents (arsenic, lead).
- Duck weed (lead), grass meal and sunflower meal (mercury)

For the following products, in which low average concentrations and no exceedances of MLs were found and currently a high sampling frequency is applied, monitoring can be reduced:

- Feed materials of vegetable origin, including forages. However, for some specific materials monitoring should be continued, viz. new materials such as duck weed (lead), grass meal and sunflower meal (mercury), seaweed (products) and calcareous marine algae (arsenic).

Furthermore, it is recommended to set MLs in EU legislation for the functional group of mycotoxin binders because high levels of lead, exceeding the ML for feed additives belonging to the functional groups of binders and anti-caking agents, were found.

Acknowledgements

The work was financed by the Dutch Ministry of Economic Affairs (EZ). The authors would like to thank the Dutch Food and Consumer Product Safety Authority (NVWA), Productschap Diervoeders (PDV) and SecureFeed for the use of their data; and Harry van Egmond and Martijn van der Lee from RIKILT Wageningen University & Research for technical information.

References

Adamse P, Driessen JJM, de Jong J, van Polanen A, van Egmond HJ and Jongbloed AW. 2009. Trendanalyse van gehalten aan kwik, cadmium en lood in diervoeders en diervoedergrondstoffen (in Dutch). RIKILT Report 2009.019.

Adamse P. 2014. Trendanalyse van historische gegevens. Handleiding voor het gebruik van monitoringsgegevens (in Dutch). RIKILT report 2014.001.

Adamse P, van der Fels-Klerx, HJ and de Jong J. 2017. Cadmium, lead, mercury and arsenic in animal feed and feed materials - trend analysis of monitoring results. Food Additives & Contaminants: Part A, 8, pp. 1298-1311.

Alldrick, A.J. 2014. Chemical safety of cereal-based foods: risk management considerations. Quality Assurance and Safety of Crops & Foods, 6(1), pp. 3–14.

Amlund H, Berntssen MHG., Lunestad BT, Lundebye AK, 2012. Aquaculture feed contamination by persistent organic pollutants, heavy metals, additives and drug residues. Animal Feed Contamination, Effects on Livestock and Food Safety, 205-229. Fink-Gremmels, J. (Ed.). Woodhead Publishing Series in Food Science, Technology and Nutrition: Number 215, Cambridge, UK.

Dai SY, Jones B, Lee K-M, Li W, Post L, Herrman TJ. 2016. Heavy Metal Contamination of Animal Feed in Texas. Journal of Regulatory Science 01 (2016) 21–32.

EC 2002. Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed. Off J Eur Union 140/10.

EC 2004. Regulation (EC) No 882/2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules. Off J Eur Union. 165/2.

EC 2009. Regulation (EC) No 767/2009 of the European Parliament and of the Council of 13 July 2009 on the placing on the market and use of feed, amending European Parliament and Council Regulation (EC) No 1831/2003 and repealing Council Directive 79/373/EEC, Commission Directive 80/511/EEC, Council Directives 82/471/EEC, 83/228/EEC, 93/74/EEC, 93/113/EC and 96/25/EC and Commission Decision 2004/217/EC. Off J Eur Union 229/1.

EFSA, 2004a. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to lead as undesirable substance in animal feed. EFSA Journal, 71, 1-20.

EFSA, 2004b. Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission related to cadmium as undesirable substance in animal feed. EFSA Journal, 72, 1-24.

EFSA, 2005. Opinion of the scientific panel on contaminants in the food chain on a request from the Commission related to arsenic as undesirable substance in animal feed. EFSA Journal 180, 1-35.

EFSA, 2008. Scientific opinion of the Panel on Contaminants in the Food Chain. Mercury as undesirable substance in animal feed. EFSA Journal 654, 1-76.

EFSA, 2013. Scientific opinion of the Panel on Contaminants in the Food Chain. Lead in food. EFSA Journal 2010; 8(4):1570 (published on 22 March 2013, replaces version 2010)

EU 2015. Commission Regulation (EU) 2015/186 of 6 February 2015 amending Annex I to Directive 2002/32/EC of the European Parliament and of the Council as regards maximum levels for arsenic, fluorine, lead, mercury, endosulfan and Ambrosia seeds. Off J Eur Union 31/11

Granados-Chinchilla, F., Prado Mena, S., Mata Arias, L. (2015). Inorganic contaminants and composition analysis of commercial feed grade mineral compounds available in Costa Rica. International Journal of Food Contamination (2015) 2:8.

Li Y., McCrory D.F., Powell J.M., Saam H. and Jackson-Smith D. (2005). A Survey of Selected Heavy Metal Concentrations in Wisconsin Dairy Feeds. J. Dairy Sci. 88:2911–2922.

López-Alonso, M., 2012. Animal feed contamination by toxic metals. In: Animal Feed Contamination, Effects on Livestock and Food Safety, 183-204. Fink-Gremmels, J. (Ed.). Woodhead Publishing Series in Food Science, Technology and Nutrition: Number 215, Cambridge, UK.

Makkar, H.P.S., Tran, G., Heuzé, V., Giger-Reverdin, S., Lessire, M., Lebas, F., Ankers, P. 2016. Seaweeds for livestock diets: A review. Animal Feed Science and Technology 212: 1–17

MIK 1985. De gehalten aan enkele spoorelementen in mengvoedergrondstoffen en voordroogkuilen en de gehalten aan enkele mineralen en spoorelementen in mengvoeders. Werkgroep mineralen in krachtvoer in relatie tot bemesting en milieu. NRLO-TNO, Den Haag, 48 pp.

Nicholson, F.A., Chambers B.J., Williams, J.R., Unwin, R.J. (1999). Heavy metal contents of livestock feeds and animal manures in England and Wales. Bioresource Technology 70, 23-31.

Nicholson, F.A., Smith, S.R., Alloway, B.J., Carlton-Smith, C., Chambers, B.J. (2003). An inventory of heavy metals inputs to agricultural soils in England and Wales. The Science of the Total Environment 311, 205–219.

NRC 2005. Mineral tolerance of animals. Second revised edition. National Research Council of the national academies, The National Academies Press, Washington, DC.

Rajaganapathy, V., Xavier, F., Sreekumar, D., Mandal, P.K., 2011. Heavy metal contamination in soil, water and fodder and their presence in livestock and products: a review. Journal of Environmental Science and Technology, 4(3), 234-249.

RASFF 2011. Rapid Alert System for Food and Feed 2011 Annual Report. doi:10.2772/96194, http://ec.europa.eu/food/safety/rasff/docs/rasff_annual_report_2011_en.pdf, accessed at 30.08.2016

RASFF 2012. Rapid Alert System for Food and Feed 2012 Annual Report. doi:10.2772/48887, http://ec.europa.eu/food/safety/rasff/docs/rasff_annual_report_2012_en.pdf, accessed at 30.08.2016

RASFF 2014: https://webgate.ec.europa.eu/rasff-window/portal/, accessed at 17.10.2014

Van Der Fels-Klerx HJ, Klemsdal S, Hietaniemi V, Lindblad M, Ioannou-Kakouri E, Van Asselt ED (2012) Mycotoxin contamination of cereal grain commodities in relation to climate in North West Europe, Food Additives & Contaminants: Part A, 29:10, 1581-1592, DOI: 10.1080/19440049.2012.689996

Wang P, Zhang Q, Lan Y, Xu S, Gao R, Li G, Zhang H, Shang H, Ren D, Zhu C, Li Y, Li X, Jiang G. Dioxins contamination in the feed additive (feed grade cupric sulfate) tied to chlorine industry. 2014. Sci Rep. 2014 Aug 7;4:5975.

Annex 1 Supplemental information arsenic

Maximum levels for arsenic in animal feed and feed materials

Directive 2002/32/EC, amended by Regulation (EU) No 744/2012 describes the maximum arsenic concentration allowed in feeds and feed materials (Table Sup1-1). The highest concentrations are allowed in feed additives belonging to the functional group of compounds of trace elements, especially cupric oxide, manganous oxide and zinc oxide. The lowest MLs are defined for complete and compounds feeds and feed materials of plant origin. No limits are defined for pre-mixtures and for feed additives **not** belonging to the functional group of compounds of trace elements.

Table Sup1-1 *Maximum levels for arsenic(1) in animal feed and feed materials according to Directive 2002/32/EC, amended by Regulation (EU) No 744/2012.*

Products intended for animal feed	Maximum content in mg/kg (ppm) relative to a feed with a moisture content of 12%
Feed materials	2
with the exception of:	
— meal made from grass, from dried lucerne and from dried clover, and dried sugar beet pulp and dried molasses sugar beet pulp;	4
— palm kernel expeller;	4 (2)
— phosphates and calcareous marine algae;	10
— calcium carbonate; calcium and magnesium carbonate (10);	15
— magnesium oxide; magnesium carbonate;	20
— fish, other aquatic animals and products derived thereof;	25 (2)
— seaweed meal and feed materials derived from seaweed.	40 (2)
Iron particles used as tracer.	50
Feed additives belonging to the functional group of compounds of trace elements	30
with the exception of:	
— cupric sulphate pentahydrate; cupric carbonate; di copper chloride trihydroxide; ferrous carbonate;	50
— zinc oxide; manganous oxide; cupric oxide.	100
Complementary feed	4
with the exception of:	
— mineral feed;	12
— complementary feed for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed;	10 (2)
— long-term supply formulations of feed for particular nutritional purposes with a concentration of trace elements higher than 100 times the established maximum content in complete feed;	30
Complete feed	2
with the exception of:	
— complete feed for fish and fur animals;	10 (2)
— complete feed for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed.	10 (2)

(1) The maximum levels refer to total arsenic.

(2) Upon request of the competent authorities, the responsible operator must perform an analysis to demonstrate that the content of inorganic arsenic was lower than 2 ppm. This analysis is of particular importance for the seaweed species *Hizikia fusiforme*.

Overall trends in percentage of samples exceeding the LOQ or the ML

The highest number of samples exceeding the ML belonged to the feed materials (Table Sup1-3). The highest percentage of samples exceeding the ML was in the group seaweed meal and feed materials derived from seaweed.

Table Sup1-2 *Samples exceeding the ML or the LOQ for arsenic between 2000 and 2013.*

Product	N Total	N > LOQ	N > ML	% > LOQ	% > ML
Complementary feed, with the exception of:	170	71	0	42	0.0
— mineral feed;	715	477	0	67	0.0
Complete feed	676	320	17	48	2.5
Complete feed for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed	8	0	0	0.0	0.0
Feed materials, with the exception of:	2926	558	**6**	19	0.2
— calcium carbonate; calcium and magnesium carbonate;	175	148	1	85	0.6
— phosphates and calcareous marine algae	200	134	0	67	0
— zinc oxide; manganous oxide; cupric oxide	77	65	0	84	0.0
— seaweed meal and feed materials derived from seaweed	64	39	7	61	**10.9**
— cupric sulphate pentahydrate; cupric carbonate; di copper chloride trihydroxide; ferrous carbonate	51	42	5	82	9.8
— fish, other aquatic animals and products derived thereof	332	288	3	87	0.9
— magnesium oxide; magnesium carbonate	119	56	0	47	0.0
— palm kernel expeller	119	81	0	69	0.0
— meal made from grass, from dried lucerne and from dried clover, and dried sugar beet pulp and dried molasses sugar beet pulp	338	294	1	87	0.3
— complete feed for fish and fur animals	8	6	0	75.0	0.0
Feed additives belonging to the functional group of compounds of trace elements	84	30	1	36	1.2
Feed additives belonging to the functional groups of binders and anti-caking agents*	293	255	-	87	-
Feed additives belonging to the category vitamins and pro-vitamins*	80	22	-	27.5	-
Other feed additives*	85	17	-	20	-
Pre-mixtures*	612	412	-	67	-
Total	**7132**	**3315**	**41**		

*no ML.

Table Sup1-3 *Samples exceeding the ML or the LOQ for arsenic between 2007 and 2013.*

Product	N Total	N > LOQ	N > ML	% > LOQ	% > ML
Complementary feed, with the exception of:	6	3	0	50	0
— mineral feed;	438	311	0	71	0
Complete feed	189	68	2	36	1.1
Complete feed for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed	8	0	0	0	0
Feed materials, with the exception of:	1188	246	1	21	0.2
— calcium carbonate; calcium and magnesium carbonate;	106	93	0	88	0.0
— phosphates and calcareous marine algae	91	68	0	75	0.0
— zinc oxide; manganous oxide; cupric oxide	45	42	0	93	0.0
— seaweed meal and feed materials derived from seaweed	64	39	7	61	10.9
— cupric sulphate pentahydrate; cupric carbonate; di copper chloride trihydroxide; ferrous carbonate	37	34	2	92	5.4
— fish, other aquatic animals and products derived thereof	232	210	1	91	0.4
— magnesium oxide; magnesium carbonate	41	30	0	73	0.0
— palm kernel expeller	64	38	0	59	0.0
— meal made from grass, from dried lucerne and from dried clover, and dried sugar beet pulp and dried molasses sugar beet pulp	121	110	0	91	0.0
— complete feed for fish and fur animals	3	1	0	33	0.0
Feed additives belonging to the functional group of compounds of trace elements	69	26	1	38	1.4
Feed additives belonging to the functional groups of binders and anti-caking agents*	209	202	-	97	-
Feed additives belonging to the category vitamins and pro-vitamins*	80	22	-	28	-
Other feed additives*	72	16	-	22	-
Pre-mixtures*	466	340	-	73	-
Total	**3529**	**1899**	**14**		

*no ML.

Results arsenic

Feed materials with the exception of several sub categories with a higher ML
RASFF reported 6 notifications regarding feed materials (excl. the subcategories with a higher ML, see next paragraphs), none of them related to the Netherlands (Table Sup1-4).
In the period from 2007-2013, no feed material samples exceeded the MRL. In the dataset studied it was not always clear whether a sample consisted of meal, hay or the fresh product but it was assumed to be meal (different ML). The highest concentrations were reported in 2006 by PDV, for rice bran (168 and 99 mg/kg) and sugarcane molasses (103 mg/kg).

Table Sup1-4 *RASFF alerts and notifications related to arsenic in feed materials with the exception of subcategories with a higher ML.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
apple, dried	2	23.2	24	2
sugar beet pulp	1	6	6	4
sunflower seed meal	1	1.8	23.7	2
yeast	2	3.2	23.1	2

(More details in Table Sup5-1).

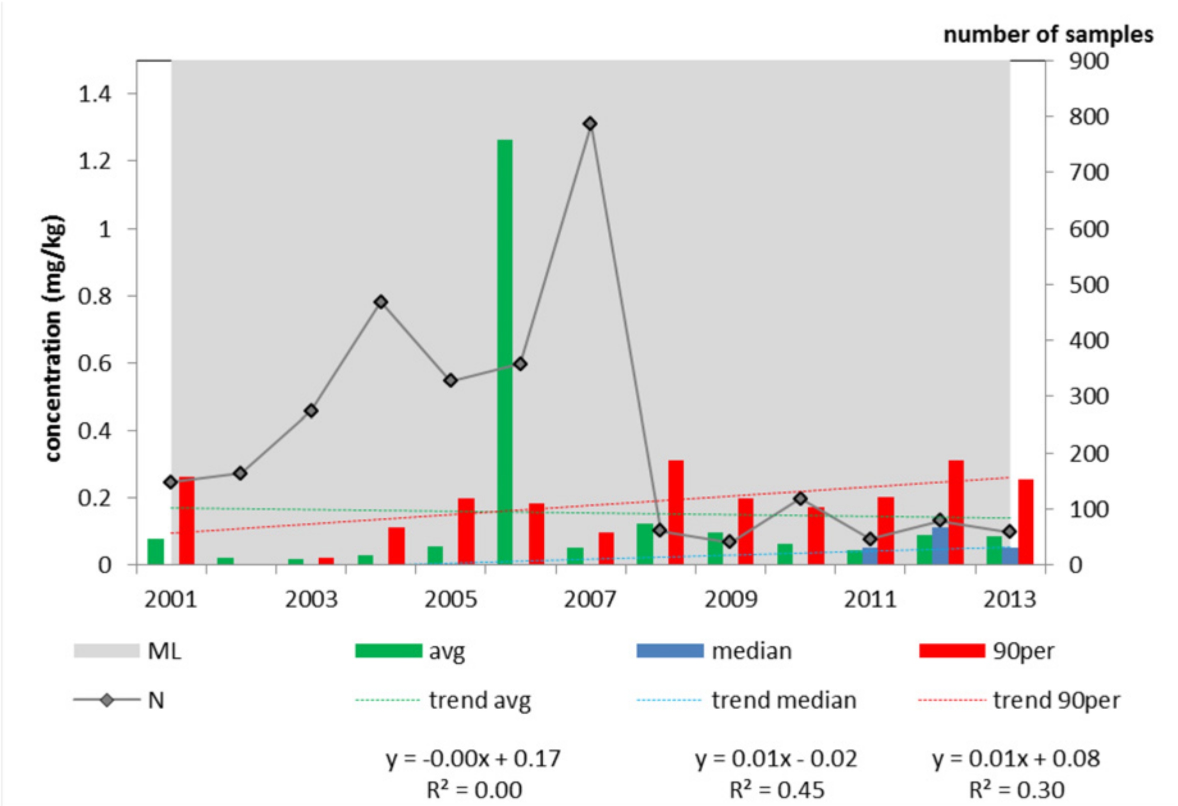

Figure 1-1 *Average, median and 90 percentile concentration of arsenic in feed materials (excl. subcategories with a higher ML); N =2926; ML = 2 mg/kg.*

Meal made from grass, from dried lucerne and from dried clover, and dried sugar beet pulp and dried molasses sugar beet pulp

The ML for this feed material was higher than the ML for the other feed materials (4 i.s.o. 2 mg/kg). From the product description it was not always clear whether a dried product concerned meal or hay. When in doubt it was classified as hay, because the ML for hay (feed material in general) was lower (2 mg/kg). One sample (alfalfa pellets from 2006 with 102 mg/kg arsenic) exceeded the ML.

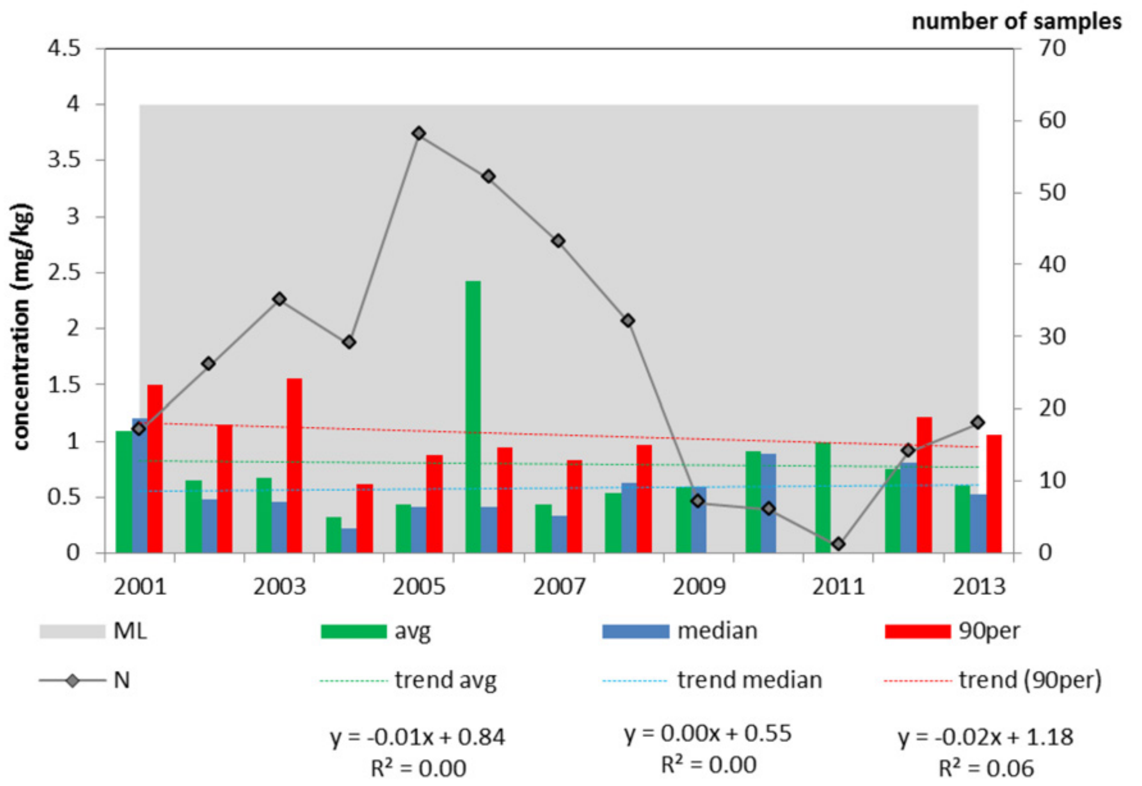

Figure 1-2 *Average, median and 90 percentile concentration of arsenic in meal made from grass, from dried lucerne and from dried clover, and dried sugar beet pulp and dried molasses sugar beet pulp; N = 338, ML = 4 mg/kg.*

Palm kernel expeller

RASFF reported 4 notifications about palm kernel expeller (Table Sup1-5). Two notifications were reported by the Netherlands and concerned palm kernel expeller from Malaysia. The other two notifications were reported by the United Kingdom and also concerned Malaysia. The two samples reported by the Netherlands in 2011, an alert (220 mg/kg) and a border rejection (134 mg/kg), were not present in the current dataset. No samples in the current dataset exceeded the ML for arsenic.

Table Sup1-5 *RASFF alerts and notifications related to arsenic in palm kernel expeller.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
palm kernel expeller	4	7.2	220	4

(More details in Table Sup5-1).

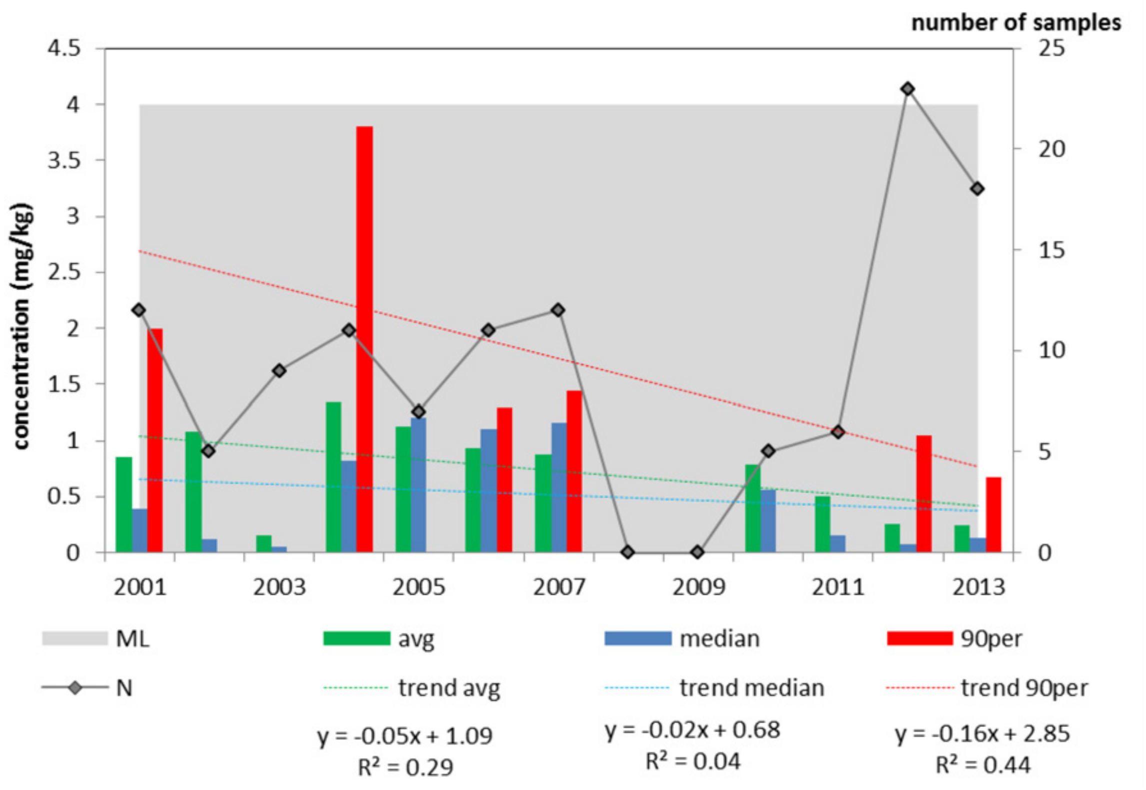

Figure 1-3 *Average, median and 90 percentile concentration of arsenic in palm kernel expeller; N = 119; ML = 4 mg/kg.*

Phosphates and calcareous marine algae;

RASFF report 2 notifications about phosphates (Table Sup1-6), neither of them related to the Netherlands. One sample exceeded the ML, PDV reported 2550 mg/kg arsenic in mono calcium phosphate from France in 2004. This sample has been excluded from the trend analysis since the highest concentration in the other samples was 6.41 mg/kg (mono-calcium phosphate in 2011) and so it was considered as an outlier.

Table Sup1-6 *RASFF alerts and notifications related to arsenic in phosphates and calcareous marine algae.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
di-calcium phosphate	1	12.9	12.9	10
mono-calcium phosphate	1	12	12	10

(More details in Table Sup5-1).

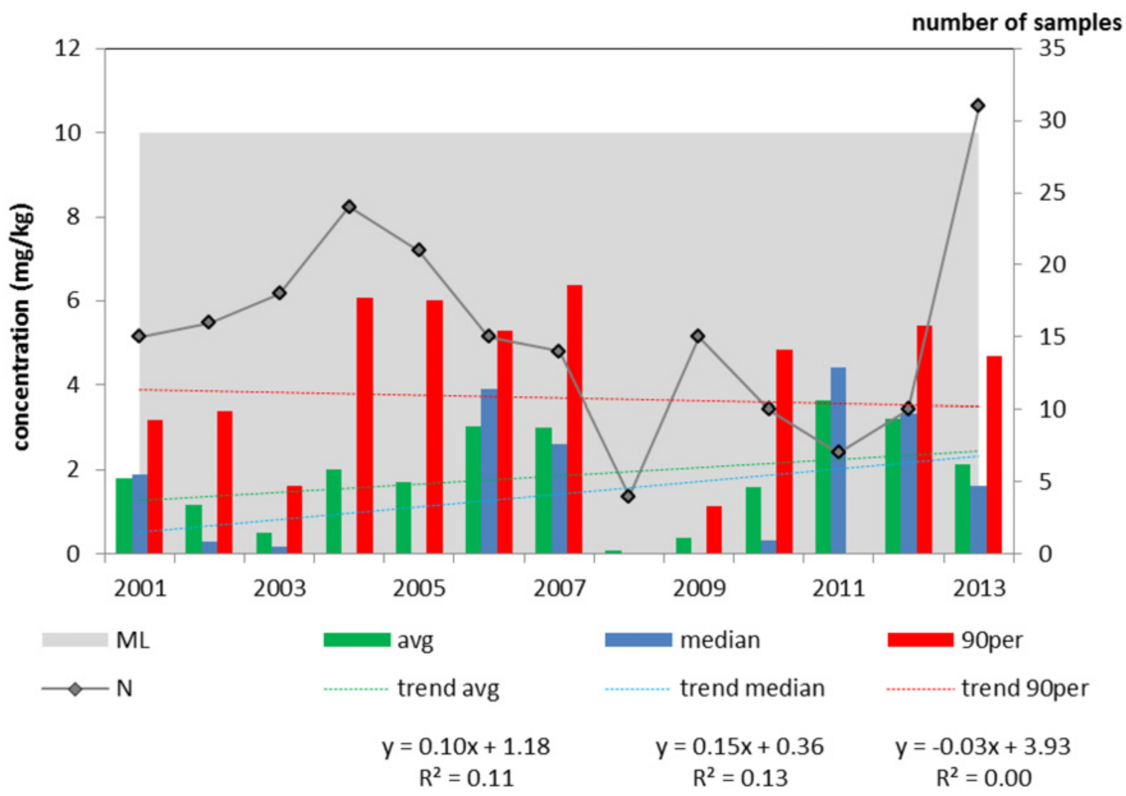

Figure 1-4 *Average, median and 90 percentile concentration of arsenic in phosphates and calcareous marine algae; N =200; ML = 10 mg/kg.*

Calcium carbonate, calcium and magnesium carbonate
RASFF did not report notifications about calcium carbonate, calcium and magnesium carbonate. In the current study one sample exceeded the ML (15 mg/kg), calcium carbonate with 43 mg/kg arsenic, reported by PDV in 2006. The highest concentration in the other samples was 13 mg/kg.

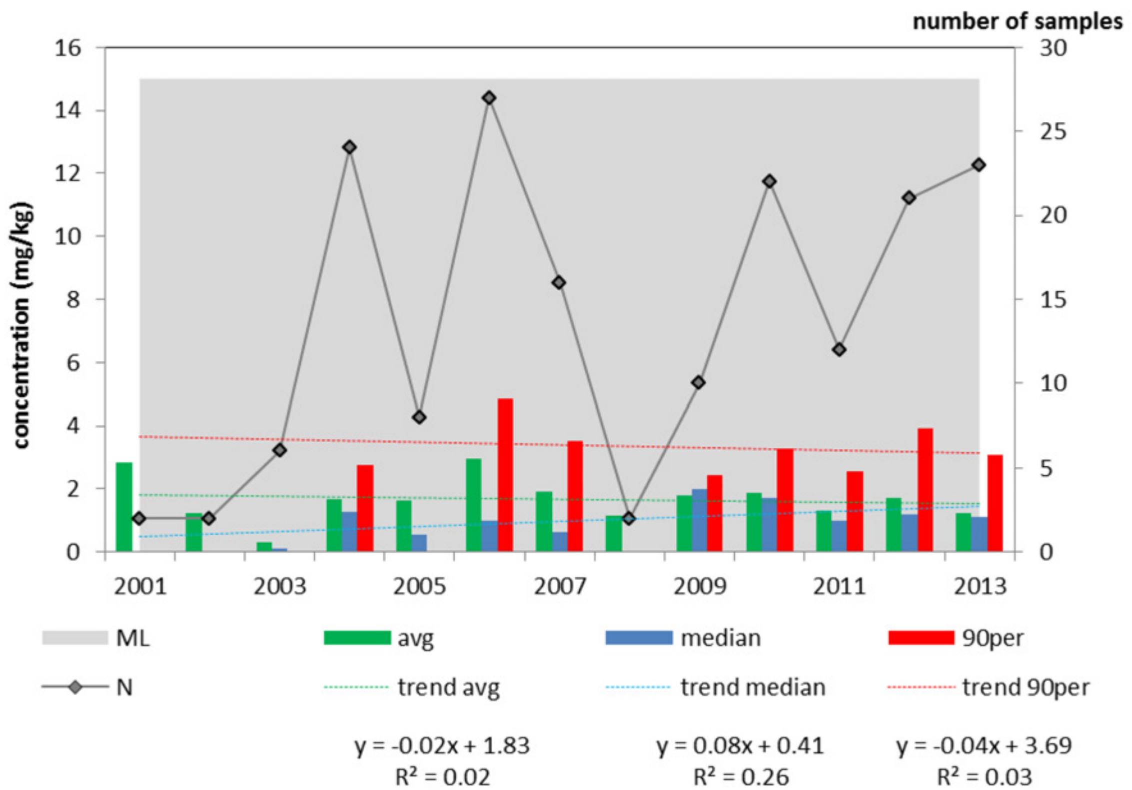

Figure 1-5 *Average, median and 90 percentile concentration of arsenic in calcium carbonate, calcium and magnesium carbonate; N =175; ML =15 mg/kg.*

Magnesium oxide and magnesium carbonate

RASFF reported two alerts regarding those products (Table Sup1-7); magnesium oxide from Spain (2003) an from Austria (2011). None of them related to the Netherlands. In the current dataset (all magnesium oxide) no samples exceeded the ML of 20 mg/kg. In 2013 one sample of magnesium oxide (out of 15 samples) contained half the ML and three samples around 30% of the ML, causing a relatively high 90 percentile value (around 30% of ML).

Table Sup1-7 *RASFF alerts and notifications related to arsenic in magnesium oxide and magnesium carbonate.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
magnesium oxide	2	8.5	56.5	20

(More details in Table Sup5-1).

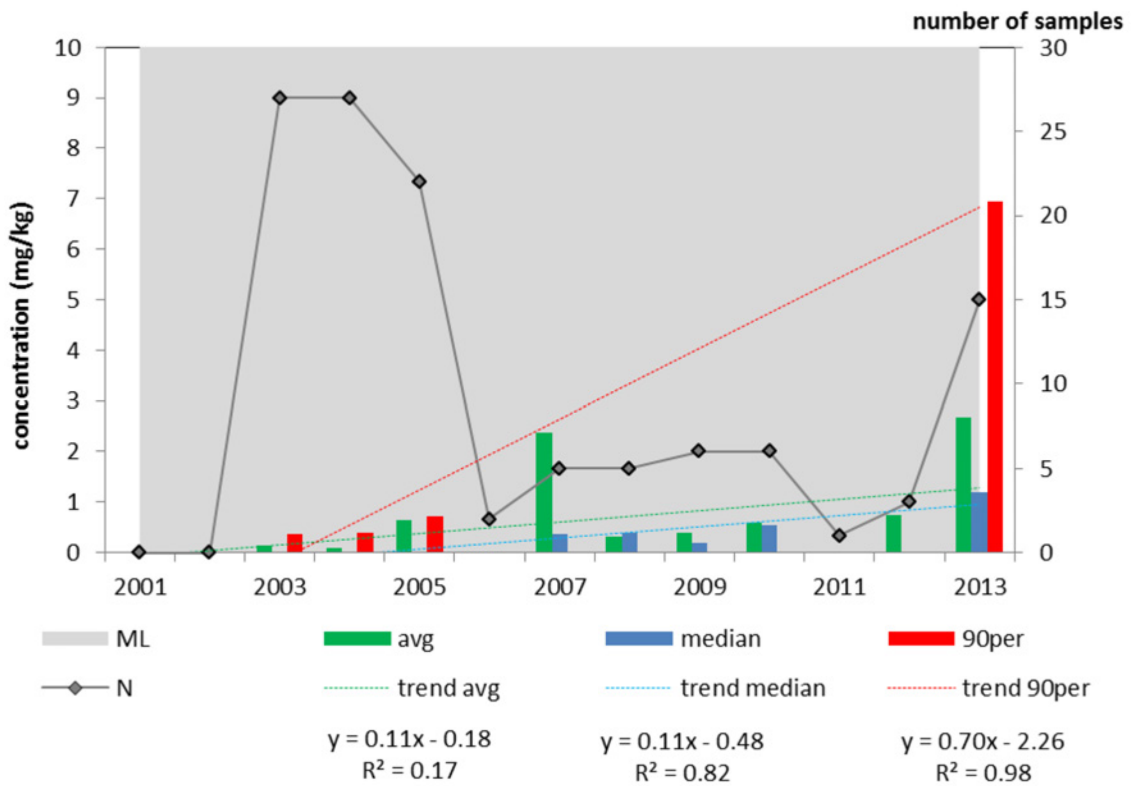

Figure 1-6 *Average, median and 90 percentile concentration of arsenic in magnesium oxide; N = 119; ML = 20 mg/kg.*

Fish, other aquatic animals and products derived thereof

Three notifications in RASFF concerned fish, other aquatic animals and products derived thereof (Table Sup1-8), none of them exceeded the ML. Two of the notifications concerned products from the Netherlands (mussel grit and oyster shells), notified by Germany (alert) and Belgium (information) respectively. The third notification concerns fish meal from Vietnam, reported by France (border rejection). In the current dataset three samples exceeded the ML of 25 mg/kg in fish meal in 2007 (148 mg/kg) and 2006 (165 and 168 mg/kg).

Table Sup1-8 *RASFF alerts and notifications related to arsenic in fish, other aquatic animals and products derived thereof.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
fish meal	1	7.1	7.1	25
mussel grit	1	24	24	25
oyster shells	1	22	22	25

(More details in Table Sup5-1).

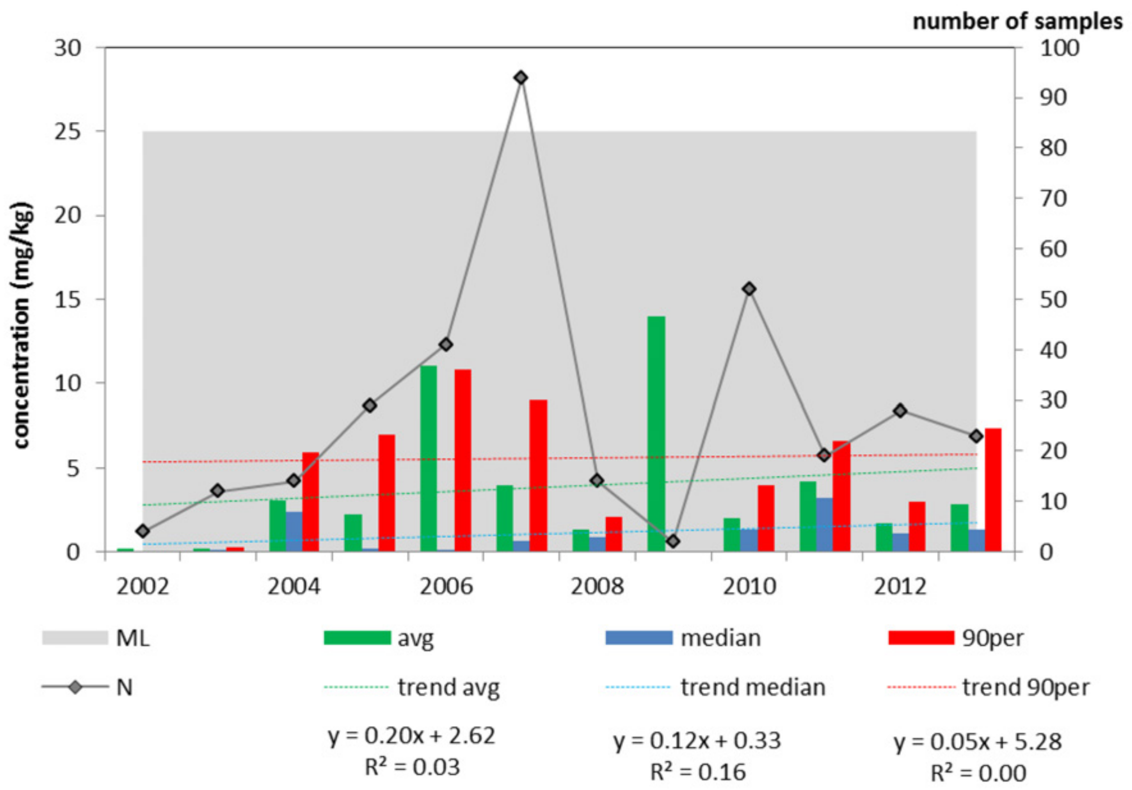

Figure 1-7 *Average, median and 90 percentile concentration of arsenic in fish, other aquatic animals and products derived thereof; 2002-2013; N =332; ML = 25 mg/kg.*

Seaweed meal and feed materials derived from seaweed

One RASFF notification refers to seaweed/algae: sea algae meal from France, reported by Austria in 2012 (Table Sup1-9). In the current dataset seven samples (of 64) exceeded the ML of 40 mg/kg, all of them in 2009. No samples were available before 2009.

Table Sup1-9 *RASFF alerts and notifications related to arsenic in seaweed meal and feed materials derived from seaweed.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
algae	1	80	80	40

(More details in Table Sup5-1).

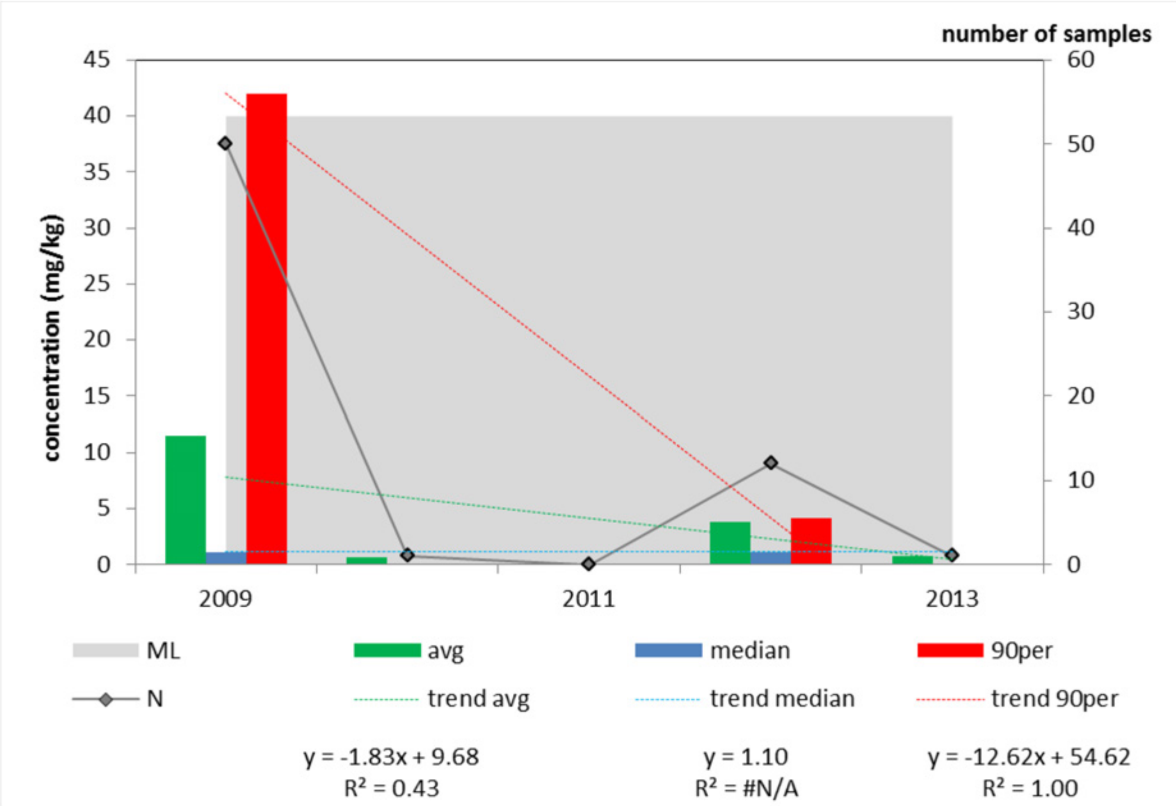

Figure 1-8 *Average, median and 90 percentile concentration of arsenic in seaweed meal and feed materials derived from seaweed; 2009-2013; N =64; ML = 40 mg/kg.*

Iron particles used as tracer

A separate ML has been defined for this product group (50 mg/kg) but there were no samples reported in RASFF or in the current study.

Feed additives belonging to the functional group of compounds of trace elements, with the exception of several specific minerals

RASFF did not report notifications regarding feed additives belonging to the functional group of compounds of trace elements. In the current study three samples (out of 84) contained an arsenic concentration above 10 mg/kg, one actually exceeding the ML; iron oxide from France in 2011 with 100.55 mg/kg arsenic.

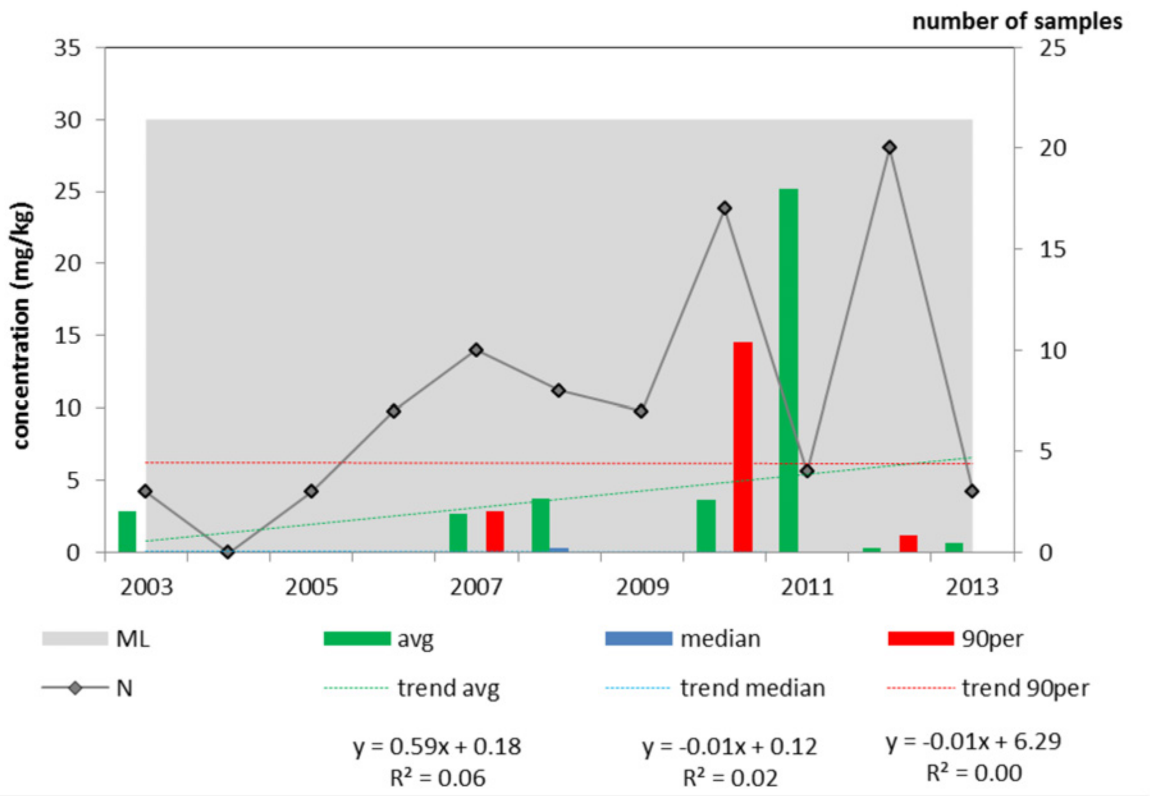

Figure 1-9 *Average, median and 90 percentile concentration of arsenic in feed additives belonging to the functional group of compounds of trace elements; 2003-2013; N =84; ML = 30 mg/kg.*

Cupric sulphate pentahydrate, cupric carbonate, di copper chloride trihydroxide and ferrous carbonate

RASFF did not report incidents with cupric sulphate pentahydrate, cupric carbonate, di copper chloride trihydroxide and ferrous carbonate. In the current study (all copper sulphate) five samples (out of 51) exceeded the ML of 50 mg/kg; 61, 59 and 54 mg/kg in 2006, 66 and 55 mg/kg in 2009 and 2010 respectively. Most samples were taken in 2009 and 2010 (Figure 1-10).

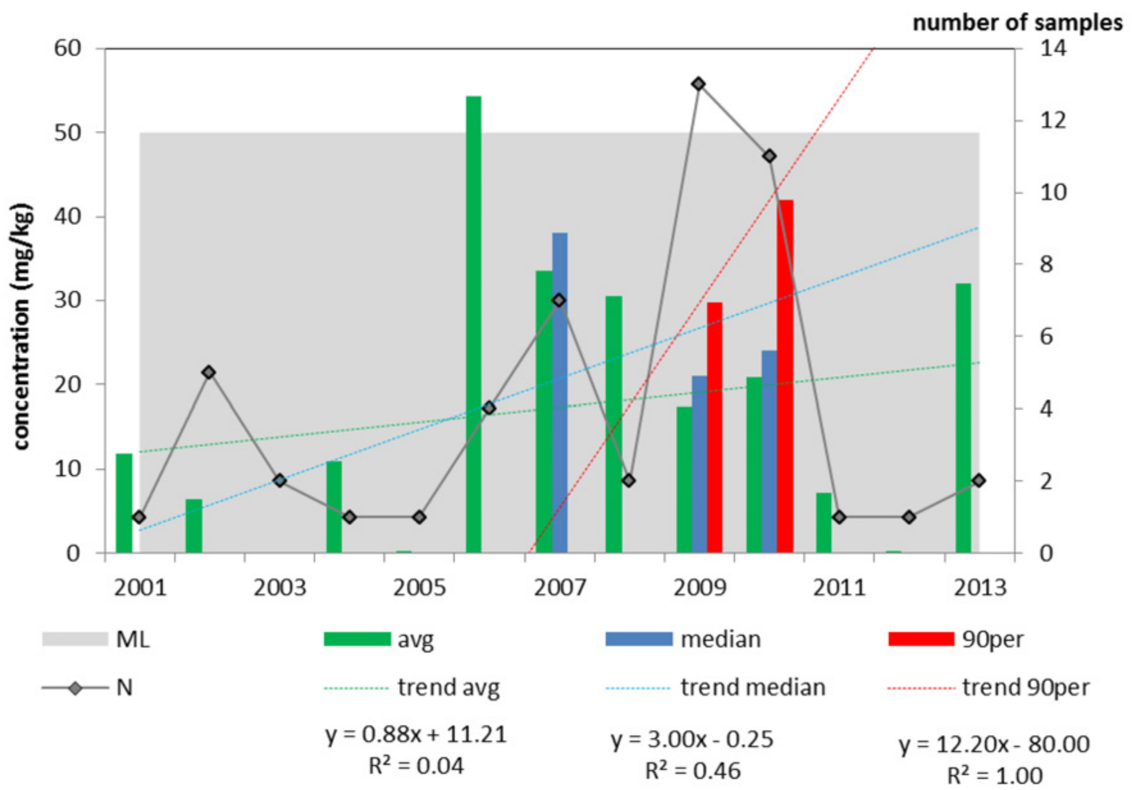

Figure 1-10 *Average, median and 90 percentile concentration of arsenic in copper sulphate; N = 51; ML = 50 mg/kg.*

Zinc oxide, manganous oxide and cupric oxide

RASFF reported one sample from this group with an arsenic concentration exceeding the ML of 100 mg/kg (Table Sup1-10). It concerns manganese oxide from India, notified by Denmark in 2012. In the current study no samples of zinc oxide or manganese oxide exceeded the ML. No cupric oxide samples were reported. The highest value was 79.5 in zinc oxide in 2004. The number of samples decreased to zero in 2013 (Figure 1-11).

Table Sup1-10 *RASFF alerts and notifications related to arsenic in zinc oxide, manganous oxide and cupric oxide.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
manganese oxide	1	110	110	100

(More details in Table Sup5-1).

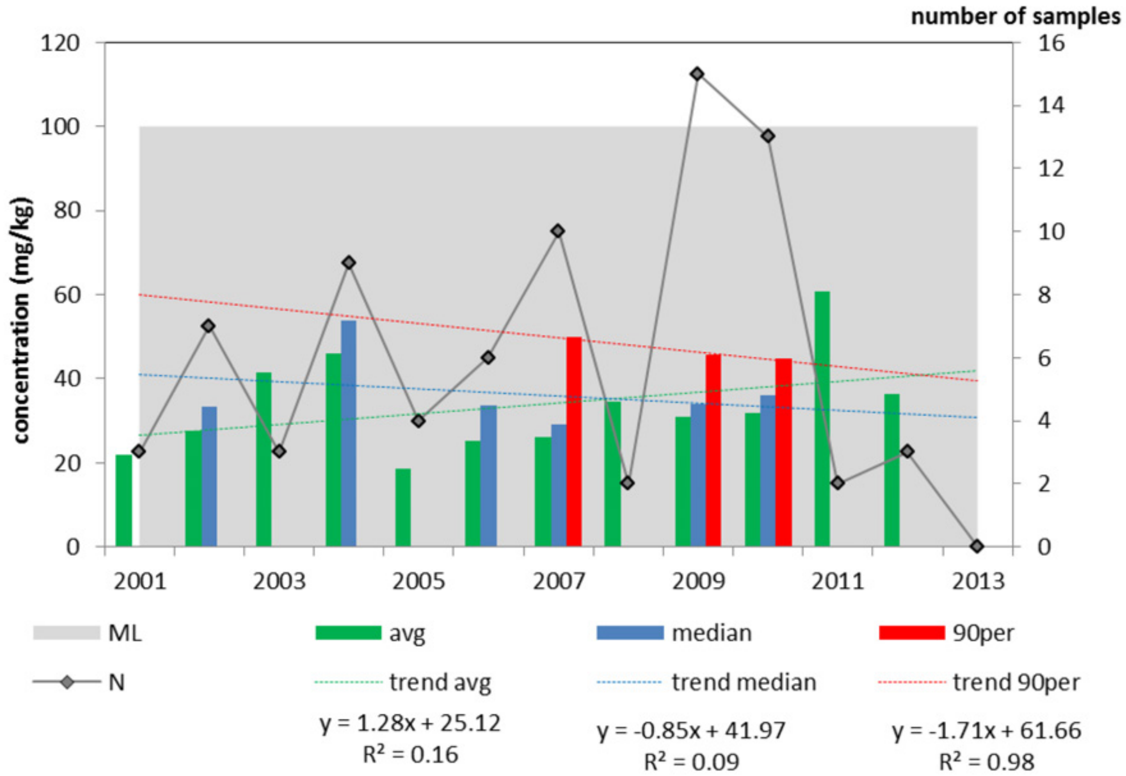

Figure 1-11 *Average, median and 90 percentile concentration of arsenic in zinc oxide, manganous oxide and cupric oxide; N =77; ML = 100 mg/kg.*

Feed additives belonging to the functional group of binders and anti-caking agents
In the current study 291 samples belong to this group. There was no ML defined for this group. The highest concentration reported was 31 mg/mg in zeolite (2013)(Figure 1-12).

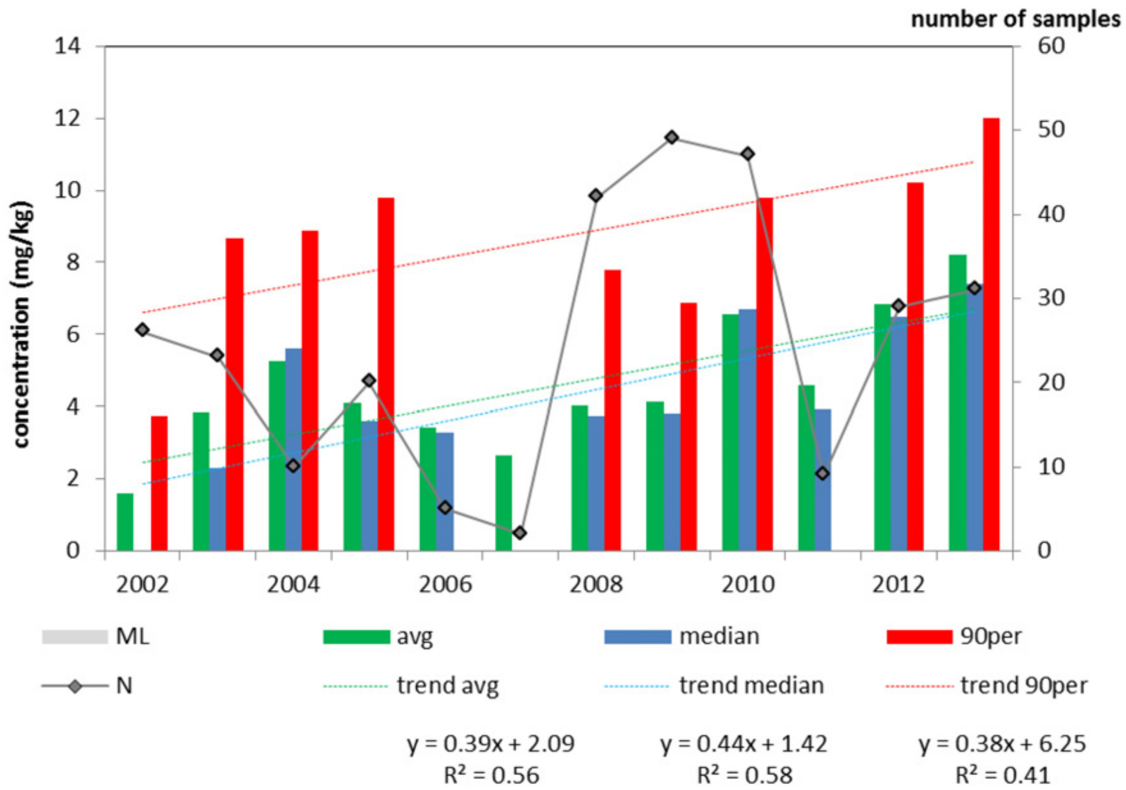

Figure 1-12 *Average, median and 90 percentile concentration of arsenic in feed additives belonging to the functional group of binders and anti-caking agents; 2002-2013; N = 293; no ML.*

With 119 of 293 samples sepiolite had the largest contribution to the group of binders (Figure 1-13). No data were available preceding 2005.

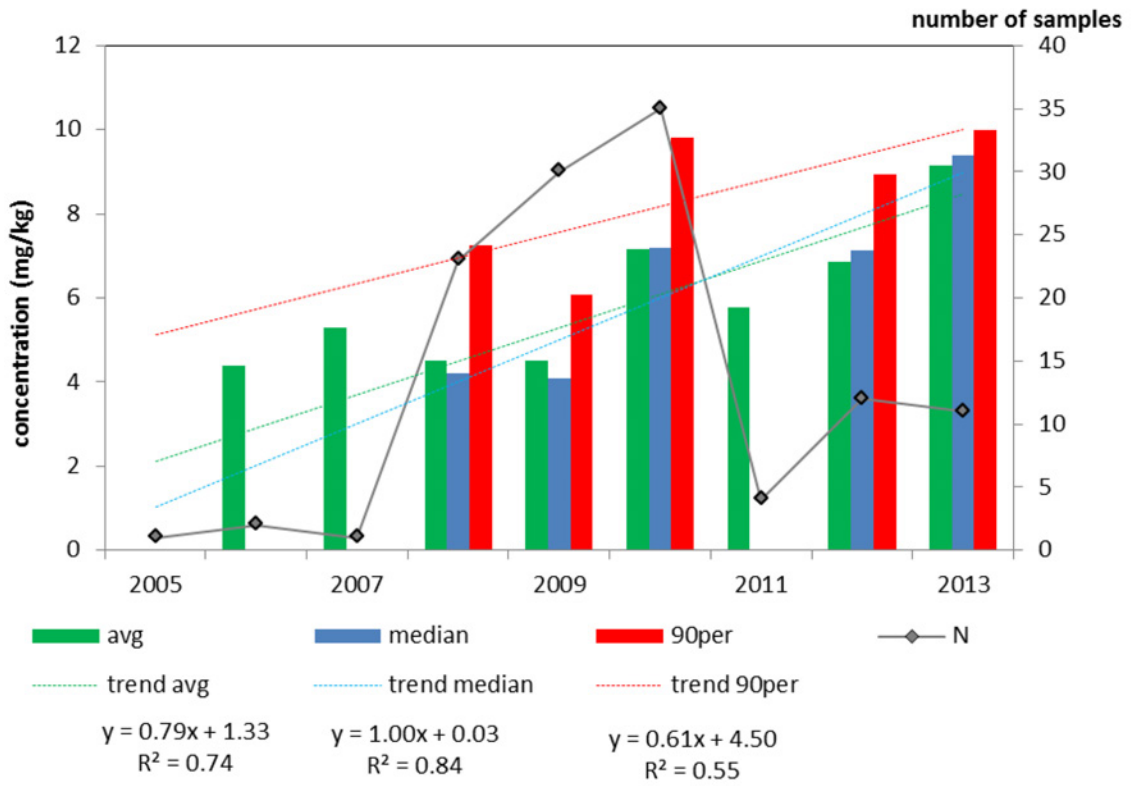

Figure 1-13 *Average, median and 90 percentile concentration of arsenic in sepiolite; N = 119; no ML.*

Other feed additives, including vitamins

In the current study 165 samples belong to this group (Figure 1-14). There was no ML defined for food additives other than trace elements. The highest concentration reported was 23.2 mg/kg in silicium oxide (2013).

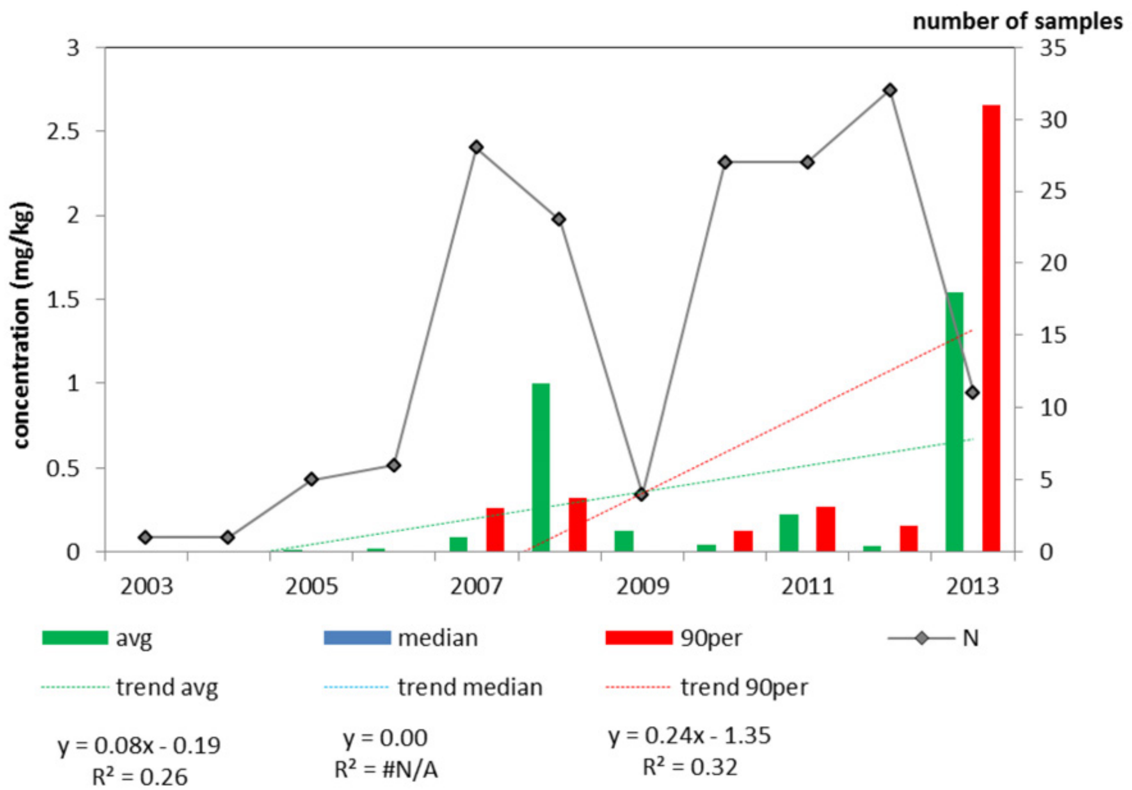

Figure 1-14 *Average, median and 90 percentile concentration of arsenic in other feed additives (incl. vitamins); 2003-2013; N =165; no ML.*

Complementary feed, with the exception of mineral feed

RASFF reported three notifications regarding complementary feed (excl. mineral feed and complementary feed for pets) (Table Sup1-11). None of the notifications were related to the Netherlands. From the 170 samples in this dataset none exceeded the ML (Figure 1-15).

Table Sup1-11 *RASFF alerts and notifications related to arsenic in complementary feed (excl. mineral feed and complementary feed for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
horse feed, complementary	2	6.7	8.7	4
pig feed, complementary	1	12.4	12.4	4

(More details in Table Sup5-1).

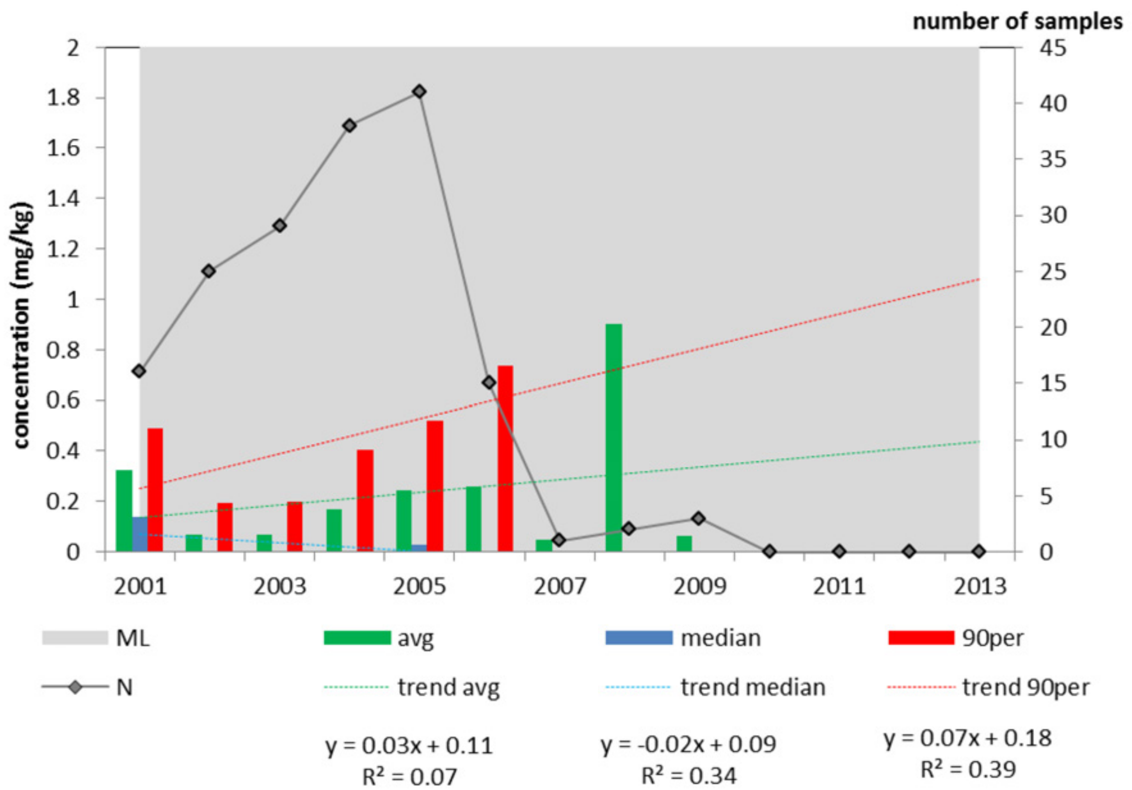

Figure 1-15 *Average, median and 90 percentile concentration of arsenic in complementary feed (excl. excl. mineral feed and complementary feed for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed); N =170; ML = 4 mg/kg.*

When all complementary ruminant feeds were combined (samples labelled as complementary feed for sheep, bovines or ruminants) there was a significant increase in the 90th percentile arsenic concentration (Figure 1-16) between 2001 and 2013. In 2007 and 2008 only four samples were taken. No samples exceeded the ML.

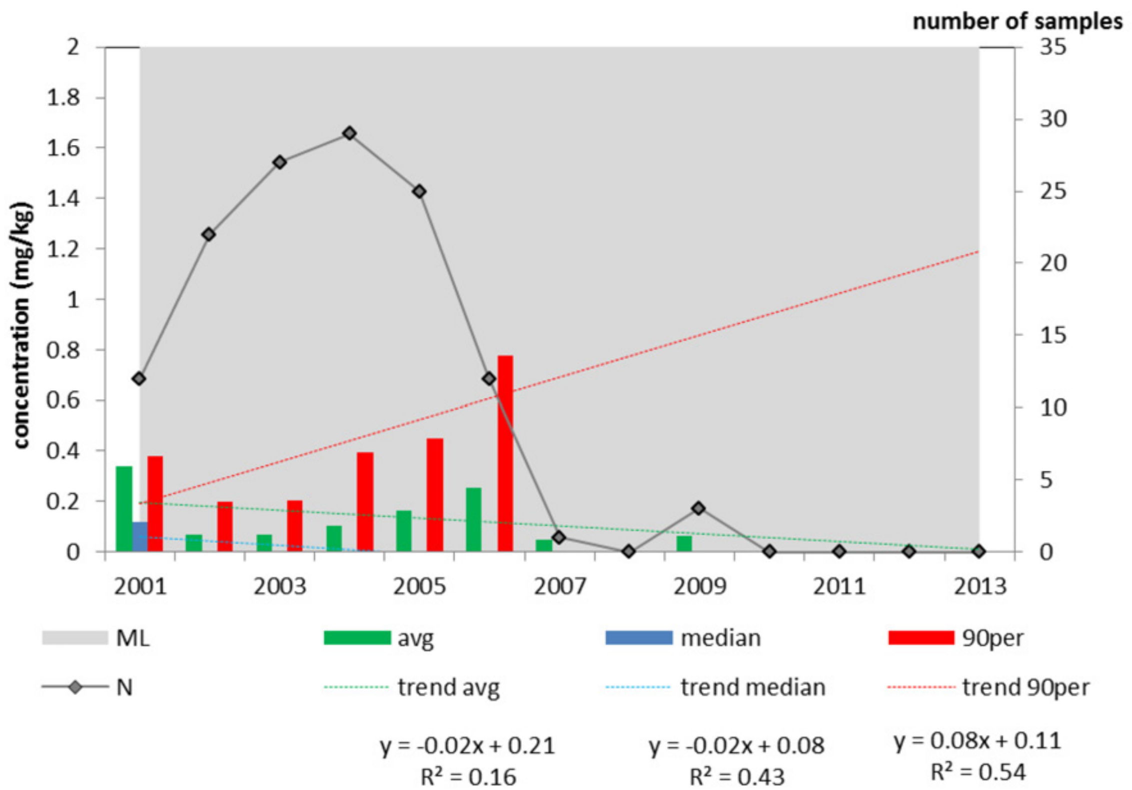

Figure 1-16 *Average, median and 90 percentile concentration of arsenic in complementary feed for all ruminants; N =131; ML = 4 mg/kg.*

Mineral feed

RASFF reported three notifications regarding mineral feed (Table Sup1-12), none of them related to the Netherlands. In the current dataset no samples exceeded the ML of 12 mg/kg. A few samples (17 out of 715) contain more than 50% of the ML. After a decrease in the number of samples taken per year, the number increases again after 2006.

Table Sup1-12 *RASFF alerts and notifications related to arsenic in mineral feed.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
mineral mix, general	3	5.9	37	12

(More details in Table Sup5-1).

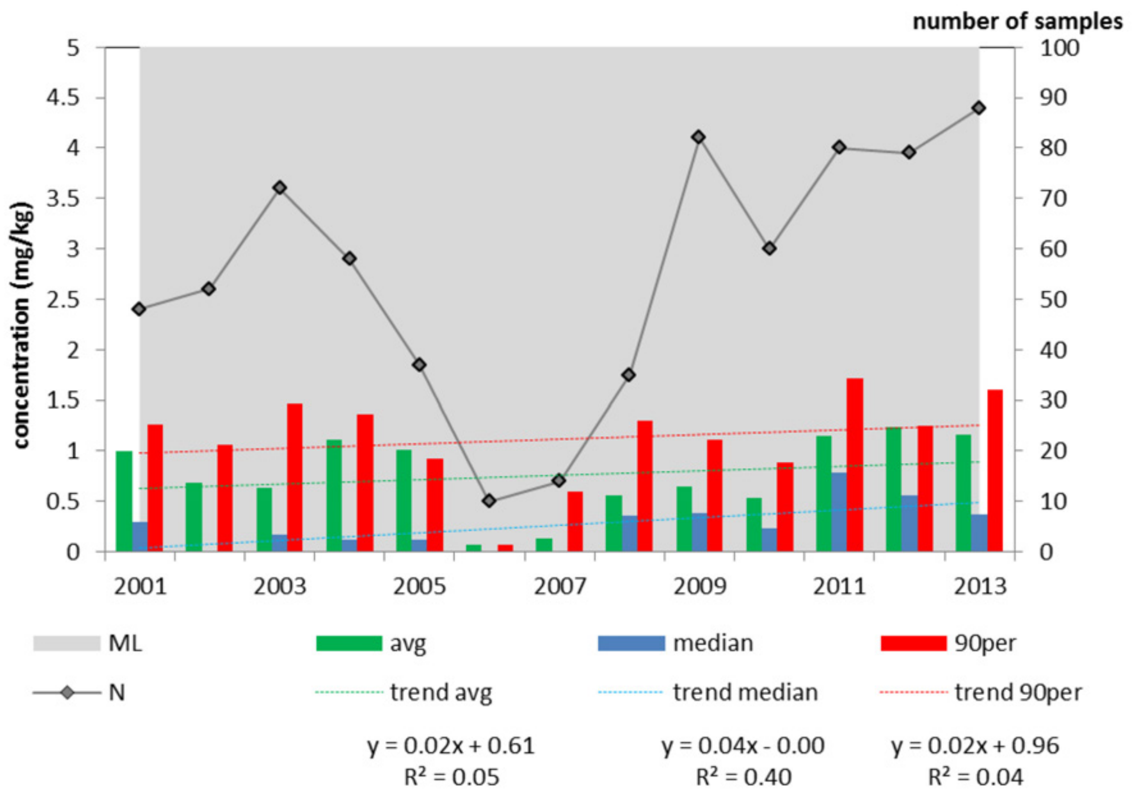

Figure 1-17 *Average, median and 90 percentile concentration of arsenic in mineral feed; N = 715; ML = 12 mg/kg.*

Complete feed with the exception of feed for fish and fur animals, and for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed

RASFF did not report notifications regarding this feed category. In the current study the number of samples was very low after 2007, most samples were from 2003-2007 (Figure 1-18). In 2006 several samples of poultry feed and pig feed contained arsenic concentrations around 150 and 50 mg/kg respectively. The ML was 2 mg/kg. It was not possible to use this dataset to find a trend due to the large variation in concentrations.

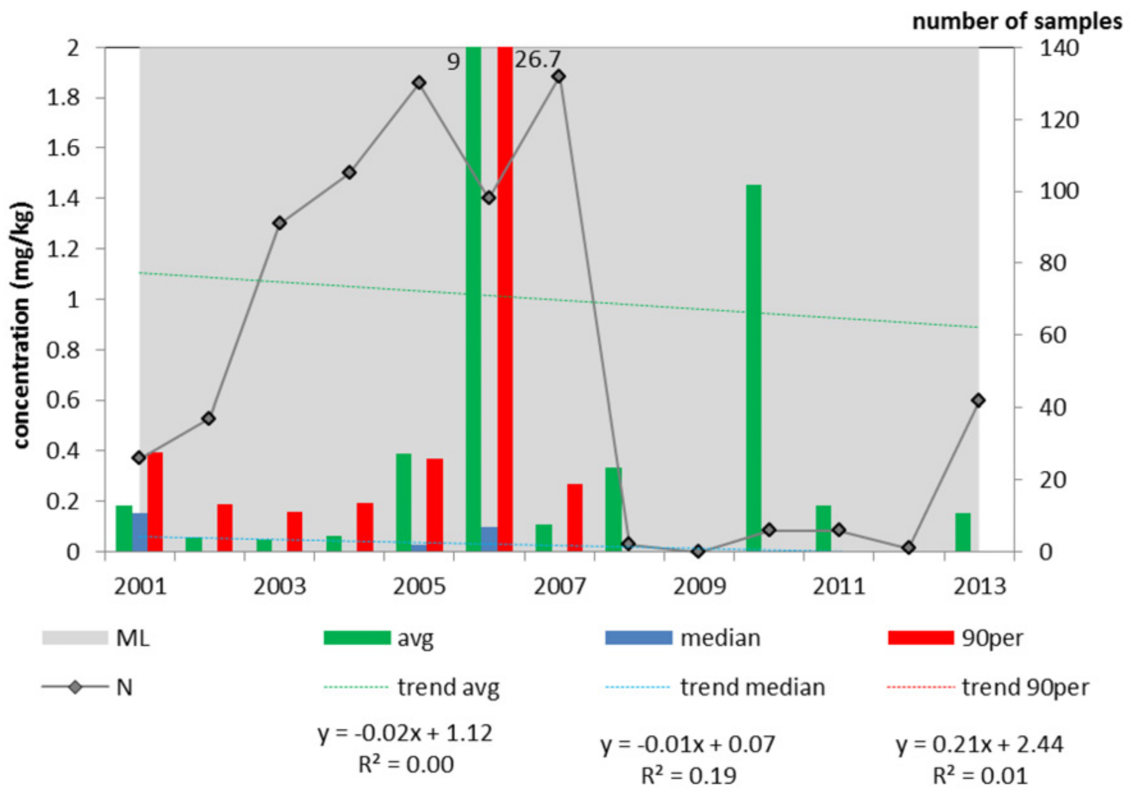

Figure 1-18 *Average, median and 90 percentile concentration of arsenic in complete feed; N = 676; ML = 2 mg/kg.*

Complete feed for fish and fur animals

RASFF reported three notifications regarding arsenic in fish feed and none regarding feed for fur animals (Table Sup1-13). None of the RASFF notifications were related to the Netherlands. In the current dataset eight samples of feed for fish or fur animals were reported. None of the samples exceeded the ML of 10 mg/kg. Because of the limited number of samples no trends could be analysed.

Table Sup1-13 *RASFF alerts and notifications related to arsenic in complete feed for fish and fur animals.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
fish feed	1	6.9	6.9	10
shrimp feed	2	7.4	11	10

(More details in Table Sup5-1).

Complete feed for pet animals containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed

RASFF reported 12 notifications regarding pet food (Table Sup1-14). However, it was not clear whether this feed contained fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed. The ML for this kind of pet food is 10 mg/kg. If the feed did not contain those ingredients the ML would have been 2 mg/kg. Considering the reported concentrations it is most likely that an ML of 2 mg/kg had been used to judge those samples. Most notifications involve petfood from Thailand in 2011 and 2012. One notification was for petfood from Vietnam. No notifications originated from the Netherlands. In the current study it was also not always clear whether a pet food contained fish or seaweed. The eight samples (out of 57 pet food samples) where the product description mentioned fish (all from 2013) did not contain arsenic above the LOQ.

Only five samples in the current dataset contained arsenic concentrations above the LOQ, and four of them were below 2 mg/kg. One sample from 2013 contained 4.7 mg/kg and thus would exceed the ML of 2 mg/kg (the product description did not indicate the presence of fish or seaweed). Most samples were from 2013 (42), one each from 2005 and 2007 (below the LOQ) and the other five samples from 2011. The number of samples was too low for trend analysis.

Table Sup1-14 *RASFF alerts and notifications related to arsenic in complete feed for pet animals.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
cat feed	5	5.79	7.1	2
dog food	2	7.1	8.5	2
pet food	5	7	11	2

(More details in Table Sup5-1).

Pre-mixtures

RASFF did not report notifications involving pre-mixtures. There was no ML defined for pre-mixtures. In the current study 613 samples were labelled as pre-mixture. The large number of samples from feed without a ML was caused by the fact that those samples were also analysed for other heavy metals that do have an ML defined, for example lead. Of the 613 samples 413 contain arsenic above the LOQ. When compared to the ML of complementary feed (4 mg/kg) the 90 percentile values were close to or exceeding this limit. Twenty-five individual samples exceeded this ML. However, only five samples (between 12.9 and 17 mg/kg) exceeded the ML for mineral feed (12 mg/kg).

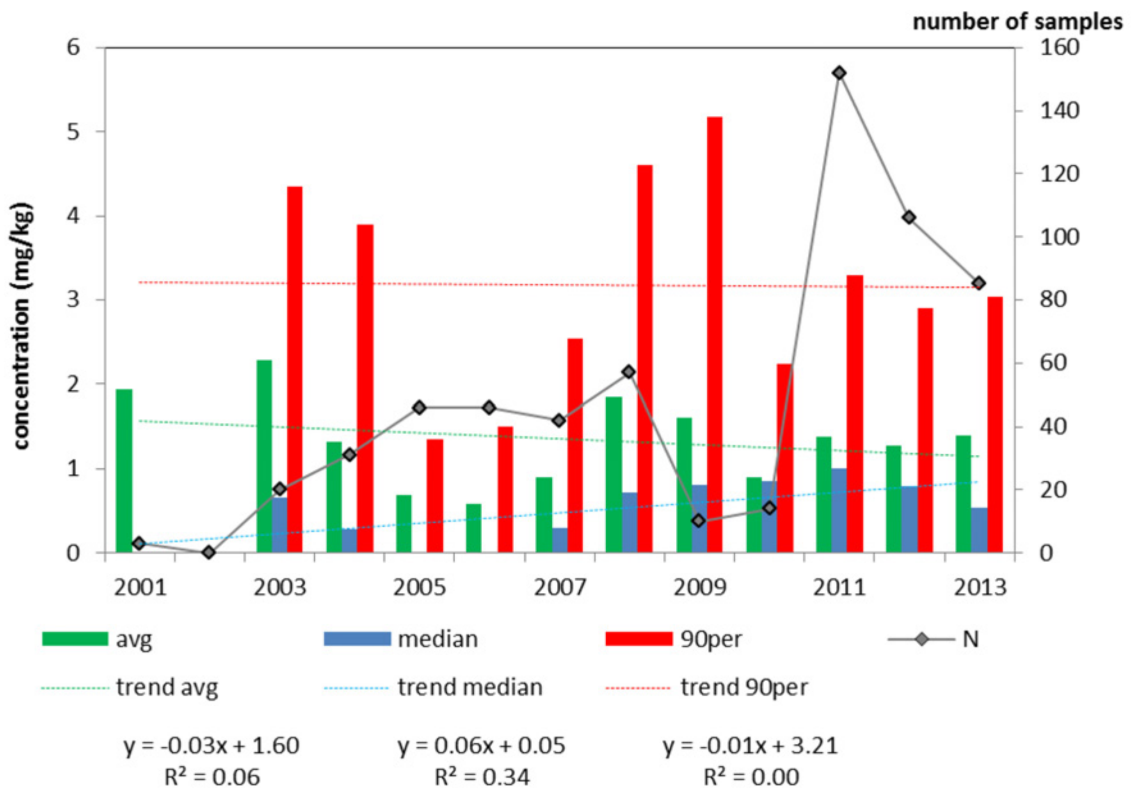

Figure 1-19 *Average, median and 90 percentile concentration of arsenic in pre-mixtures; N = 612; no ML.*

Annex 2 Supplemental information cadmium

Maximum levels for cadmium in animal feed and feed materials

Directive 2002/32/EC, as last amended for cadmium by Regulation (EU) No 1275/2013 describes the maximum cadmium concentration allowed in feeds and feed materials (Table Sup2-1). The highest concentrations were allowed in feed additives belonging to the functional group of compounds of trace elements, especially cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate. The lowest MLs were defined for complete and complementary feeds.

Table Sup2-15 *Maximum levels for cadmium in animal feed and feed materials according to Directive 2002/32/EC, amended by Regulation (EU) No 1275/2013.*

Products intended for animal feed	Maximum content in mg/kg (ppm) relative to a feed with a moisture content of 12%
Feed materials of vegetable origin	1
Feed materials of animal origin	2
Feed materials of mineral origin	2
with the exception of:	
— phosphates.	10
Feed additives belonging to the functional group of compounds of trace elements	10
with the exception of:	
— cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate.	30
Feed additives belonging to the functional groups of binders and anti-caking agents	2
Pre-mixtures (6)	15
Complementary feed	0,5
with the exception of:	
— mineral feed	
– – containing < 7% phosphorus (8)	5
– – containing ≥ 7% phosphorus (8)	0,75 per 1% phosphorus (8), with a maximum of 7,5
— complementary feed for pet animals	2
— long-term supply formulations of feed for particular nutritional purposes with a concentration of trace elements higher than 100 times the established maximum content in complete feed;	15
Complete feed	0,5
with the exception of:	
— complete feed for cattle (except calves), sheep (except lambs), goats (except kids) and fish;	1
— complete feed for pet animals.	2

(6) The maximum level established for pre-mixtures takes into account the additives with the highest level of lead and cadmium and not the sensitivity of the different animal species to lead and cadmium. As provided in Article 16 of Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition (OJ L 268, 18.10.2003, p. 29), in order to protect animal and public health, it was the responsibility of the producer of pre-mixtures to ensure that, in addition to compliance with the maximum levels for pre-mixtures, the instructions for use on the pre-mixture were in accordance with the maximum levels for complementary and complete feed.

(8) The % of phosphorus was relative to a feed with a moisture content of 12%.

Overall trends in percentage of samples exceeding the LOQ or the ML

When looking at the different product groups, grouped according to the ML legislation, the highest percentage of samples with cadmium concentrations exceeding the ML were from complementary feeds (Table Sup2-2). But also in other product groups some samples exceed the ML.

Table Sup2-16 *Samples exceeding the ML or the LOQ for cadmium (between 2000 and 2013).*

Product	N Total	N > LOQ	N > ML	% > LOQ	% > ML
Complementary feed, with the exception of mineral feed and pet feed:	169	154	8	91	4.7
subset: complementary feed for ruminants	131	120	6	92	4.6
Complementary feed mineral feed	713	665	0	93	0
subset: complementary mineral feed for ruminants	537	514	0	96	0
Complete feed, with the exception of:	500	341	5	68	1
- Complete feed for cattle (except calves), sheep (except lambs), goats (except kids) and fish	75	53	1	71	1.3
- Complete feed for pet animals.	58	16	0	28	0
Feed materials of animal origin	401	249	4	62	1.0
Feed materials of vegetable origin	2703	1544	1	57	0
Feed materials of mineral origin, with the exception of:	416	200	2	48	0.5
- Phosphates	232	212	0	91	0
Pre-mixtures	734	577	0	79	0
Feed additives belonging to the functional groups of binders and anti-caking agents	295	260	2	88	0.7
Feed additives belonging to the functional group of compounds of trace elements with the exception of:	135	102	0	76	0
- Cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate	84	60	0	71	0
Feed additives belonging to the functional group of vitamins and pro-vitamins	80	22	n.a.	28	n.a.
Feed additives, other	79	8	n.a.	10	n.a.
Total	**7342**	**5097**	**29**		

Table Sup2-17 *Samples exceeding the ML or the LOQ for cadmium (between 2007 and 2013).*

Product	N Total	N > LOQ	N > ML	% > LOQ	% > ML
Complementary feed, with the exception of mineral feed and pet feed	5	5	0	100	0
subset: complementary feed for ruminants	3	3	0	100	0
Complementary mineral feed	436	412	0	94	0
subset: complementary mineral feed for ruminants	320	514	0	96	0
Complementary feed for pet animals.	0	0	0	0	0
Complete feed, with the exception of:	57	8	2	14	4
- Complete feed for cattle (except calves), sheep (except lambs), goats (except kids) and fish	1	1	0	100	0
- Complete feed for pet animals	56	14	0	25	0
Feed materials of animal origin	183	164	4	90	2.2
Feed materials of vegetable origin	668	521	1	78	0.2
Feed materials of mineral origin, with the exception of:	203	118	2	58	1
- Phosphates	73	65	0	89	0
Pre-mixtures	453	432	0	95	0
Feed additives belonging to the functional groups of binders and anti-caking agents	204	191	1	94	0.5
Feed additives belonging to the functional group of compounds of trace elements with the exception of:	100	84	0	84	0
- Cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate	41	41	0	100	0
Feed additives belonging to the functional group of vitamins and pro-vitamins	80	22	-	11	-
Feed additives, other	66	7	-	79	-
Total	**2949**	**2602**	**10**		

Complementary feed (except pet food and mineral feed)
RASFF reported 2 incidents regarding complementary feed (Table Sup2-4), not related to the Netherlands. The product group contributing the most to the number of samples in the current study with cadmium concentrations > ML were complementary feeds (Table Sup2-2 and Table Sup2-3).

Table Sup2-18 *RASFF alerts and notifications related to cadmium and complementary feed (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
complementary feed, general	1	1.1	1.1	0.5
bovine feed, complementary	1	1.4	1.4	0.5

(More details in Table Sup5-3).

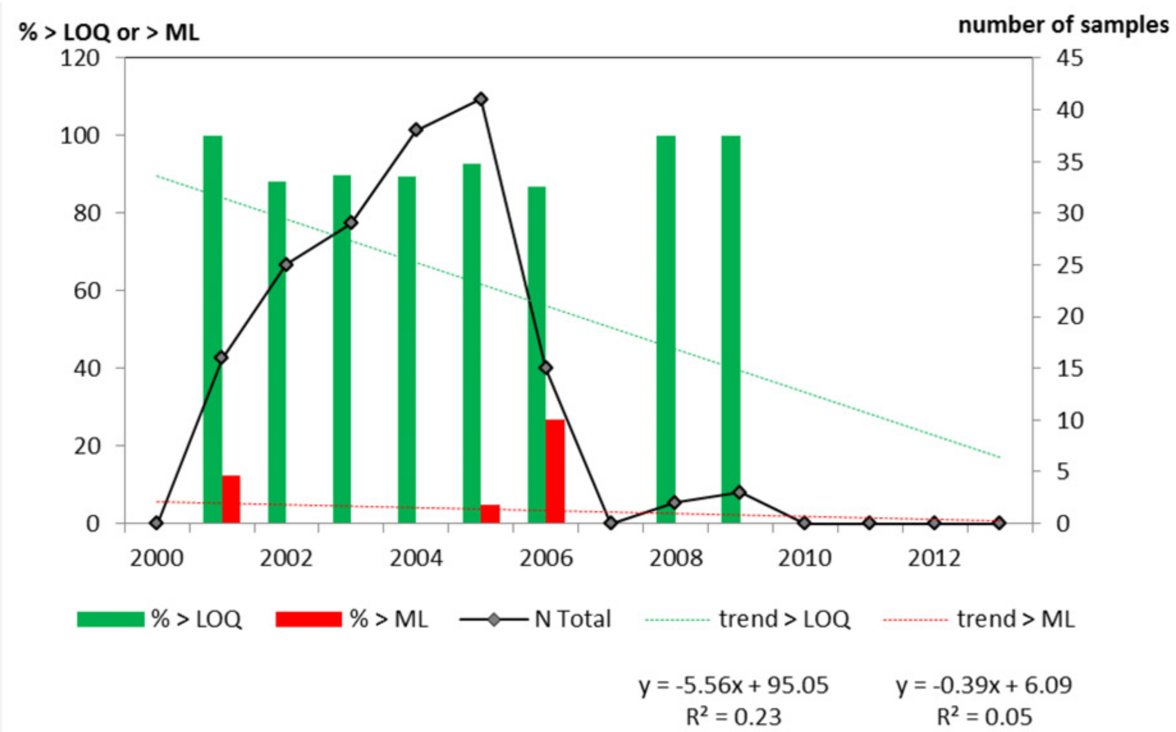

Figure 2-20 *Percentage of samples exceeding the ML and/or LOQ for cadmium; complementary feed (except pet food and mineral feed); N = 169.*

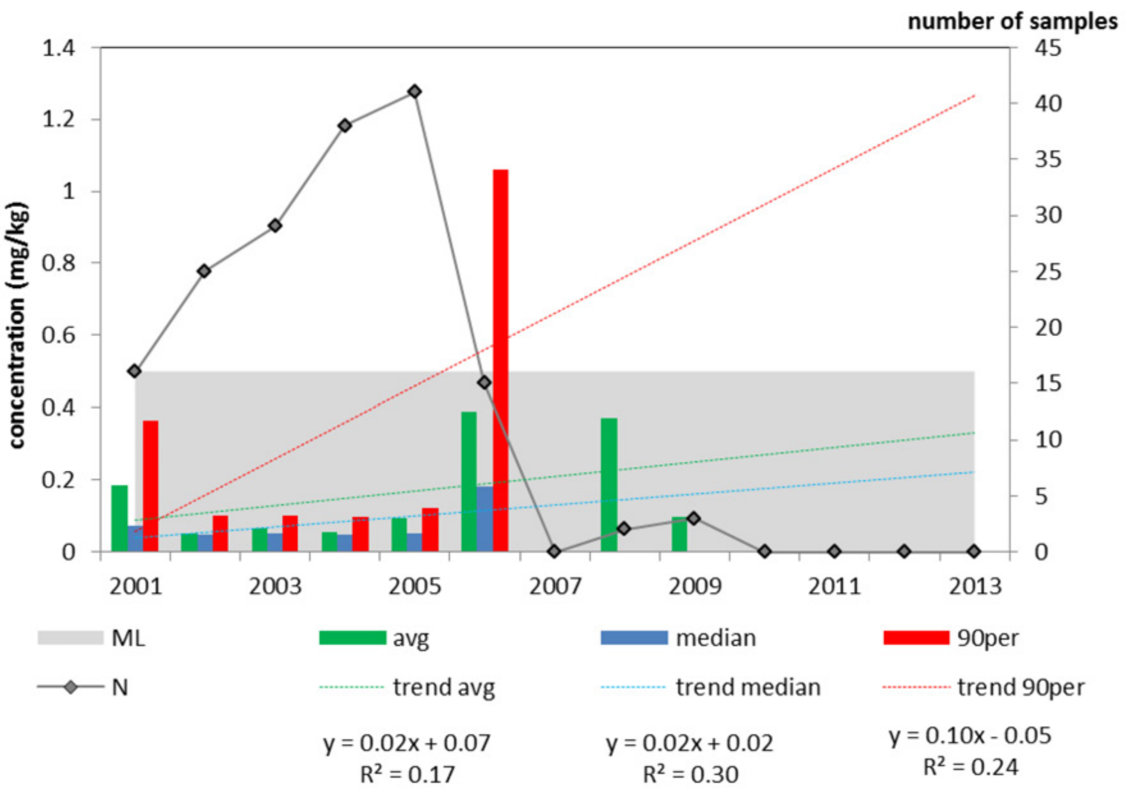

Figure 2-21 *Average, median and 90 percentile concentration of cadmium in complementary feed; N = 169; ML = 0.5 mg/kg.*

Of the complementary feeds, feed for ruminants had the highest percentage (4.6% over 2000-2013) of samples with a concentration exceeding the ML (Figure 2-3). Neither the percentage of samples exceeding the LOQ nor the percentage exceeding the ML nor the average concentration (Figure 2-4) decreased or increased significantly.

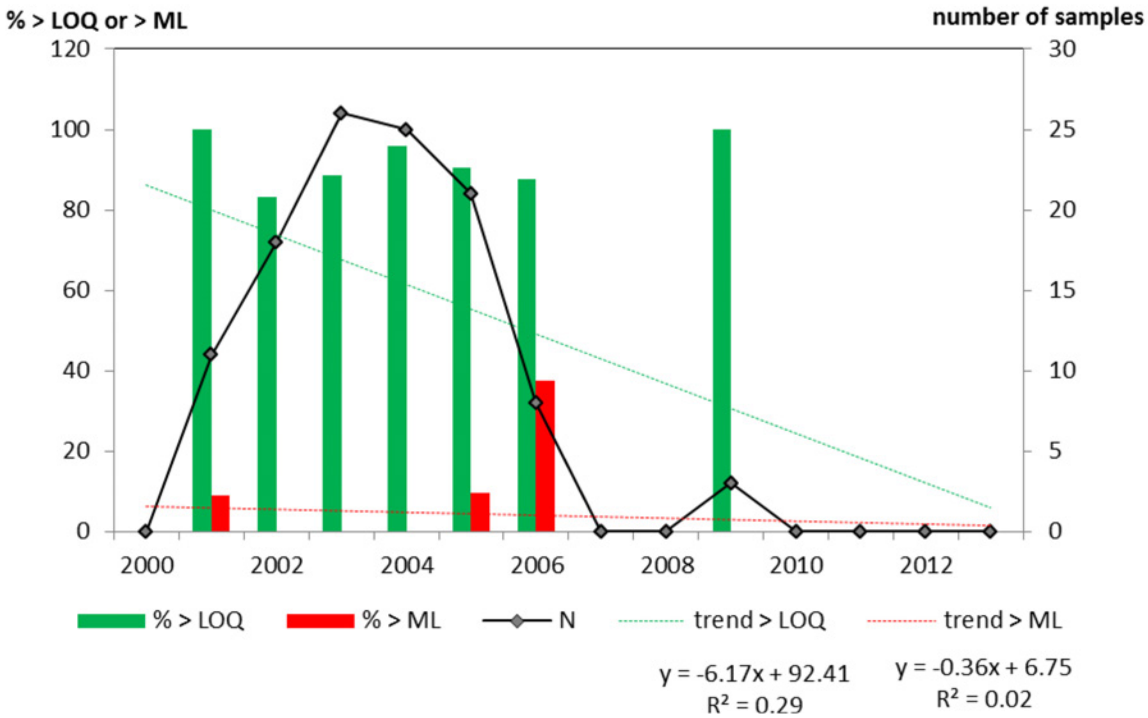

Figure 2-22 *Percentage of samples exceeding the ML and/or LOQ for cadmium; complementary ruminant feed; N=131.*

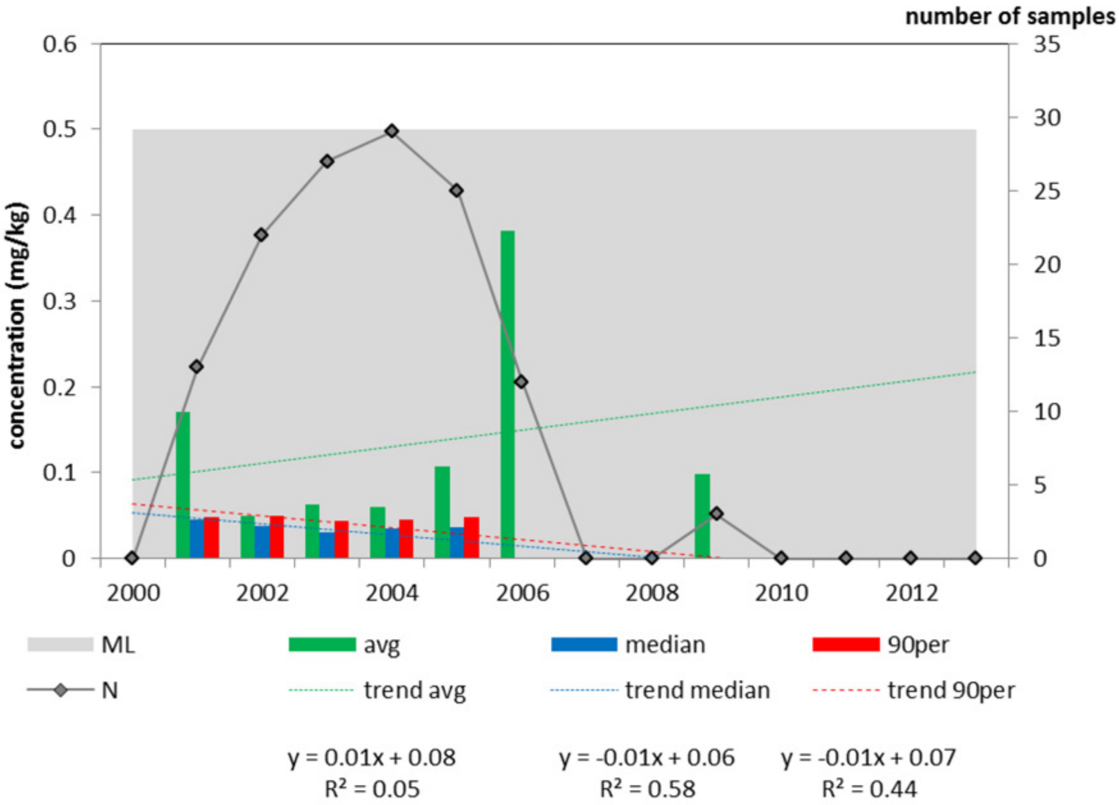

Figure 2-23 *Average, median and 90 percentile concentration of cadmium in complementary ruminant feed; N = 131; ML = 0.5 mg/kg.*

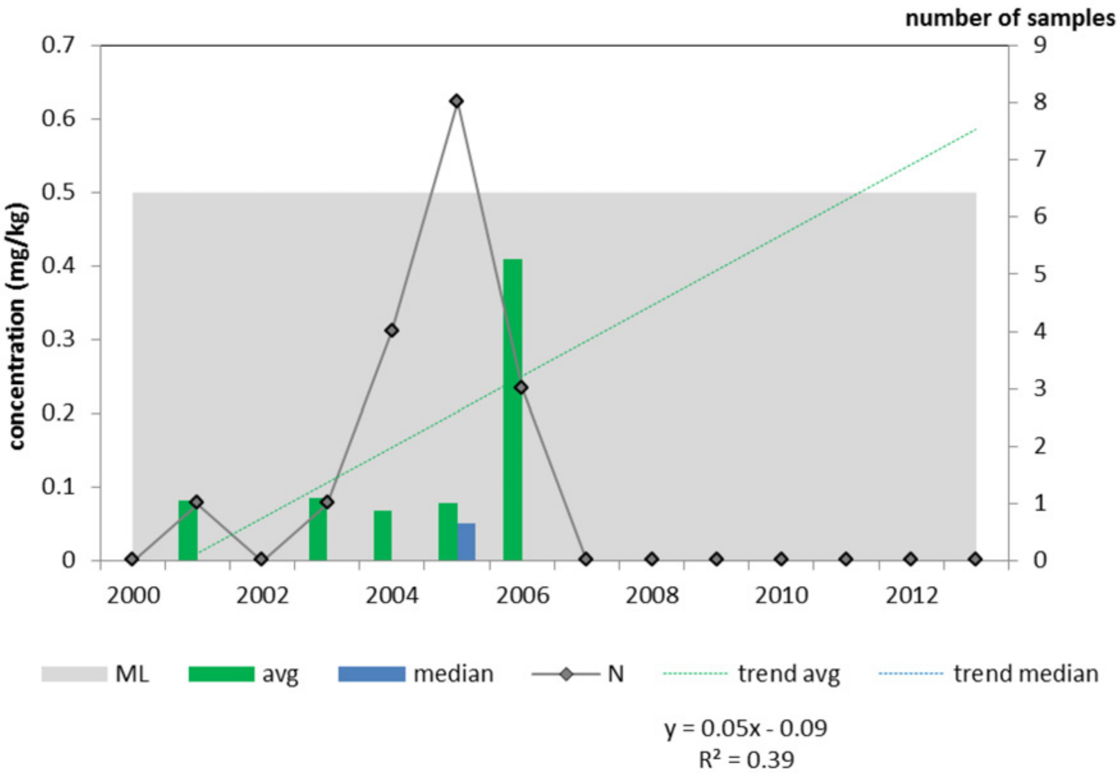

Figure 2-24 *Average and median concentration of cadmium in complementary feed for pigs; N = 17; ML = 0.5 mg/kg.*

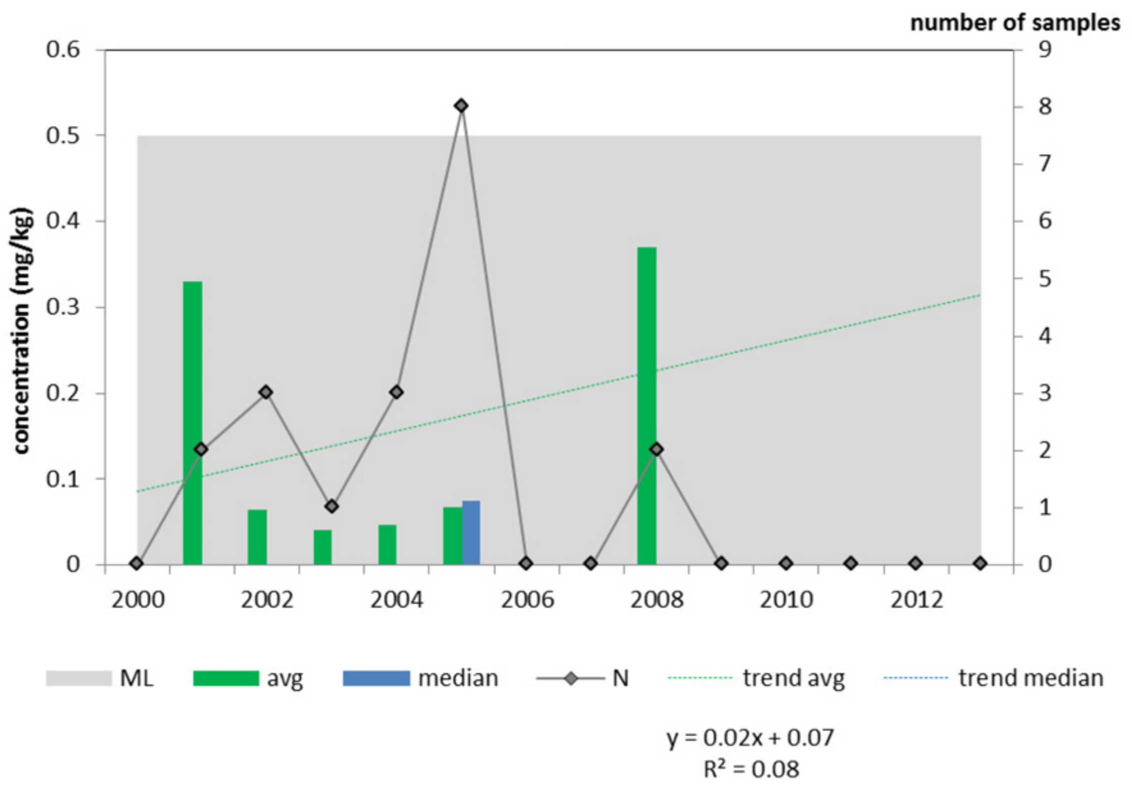

Figure 2-25 *Average, median and 90 percentile concentration of cadmium in complementary feed for poultry; N = 19; ML = 0.5 mg/kg.*

Complementary feed for pet animals

No samples were reported from this category. All petfood samples were considered to be complete feed.

Complementary mineral feed

No samples with cadmium concentrations exceeding the ML (of 5) were found in this dataset. The average cadmium concentration in complementary mineral feed did not in- or decrease significantly (Figure 2-7) between 2000 and 2013. A substantial amount of this feed (142 out of 436 samples between 2007 and 2013) was for ruminants (Figure 2-9). In total complementary mineral feed (Figure 2-8) and in complementary mineral feed for ruminants the average cadmium concentration decreased significantly between 2007 and 2013.

Table Sup2-19 *RASFF alerts and notifications related to cadmium and feed materials of mineral origin (except phosphates) (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
mineral mix, general	1	25	25	5

(More details in Table Sup5-3).

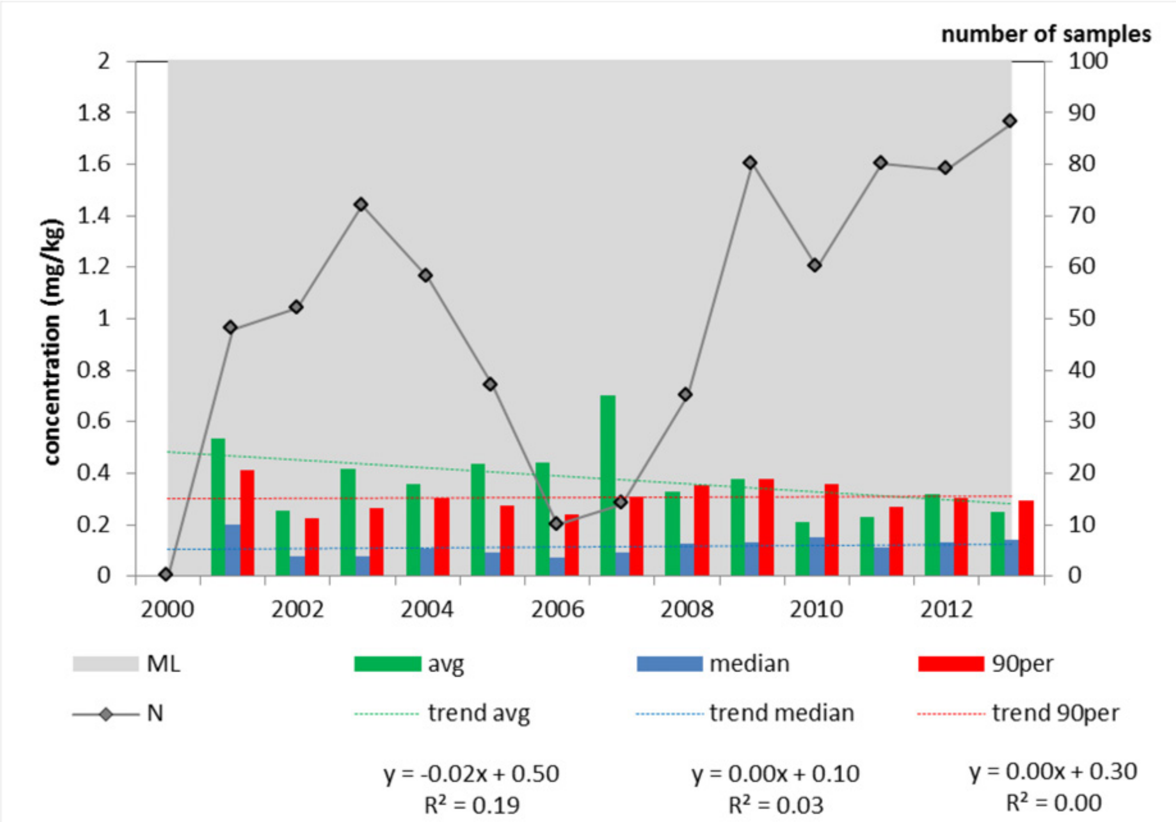

Figure 2-26 *Average, median and 90 percentile concentration of cadmium in complementary mineral feed; N = 713; ML = 5 mg/kg.*

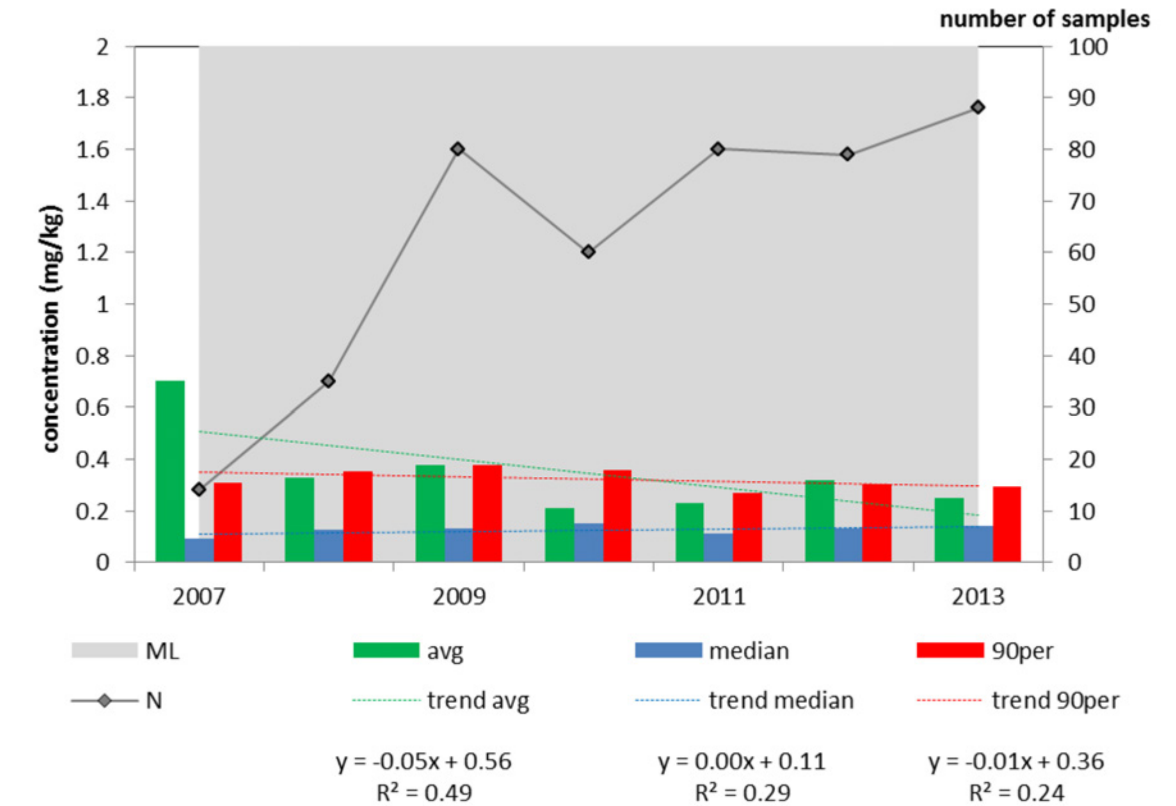

Figure 2-27 *Average, median and 90 percentile concentration of cadmium in complementary mineral feed between 2007 and 2013; N = 436; ML = 5 mg/kg.*

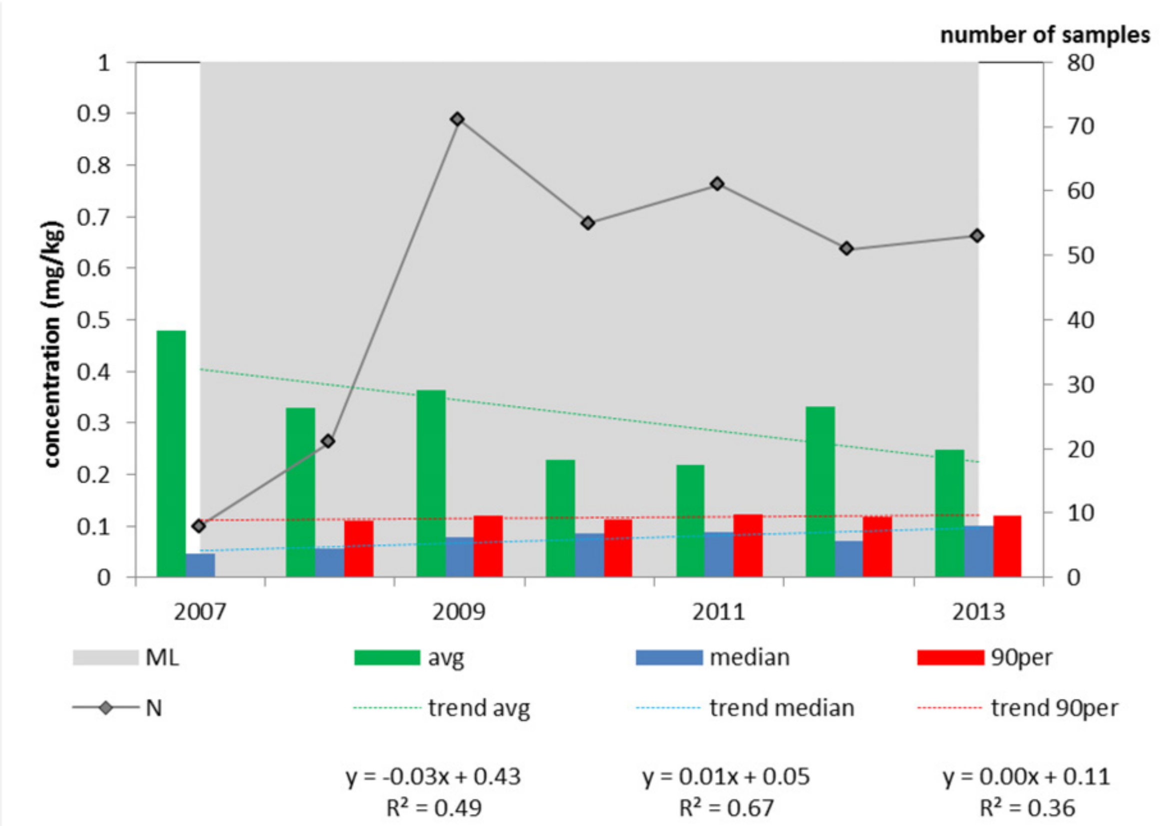

Figure 2-28 *Average, median and 90 percentile concentration of cadmium in complementary mineral feed for ruminants between 2007 and 2013; N =320; ML = 5 mg/kg.*

Complete feed for cattle (except calves), sheep (except lambs), goats (except kids) and fish

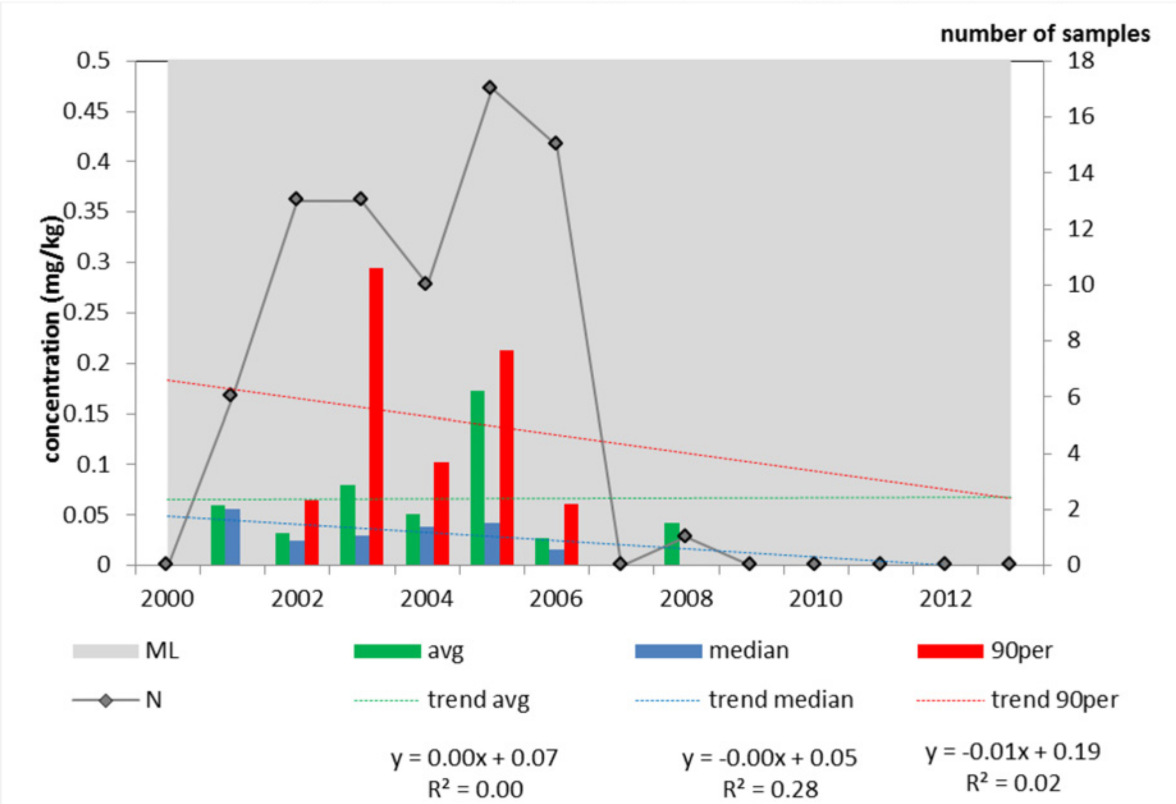

Figure 2-29 *Average, median and 90 percentile concentration of cadmium in complete feed for cattle (except calves), sheep (except lambs), goats (except kids) and fish; N = 75; ML = 1 mg/kg.*

Complete feed for pet animals

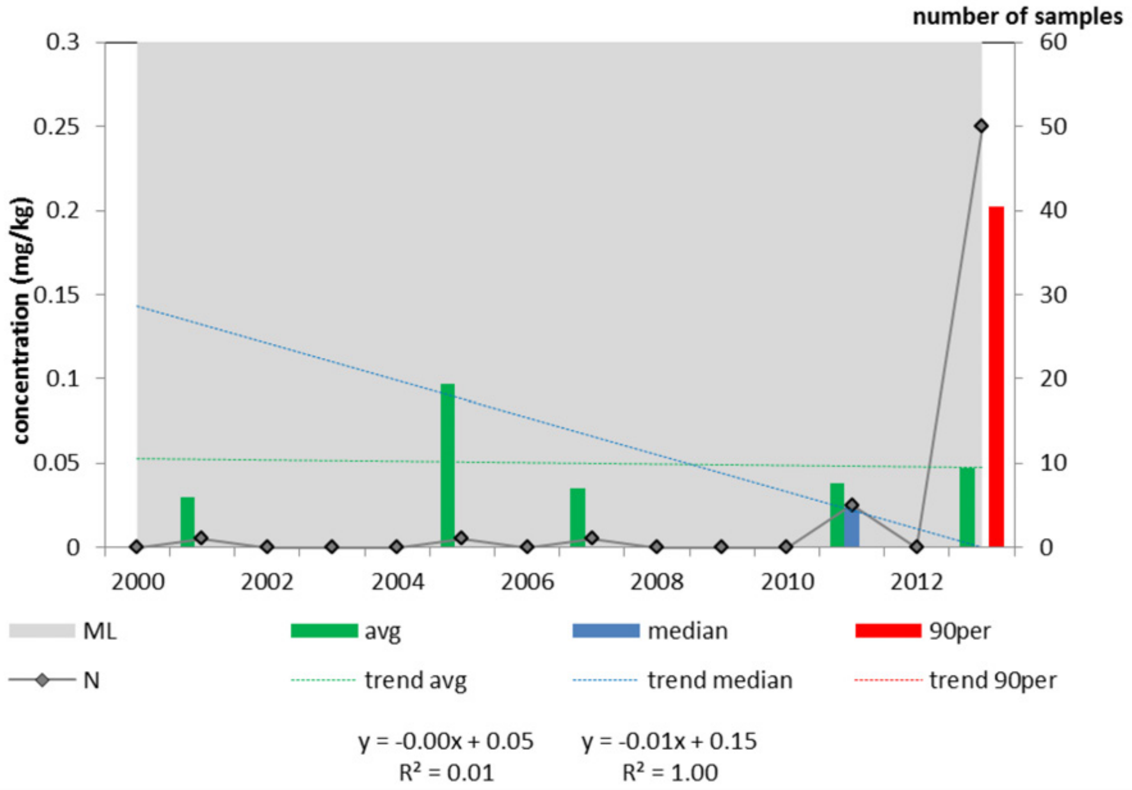

Figure 2-30 *Average, median and 90 percentile concentration of cadmium in complete feed for pet animals; N = 58; ML = 2 mg/kg.*

Table Sup2-20 *Cadmium in complete feed for pet animals (mg/kg).*

Values	2001	2005	2007	2011	2013
N	1	1	1	5	50
avg	0.03	0.10	0.04	0.04	0.05
ML	2	2	2	2	2

Other complete feed

Complete feed (excluding complete feed for cattle, sheep, goats, fish and pets because those feeds have a different ML, but including complete feed for calves, lambs and kids). In 2000 and 2011 the average cadmium concentration was relatively high. This was caused by two samples of pig feed in 2000 with cadmium concentrations of 1 and 0.9 mg/kg and one sample of horse feed[1] in 2011 with a cadmium concentration of 0.8 mg/kg, all above the ML. Those were the only samples taken in 2000 and 2011, causing the high average value. This strongly influences the significance of a possible trend between 2000 and 2013.

[1] Unclear whether the horse feed was complete feed or complementary feed but the ML is the same for both.

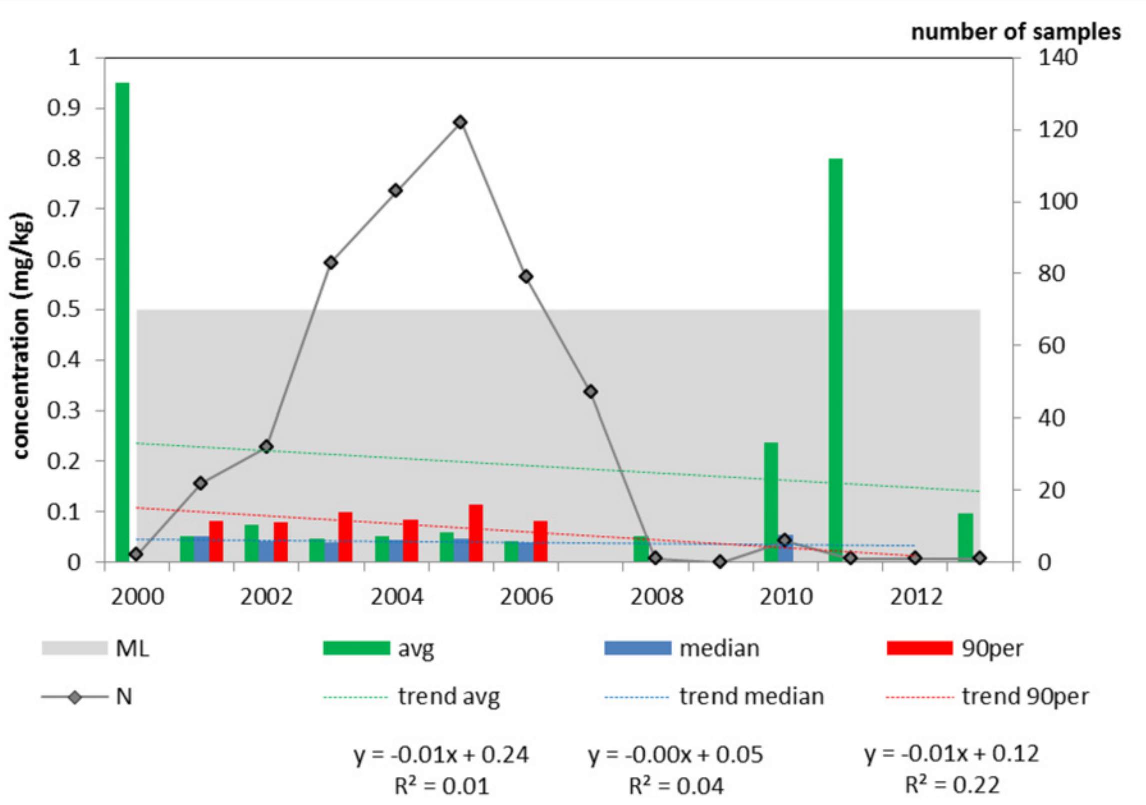

Figure 2-31 *Average, median and 90 percentile concentration of cadmium in complete feed, excluding complete feed for cattle, sheep, goats, fish and pets, including complete feed for calves, lambs and kids; N = 500; ML = 0.5 mg/kg.*

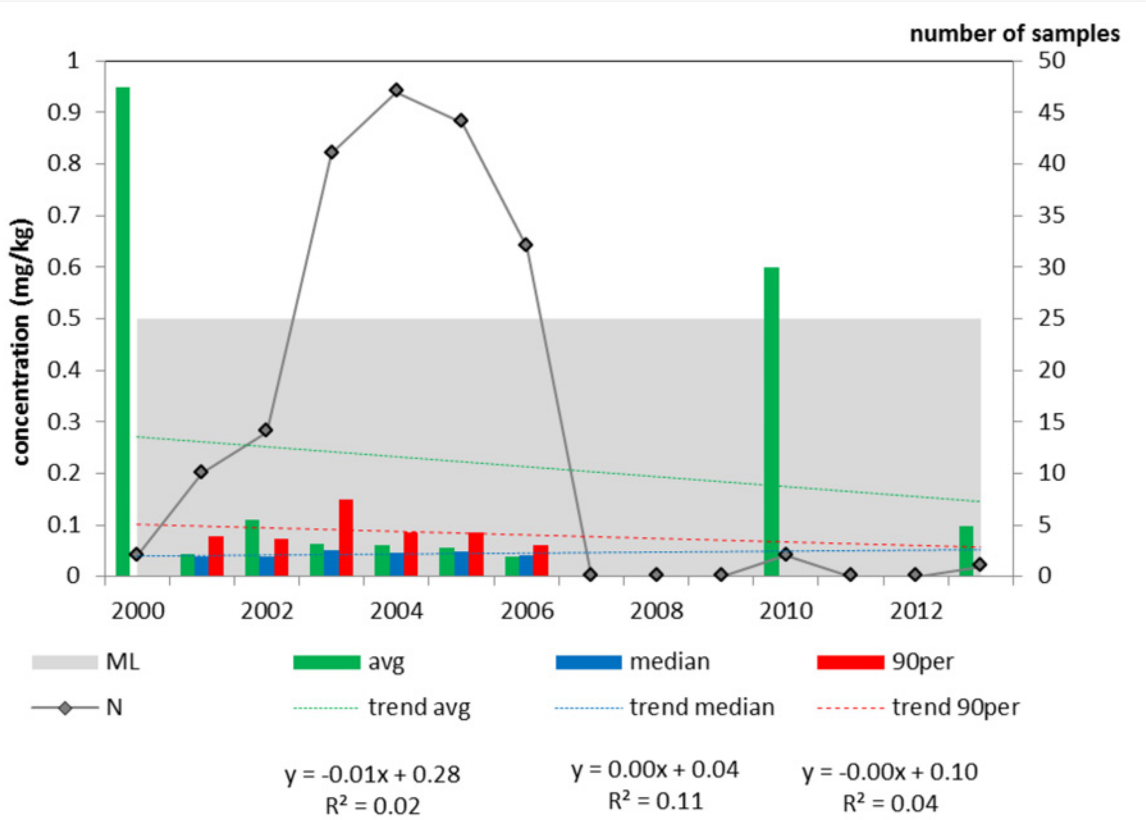

Figure 2-32 *Average, median and 90 percentile concentration of cadmium in complete feed for pigs; N = 193; ML = 0.5 mg/kg.*

Another contribution to this feed category was the product group complete feed for poultry (156 samples, Figure 2-14). The average cadmium concentration are low compared to the ML and did not in- or decrease significantly.

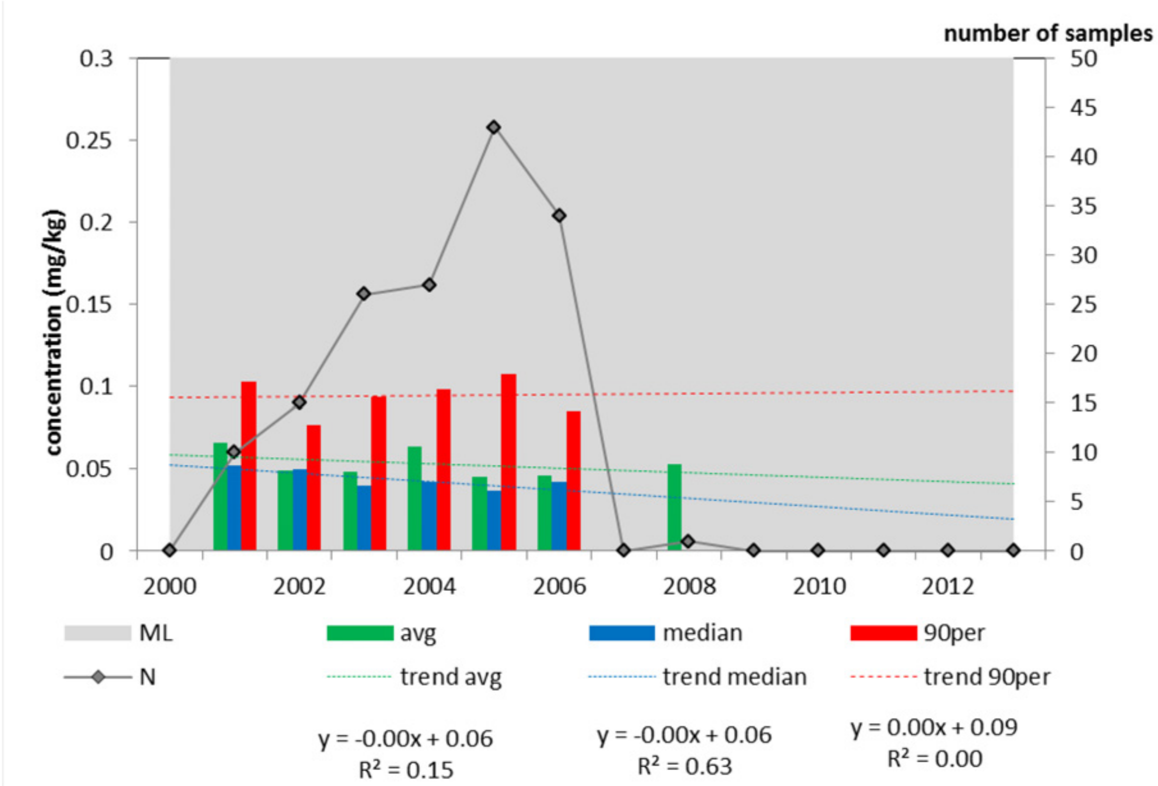

Figure 2-33 *Average, median and 90 percentile concentration of cadmium in complete feed for poultry; N = 156; ML = 0.5 mg/kg.*

Feed materials of animal origin

Another product group with occasional exceedances of the ML is feed materials of animal origin. RASFF also reported a few alerts and notifications regarding this product group, especially sea animals (Table Sup2-7). In this study 4 samples exceeded the ML: fishmeal from Spain (2011), from Germany (2010, 2013) and from unknown origin (2007).

Table Sup2-21 *RASFF alerts and notifications related to cadmium and feed materials of animal origin (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
fish meal	5	2.81	6.1	2
squid	2	2.5	13.8	2
lobster shell powder	1	4.3	4.95	2

(More details in Table Sup5-3).

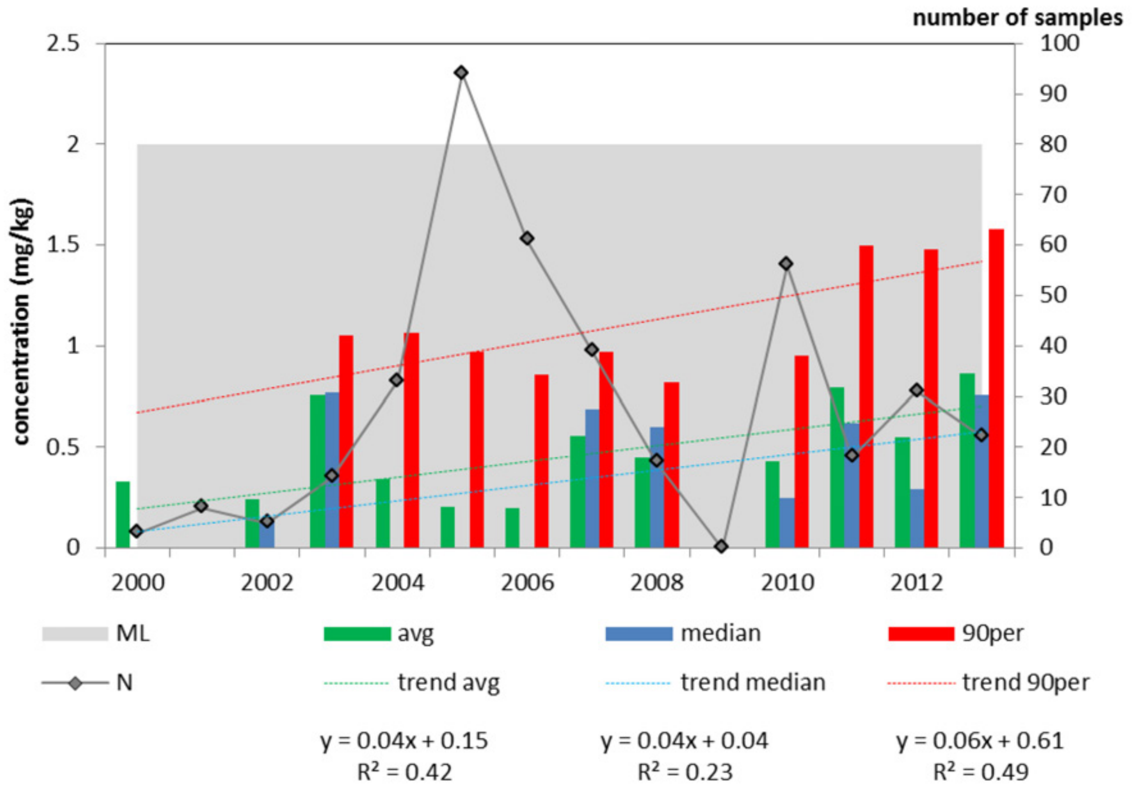

Figure 2-34 *Average, median and 90 percentile concentration of cadmium in feed materials of animal origin; N = 401; ML = 2 mg/kg.*

A large contributor to the feed materials of animal origin was fish meal (223 samples). RASFF reported 5 notifications (information) regarding fish meal (Table Sup2-7), one of those was notified by the Netherlands in 2013: cadmium (3 mg/kg - ppm) in tuna meal from Ecuador, via Germany (see Annex, Table Sup5-3). This sample coincides with one of the samples from the NP dataset. The other three samples exceeding the ML in this study originated from Spain (2011, 3.1 mg/kg; Germany (2010, 2.8 mg/kg) and unknown origin (2007, 2.2 mg/kg). A considerable number of fish meal samples originated from Peru (49 out of 224 in total). However, no significant in- or decrease could be found and none of the samples from Peru exceeded the ML (data not shown). The significant increase of the average and 90 percentile cadmium concentration was caused by samples from several European countries (Spain, Germany, Denmark, Poland, the Netherlands, EU unspecified with relatively high cadmium concentrations (between 1 and 2 mg/kg or higher, see above) in the last few years (data not shown).

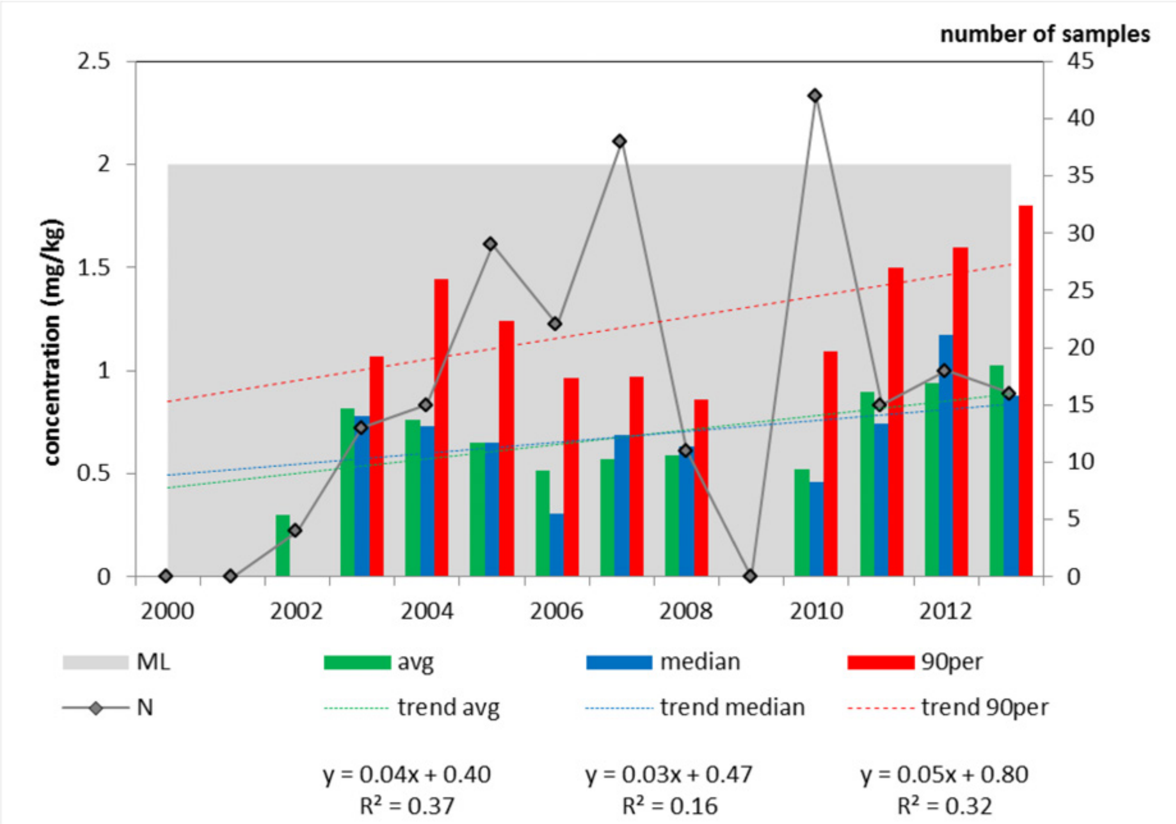

Figure 2-35 *Average, median and 90 percentile concentration of cadmium in fish meal; N = 223; ML = 2 mg/kg.*

Feed materials of mineral origin (except phosphates)

RASFF reported 2 notifications related to feed materials of mineral origin (except phosphates) (Table Sup2-8). The products originate from Germany and Spain. None of the notifications originate from the Netherlands. In the current study there were two positive samples: magnesium oxide in 2012 (2.5 mg/kg) and ammonium chloride in 2013 (3 mg/kg).

Table Sup2-22 *RASFF alerts and notifications related to feed materials of mineral origin (except phosphates) (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
calcium carbonate	2	6.3	20.6	2

(More details in Table Sup5-3).

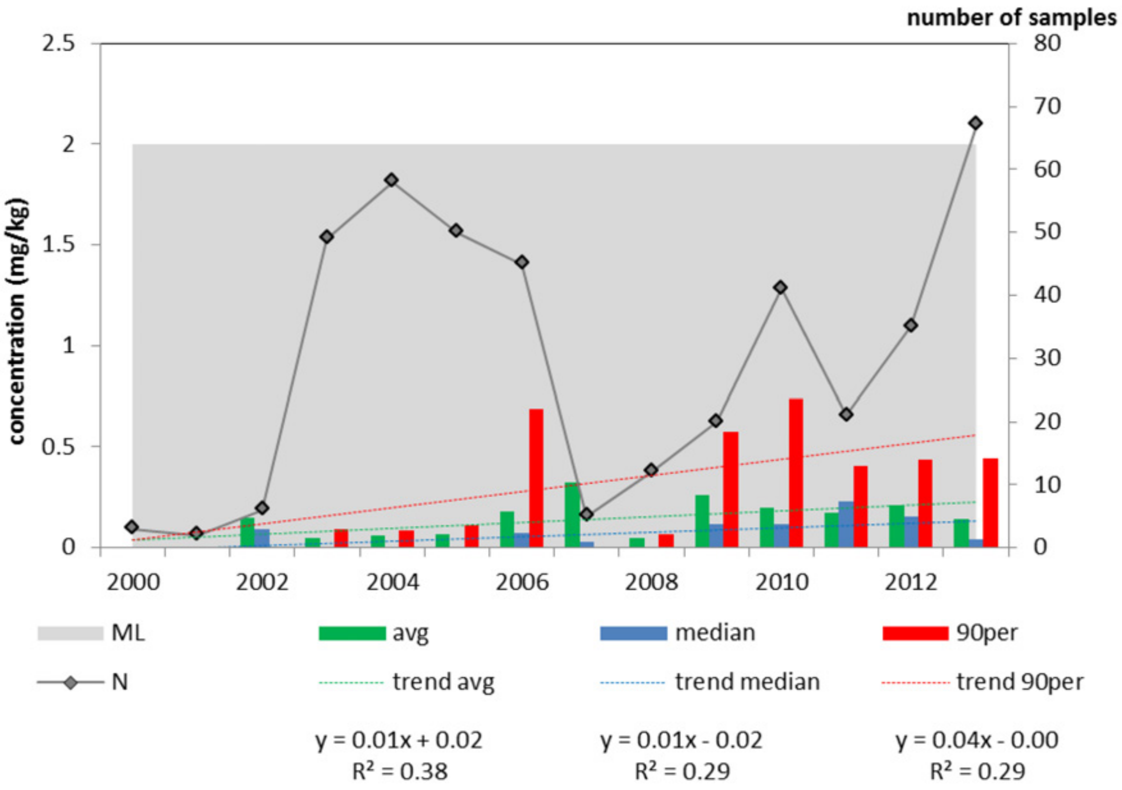

Figure 2-36 *Average, median and 90 percentile concentration of cadmium in feed materials of mineral origin (excl. phosphates); N = 414; ML = 2 mg/kg.*

A large contributor to the feed materials of mineral origin (excl. phosphates) was calcium carbonate (208 samples).

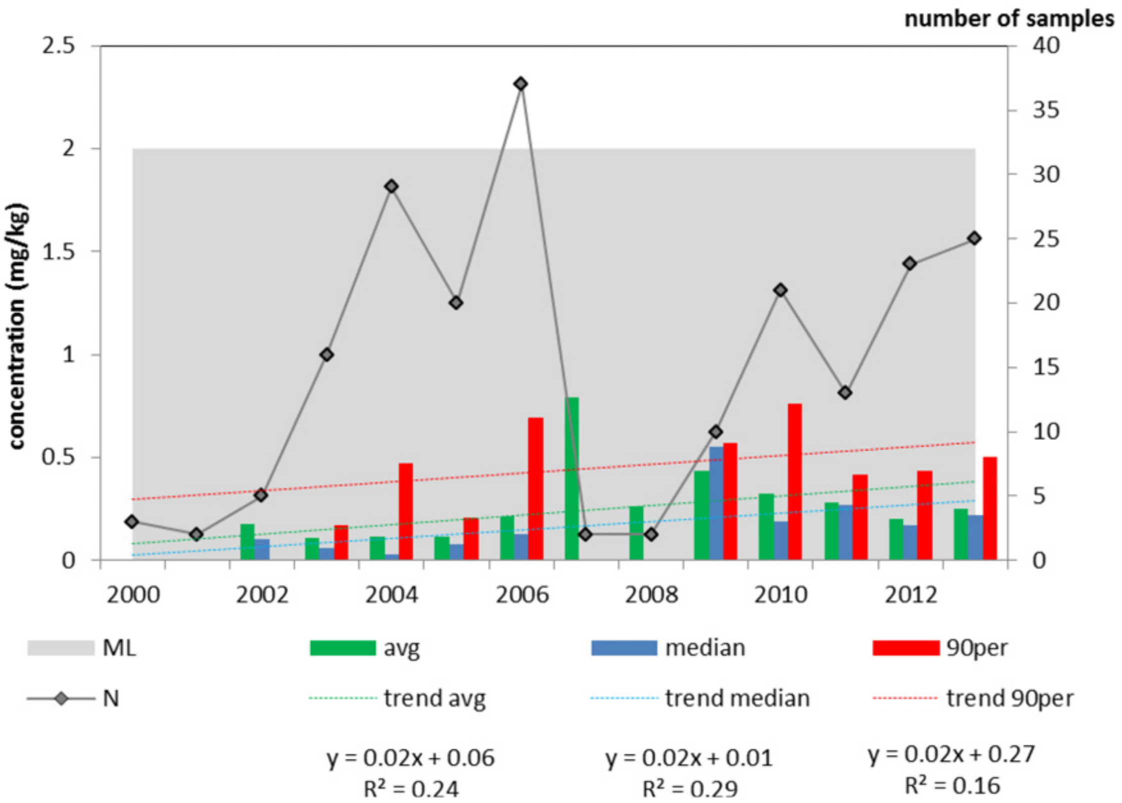

Figure 2-37 *Average, median and 90 percentile concentration of cadmium in feed materials of calcium carbonate; N = 208; ML = 2 mg/kg.*

Phosphates
RASFF reported 4 incidents regarding phosphates, none of them related to the Netherlands.

Table Sup2-23 *RASFF alerts and notifications related to cadmium and phosphates (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
di-calcium phosphate	3	12.4	16.7	10
mono-calcium phosphate	1	19.5	19.5	10

(More details in Table Sup5-3).

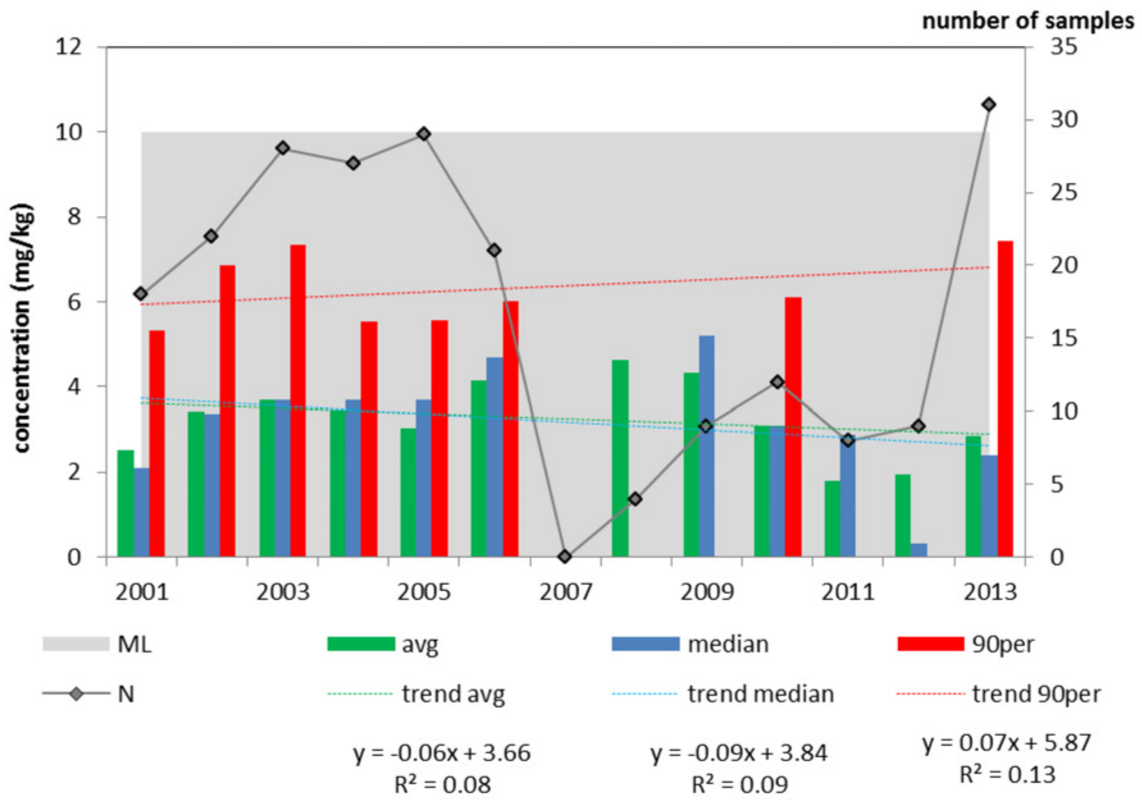

Figure 2-38 *Average, median and 90 percentile concentration of cadmium in phosphates; N = 232; ML = 10 mg/kg.*

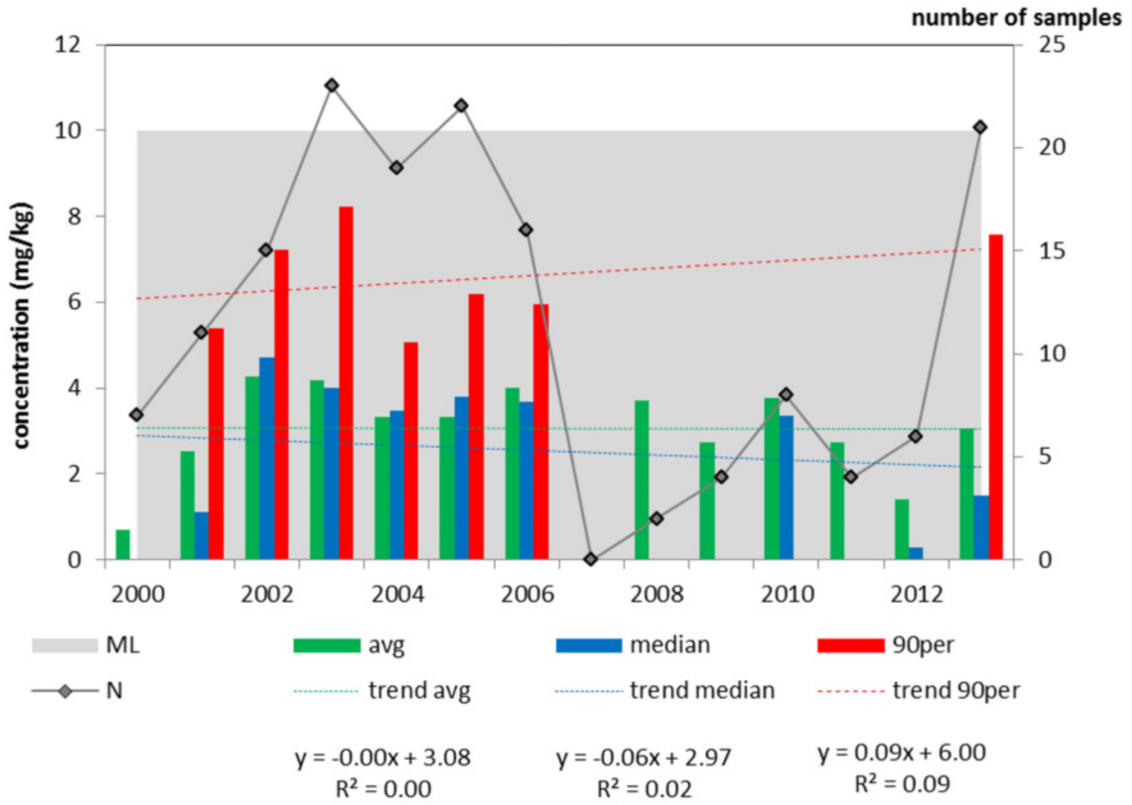

Figure 2-39 *Average, median and 90 percentile concentration of cadmium in mono-calcium phosphate; N = 158; ML = 10 mg/kg.*

Feed materials of vegetable origin
Only one RASFF notification was related to feed material of vegetable origin). This concerns celery stalks from Poland reported by Germany in 2014 with a cadmium concentration higher than the ML.

Table Sup2-24 *RASFF alerts and notifications related to cadmium and feed materials of vegetable origin (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
celery	1	2.7	2.7	1

(More details in Table Sup5-3).

Many feed samples of vegetable origin have been analysed for cadmium content (N = 2703). Only one sample exceeded the ML: grass meal, 2.4 mg/kg (see below).

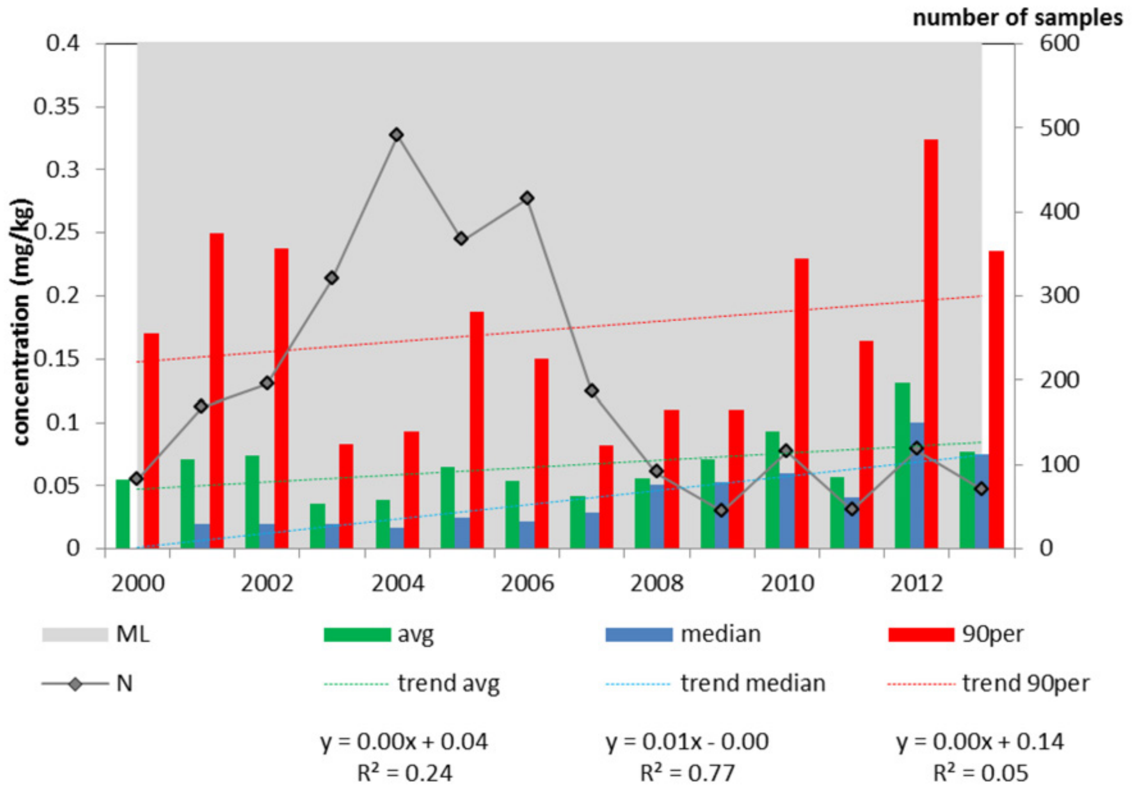

Figure 2-40 *Average, median and 90 percentile concentration of cadmium in feed materials of vegetable origin; N = 2703; ML = 1 mg/kg.*

One of the main products with feed materials of vegetable origin was grass (Figure 2-22). In 2012 one sample of grass meal contained a much higher cadmium concentration than the other samples (2.4 mg/kg), above the ML of 1 mg/kg. This single sample forced the trend to an increase.
The average cadmium concentration did not change significantly in alfalfa (Figure 2-23), and decreased significantly in soya bean products (Figure 2-24 and sunflower products (Figure 2-25).

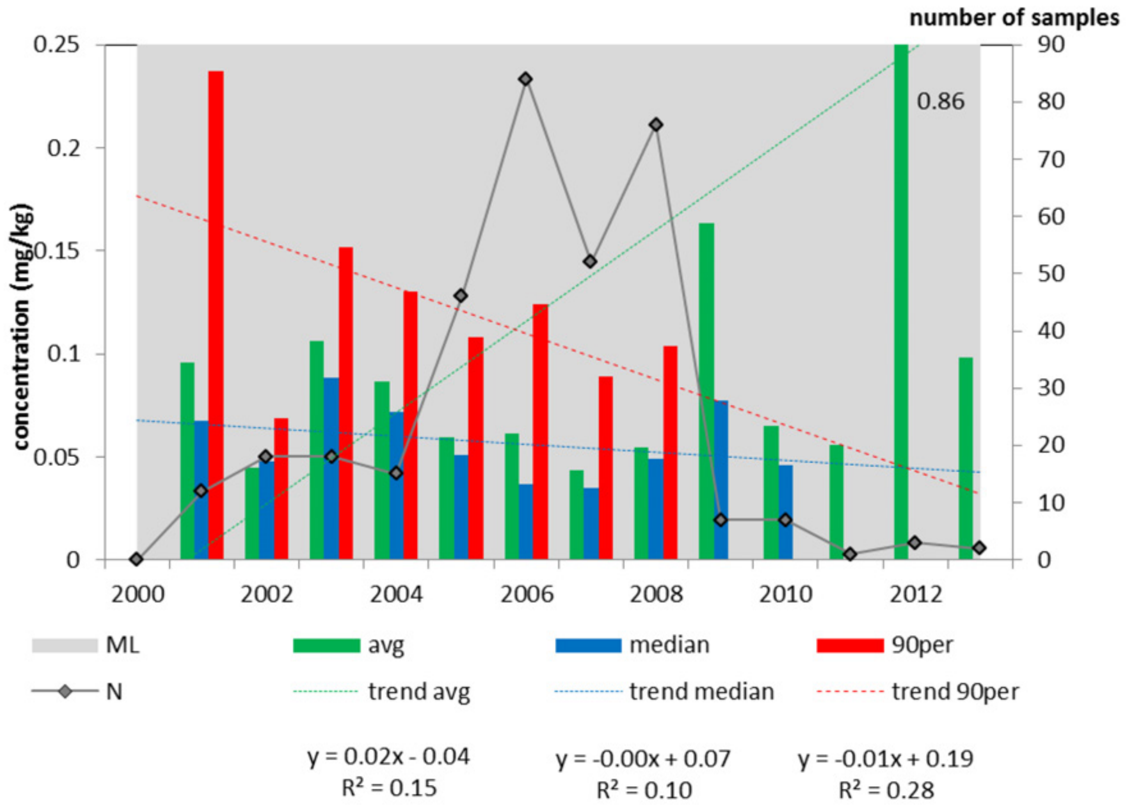

Figure 2-41 *Average, median and 90 percentile concentration of cadmium in grass; fresh (5), silage (160) and dry (165) combined; N = 341; ML = 1 mg/kg.*

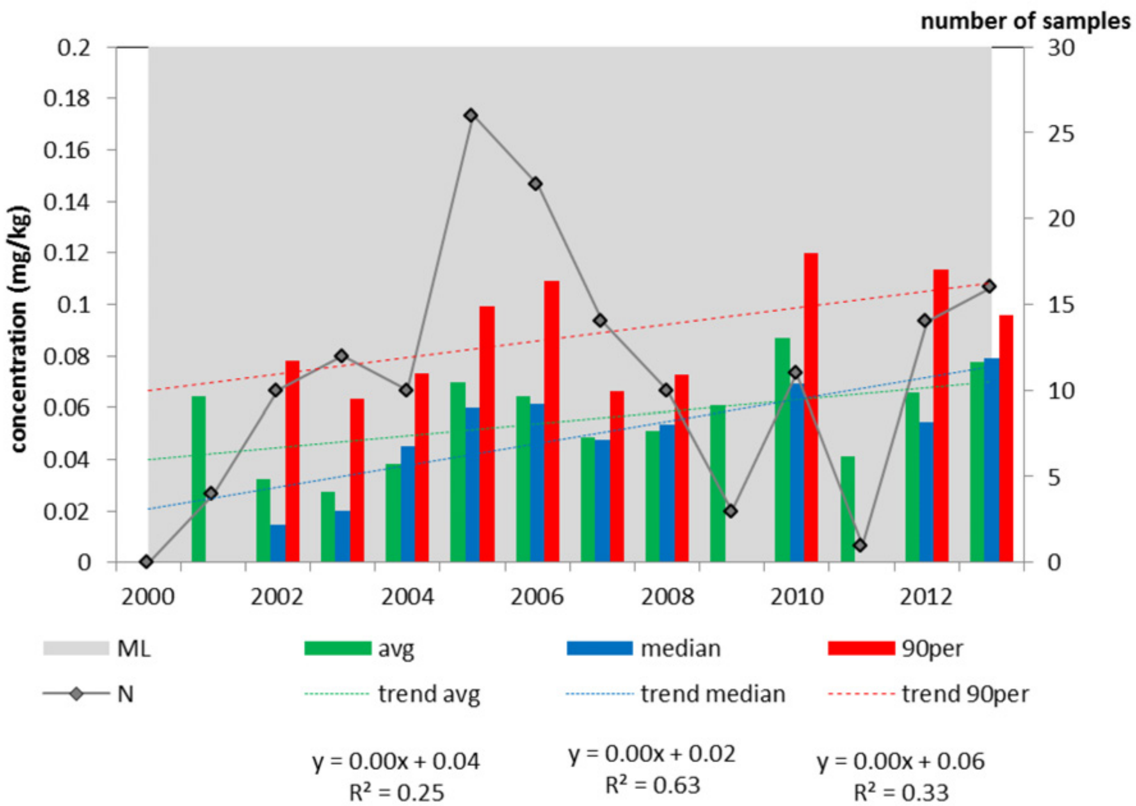

Figure 2-42 *Average, median and 90 percentile concentration of cadmium in alfalfa; N = 153; ML = 1 mg/kg.*

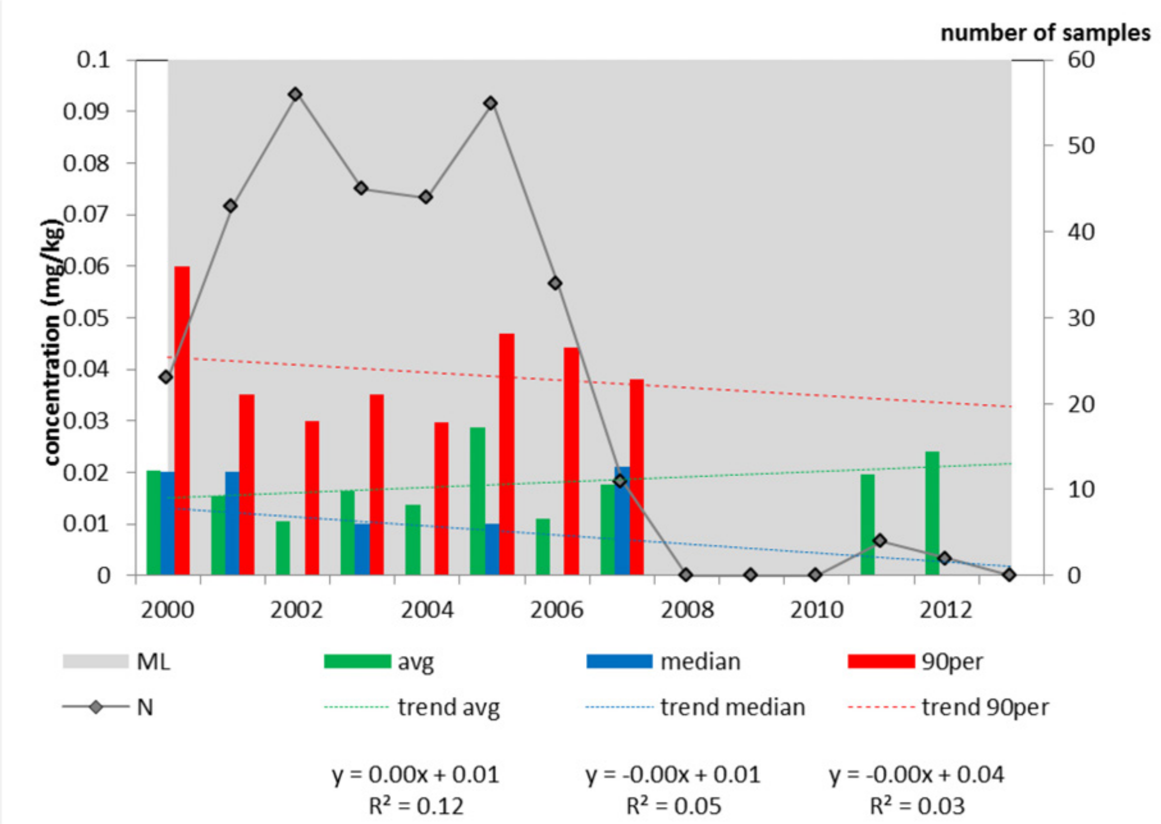

Figure 2-43 *Average, median and 90 percentile concentration of cadmium in soya bean products; N = 317; ML = 1 mg/kg.*

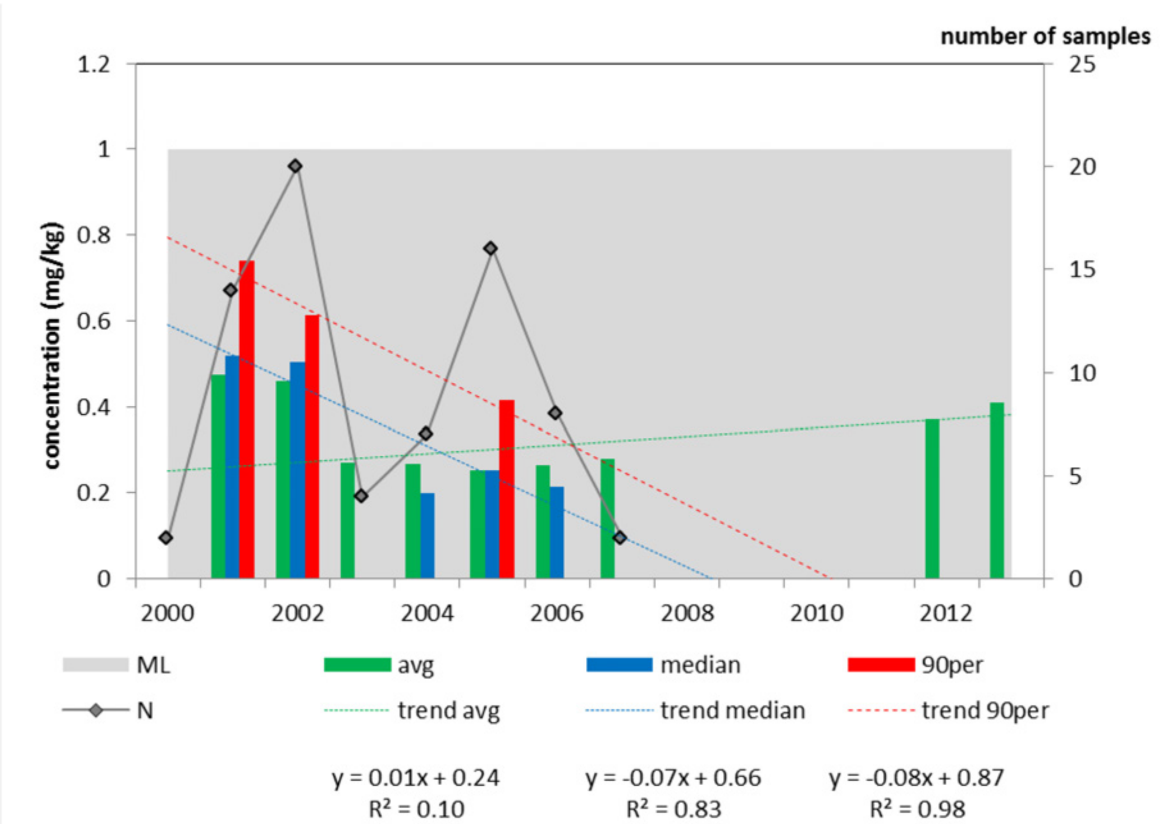

Figure 2-44 *Average, median and 90 percentile concentration of cadmium in sunflower products; N = 78; ML = 1 mg/kg.*

Other product groups from the category feed materials of vegetable origin include cereals, maize and other oil seeds. None of the samples from those groups contained cadmium levels exceeding the ML, the average concentrations are well below the ML (the average concentration is 0.05 (5% of the ML), 790 individual values are < LOQ, 1029 <= 0.5, 16 between 0.5 and 0.9 (wheat, poppy seeds, potato) and no significant trends could be detected (data not shown).

Pre-mixtures
RASFF report 2 notifications related to pre-mixtures (Table Sup2-11), one originating from and reported by Norway (pre-mixture for fish) and one originating from and reported by Belgium (pre-mixture for poultry).

Table Sup2-25 *RASFF alerts and notifications related to cadmium and pre-mixtures (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
premix, fish	1	500	11500	15
premix, poultry	1	160	160	15

(More details in Table Sup5-3).

In this study no samples exceeding the ML were found.

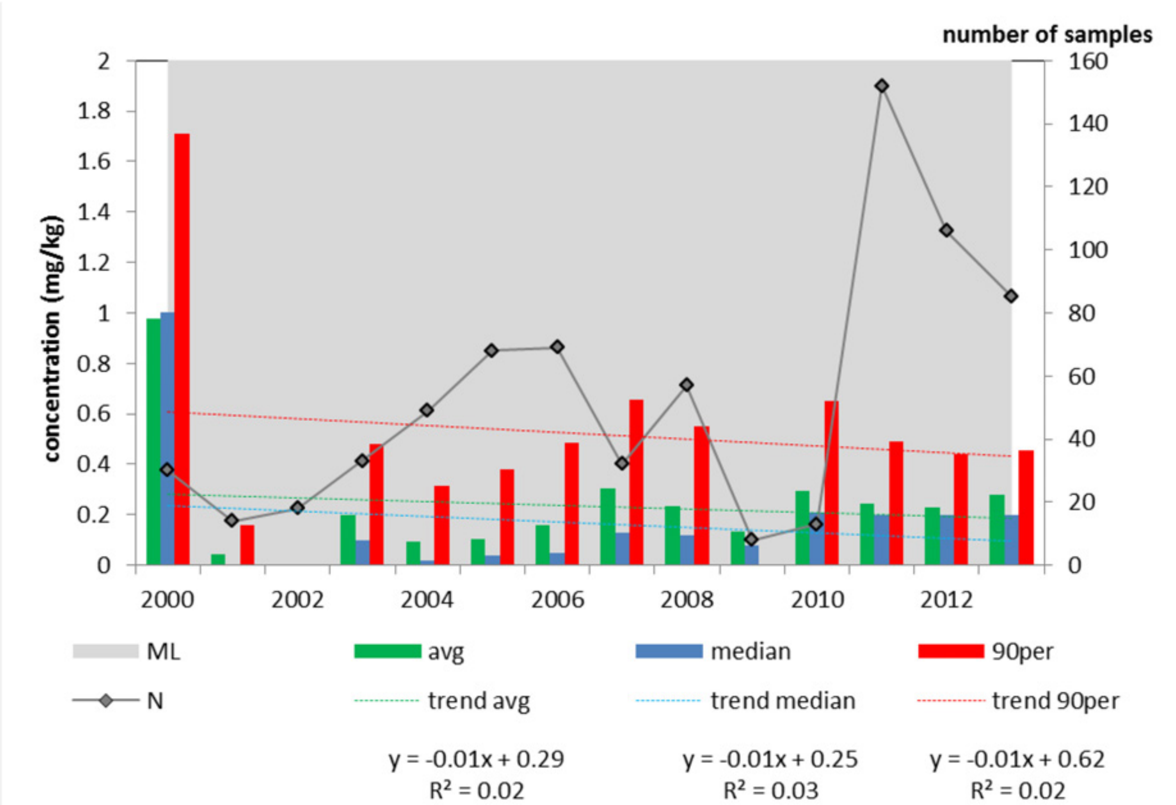

Figure 2-45 *Average, median and 90 percentile concentration of cadmium in pre-mixtures; 2000-2013; N = 735; ML = 15 mg/kg.*

Feed additives belonging to the functional groups of binders and anti-caking agents
Two out of 294 samples exceeded the ML; kaolinite (3.3 mg/kg in 2002) and sepiolite (5.4 mg/kg in 2012).

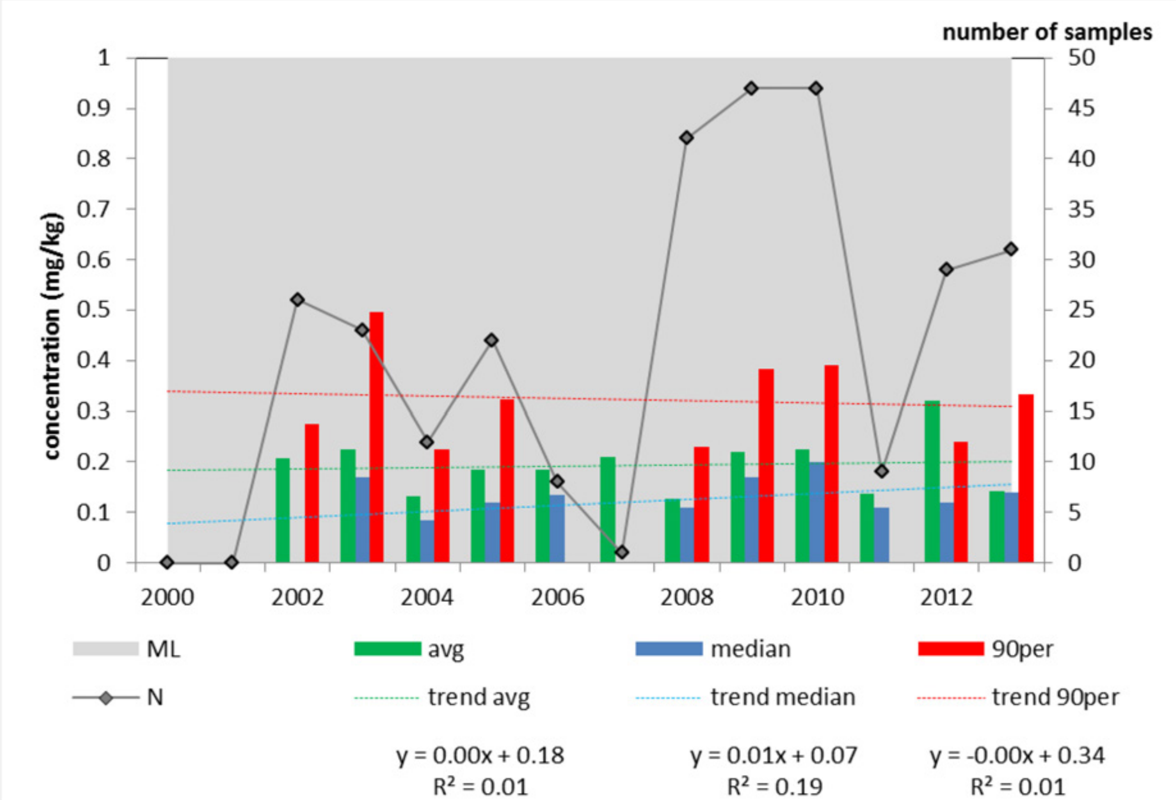

Figure 2-46 *Average, median and 90 percentile concentration of cadmium in feed additives belonging to the functional groups of binders and anti-caking agents; N = 297; ML = 2 mg/kg.*

Almost 50% of the feed additives belonging to the functional groups of binders and anti-caking agents in this dataset consisted of sepiolite, especially after 2007 (Figure 2-28). Before 2007 the number of samples taken per year was too low to calculate median and 90 percentile concentrations.

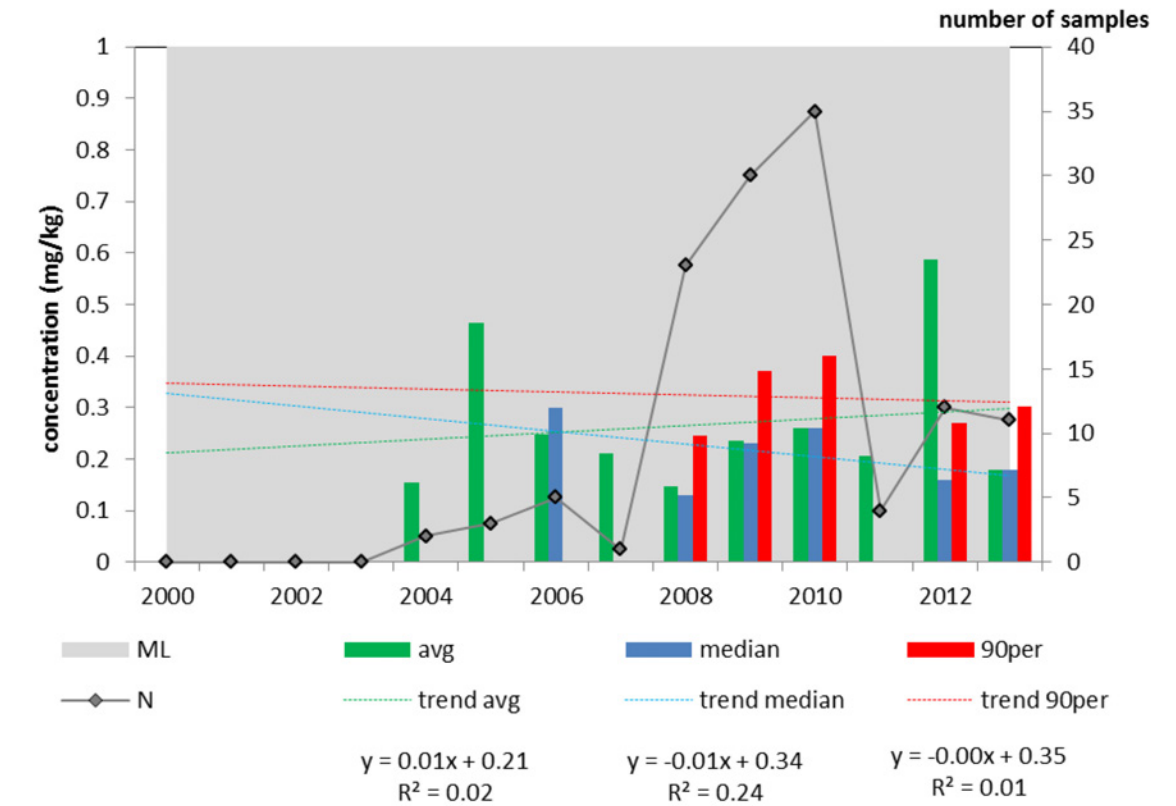

Figure 2-47 *Average, median and 90 percentile concentration of cadmium in sepiolite; N = 126; ML = 2 mg/kg.*

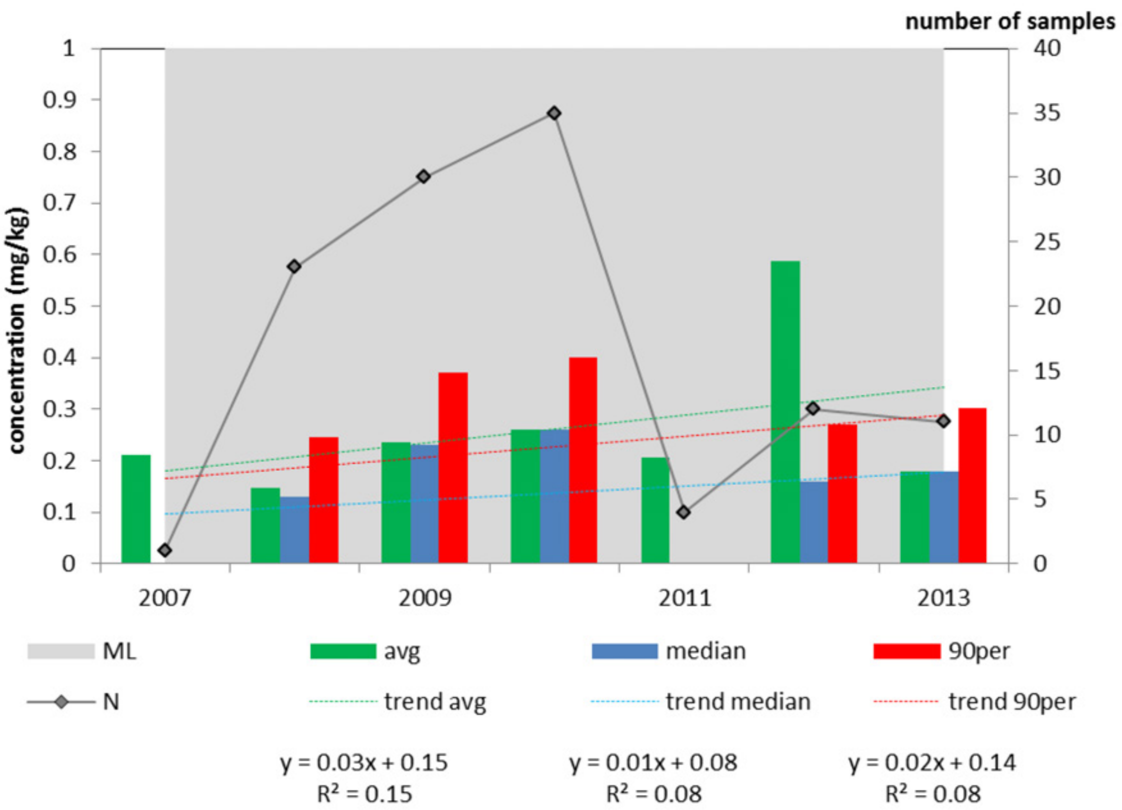

Figure 2-48 *Average, median and 90 percentile concentration of cadmium in sepiolite between 2007 and 2013; N = 116; ML = 2 mg/kg.*

Another binder was kaolinite. Between 2000 and 2013 67 samples have been analysed. Most of them in 2002 and 2003. In 2002 one sample (3.3 mg/kg) exceeded the ML, but the average values remained well below de ML (< 0.3 mg/kg) The number of samples per year was too low to determine trends (data not shown).

Cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate
RASFF reported three cases of zinc oxide and two cases of manganese oxide with non-compliant cadmium levels (Table Sup2-12) and more details in Annex Table Sup5-3); zinc oxide from China and Turkey and manganese oxide from China and Brazil. None of those were notified by the Netherlands.

Table Sup2-26 *RASFF alerts and notifications related to cadmium in cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
zinc oxide	3	52	480	30
manganese oxide	2	41	45	30

(More details in Table Sup5-3).

In this study no samples exceeding the ML were found. Zinc oxide was the main contributor to this product group.

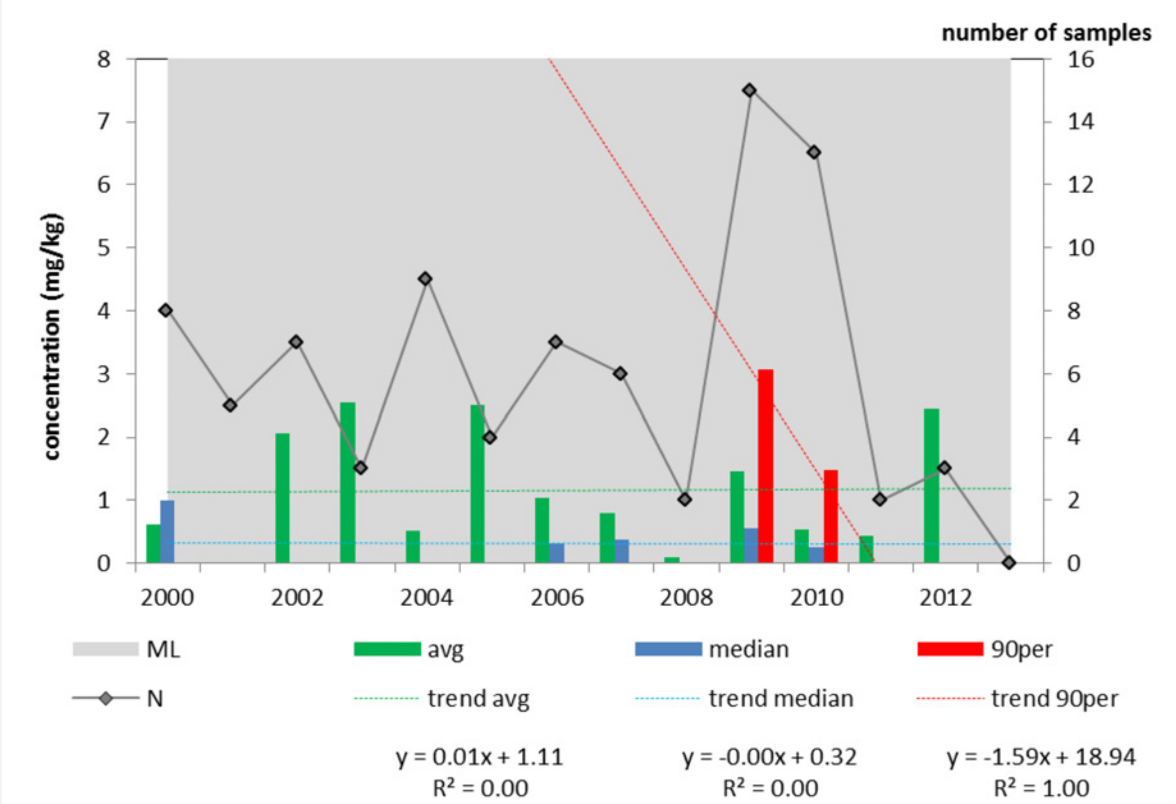

Figure 2-49 *Average, median and 90 percentile concentration of cadmium in cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate; N = 84; ML = 30 mg/kg.*

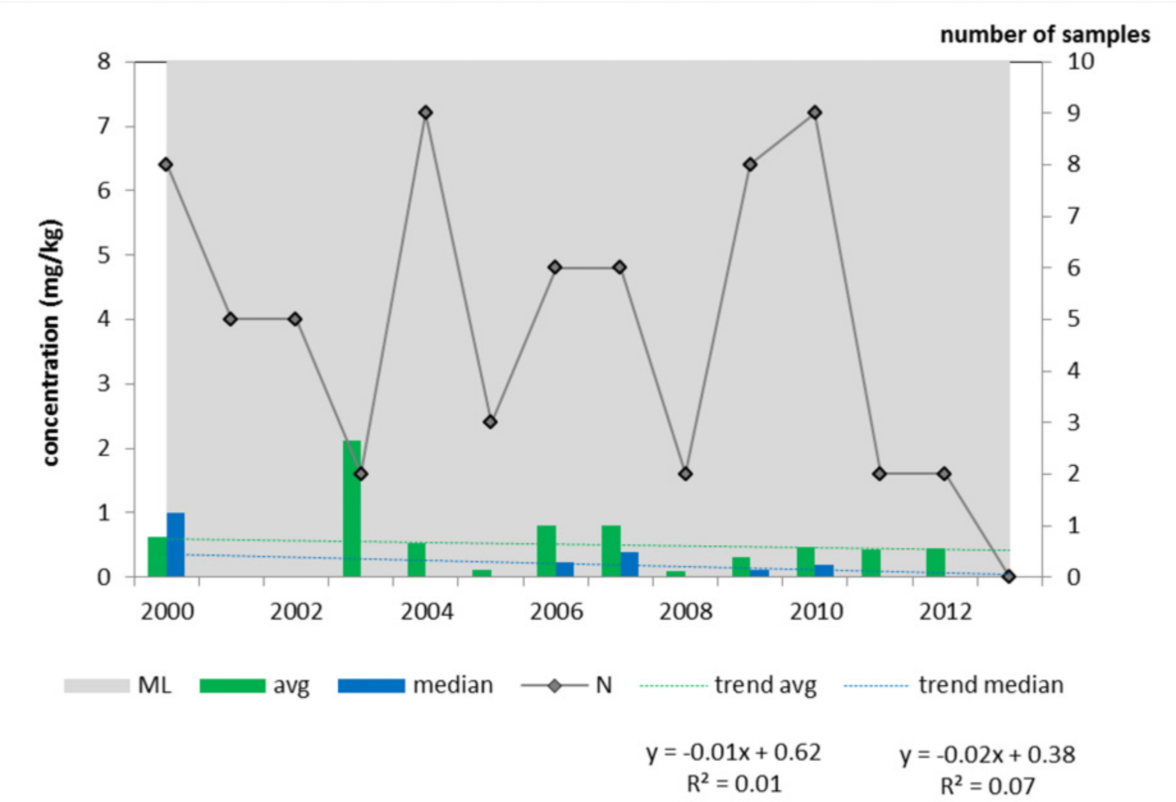

Figure 2-50 *Average, median and 90 percentile concentration of cadmium in zinc oxide; N = 67; ML = 30 mg/kg.*

Feed additives belonging to the functional group of compounds of trace elements
RASFF report 8 notifications related to feed additives belonging to the functional group of compounds of trace elements, excluding cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate (Table Sup2-13). Most products originate from China, one each from Slovakia and Italy (zinc sulphate. None of the notifications originate from the Netherlands.

Table Sup2-27 *RASFF alerts and notifications related to cadmium and feed additives belonging to the functional group of compounds of trace elements (2002-2014).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
zinc sulphate	8	3.7	966	10

(More details in Table Sup5-3).

In this study no samples exceeding the ML were found.

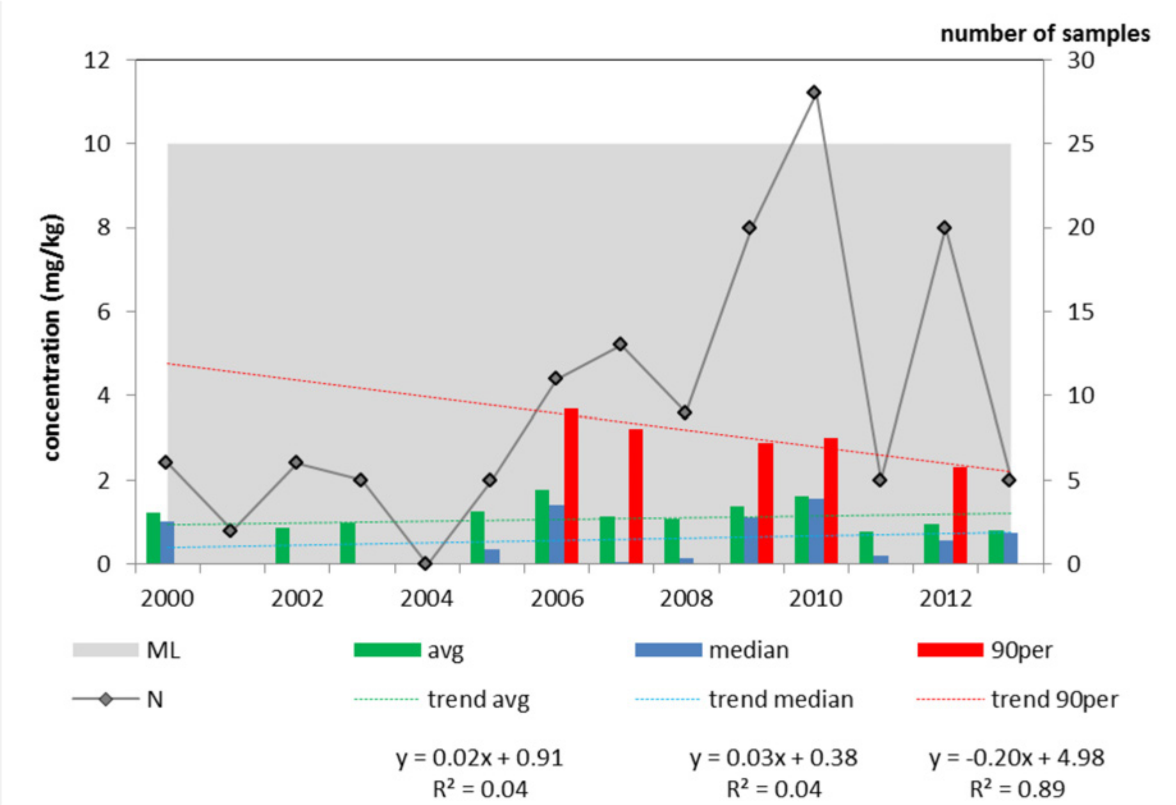

Figure 2-51 *Average, median and 90 percentile concentration of cadmium in feed additives belonging to the functional group of compounds of trace elements; N = 135; ML = 10 mg/kg.*

Annex 3 Supplemental information lead

Maximum levels for lead in animal feed and feed materials

Directive 2002/32/EC, amended by Regulation (EU) No 744/2012 describes the maximum lead concentration allowed in feeds and feed materials (Table Sup3-1). The highest concentrations were allowed in feed additives belonging to the functional group of compounds of trace elements, especially zinc oxide. The lowest MLs were defined for complete feeds and yeasts.

Table Sup3-28 *Maximum levels for lead(12) in animal feed and feed materials according to Directive 2002/32/EC, amended by Regulation (EU) No 744/2012.*

Products intended for animal feed	Maximum content in mg/kg (ppm) relative to a feed with a moisture content of 12%
Feed materials	10
with the exception of:	
— forage (3);	30
— phosphates and calcareous marine algae;	15
— calcium carbonate; calcium and magnesium carbonate ((10);	20
— yeasts.	5
Feed additives belonging to the functional group of compounds of trace elements	100
with the exception of:	
— zinc oxide;	400
— manganous oxide, ferrous carbonate, cupric carbonate.	200
Feed additives belonging to the functional groups of binders and anti-caking agents	30
with the exception of:	
— clinoptilolite of volcanic origin; natrolite-phonolite;	60
Pre-mixtures (6)	200
Complementary feed	10
with the exception of:	
— mineral feed;	15
— long-term supply formulations of feed for particular nutritional purposes with a concentration of trace elements higher than 100 times the established maximum content in complete feed;	60
Complete feed.	5

(3) Forage includes products intended for animal feed such as hay, silage, fresh grass, etc.

(6) The maximum level established for pre-mixtures takes into account the additives with the highest level of lead and cadmium and not the sensitivity of the different animal species to lead and cadmium. As provided in Article 16 of Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition (OJ L 268, 18.10.2003, p. 29), in order to protect animal and public health, it was the responsibility of the producer of pre-mixtures to ensure that, in addition to compliance with the maximum levels for pre-mixtures, the instructions for use on the pre-mixture were in accordance with the maximum levels for complementary and complete feed.

(12) For the determination of lead in kaolinitic clay and in feed containing kaolinitic clay, the maximum level refers to an analytical determination of lead, whereby extraction was performed in nitric acid (5% w/w) for 30 minutes at boiling temperature. Equivalent extraction procedures can be applied for which it can be demonstrated that the used extraction procedure had an equal extraction efficiency.

Overall trends in percentage of samples exceeding the LOQ or the ML

Table Sup3-29 *Samples exceeding the ML or the LOQ for lead (2001-2013).*

Product	N Total	N > LOQ	N > ML	% > LOQ	% > ML
Complementary feed, with the exception of:	168	156	0	93	0
— mineral feed	711	671	14	94	2.0
Complete feed	604	364	1	60	0.2
Feed materials, with the exception of:	2679	936	1	35	0.04
— forage	565	520	0	92	0
— phosphates and calcareous marine algae	182	163	0	90	0
— calcium carbonate; calcium and magnesium carbonate	307	290	4	94	1.3
— yeasts	3	1	0	33	0
Feed additives belonging to the functional groups of binders and anti-caking agents, with the exception of:	278	273	14	98	5.0
— clinoptilolite of volcanic origin; natrolite-phonolite	20	20	0	100	0
Feed additives belonging to the functional group of compounds of trace elements, with the exception of:	129	72	0	56	0.0
— zinc oxide	60	53	0	88	0
— manganous oxide, ferrous carbonate, cupric carbonate	16	14	0	88	0
Pre-mixtures	719	574	0	80	0
Feed additives belonging to the category vitamins and pro-vitamins	79	28	no ML	13	-
Other feed additives	77	14	no ML	15	-
Total	**6597**	**4149**	**34**		

Table Sup3-30 *Samples exceeding the ML or the LOQ for lead (2007-2013).*

Product	N Total	N > LOQ	N > ML	% > LOQ	% > ML
Complementary feed, with the exception of:	5	4	0	80	0
— mineral feed	434	404	6	93	1.4
Complete feed	114	12	0	11	0.0
Feed materials, with the exception of:	645	296	1	46	0.2
— forage	280	248	0	89	0.0
— phosphates and calcareous marine algae	73	67	0	92	0.0
— calcium carbonate; calcium and magnesium carbonate	78	74	0	95	0.0
— yeasts	2	1	0	50	0.0
Feed additives belonging to the functional groups of binders and anti-caking agents, with the exception of:	187	184	2	99	1.1
— clinoptilolite of volcanic origin; natrolite-phonolite	20	20	0	100	0.0
Feed additives belonging to the functional group of compounds of trace elements, with the exception of:	99	48	0	48	0.0
— zinc oxide	29	27	0	93	0.0
— manganous oxide, ferrous carbonate, cupric carbonate	13	11	0	85	0.0
Pre-mixtures	454	392	0	86	0.0
Feed additives belonging to the category vitamins and pro-vitamins	79	28	no ML	35	
Other feed additives	64	12	no ML	19	
Total	**2576**	**1828**	**9**		

Complementary feed (excl. mineral feed)

RASFF reported two notifications regarding lead in complementary feed; complementary feed for pigs from Spain (2003) and complementary feed for horses from France (2005) (Table Sup3-4). In the current study no samples exceeded the ML for lead.

Table Sup3-31 *RASFF alerts and notifications related to lead complementary feed (excl. mineral feed).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
horse feed, complementary	1	52	52	10
pig feed, complementary	1	165.3	281.4	10

(More details in Table Sup5-2).

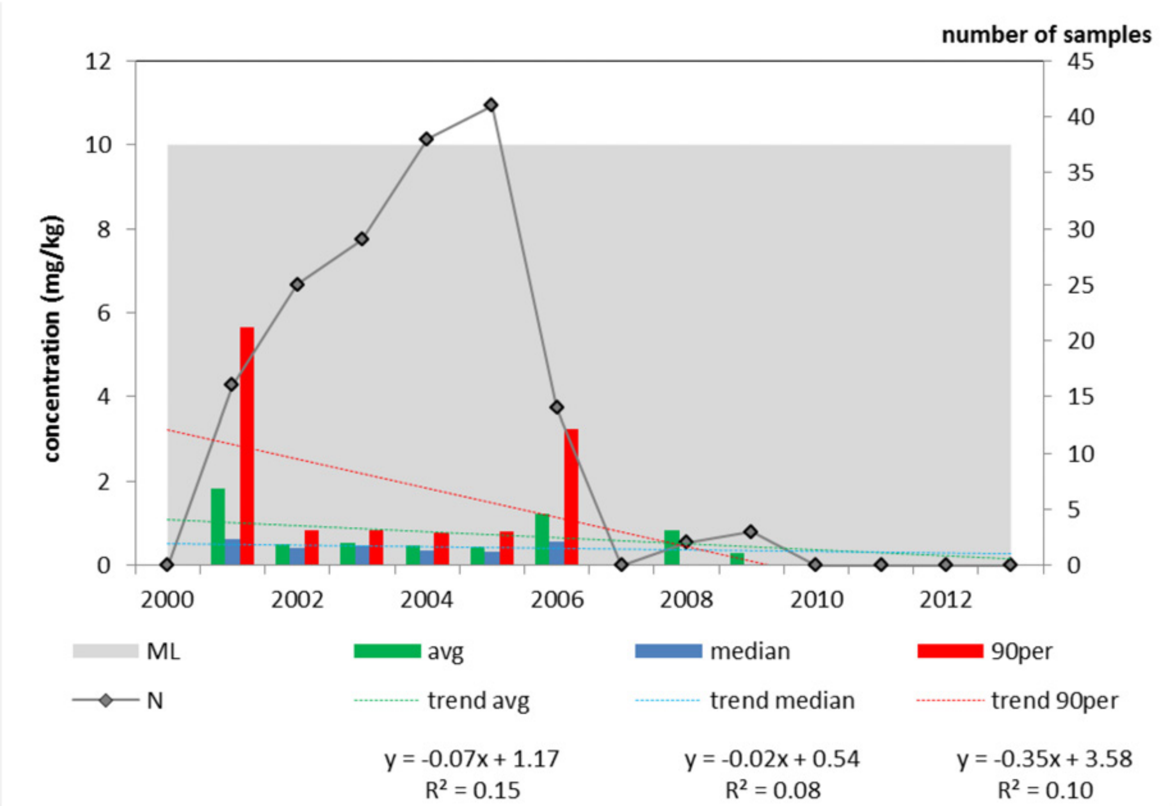

Figure 3-52 *Average, median and 90 percentile concentration of lead in complementary feed, excl. mineral feed; N = 168; ML = 10 mg/kg.*

Complementary bovine feed

Complementary bovine feed was the largest subgroup of complementary feed (135 out of 243) between 2001 and 2013 (Figure 3-2). RASFF does not report alerts or notifications for this product group. The current study did not contain samples of complementary bovine feed exceeding the ML. There were no significant trends.

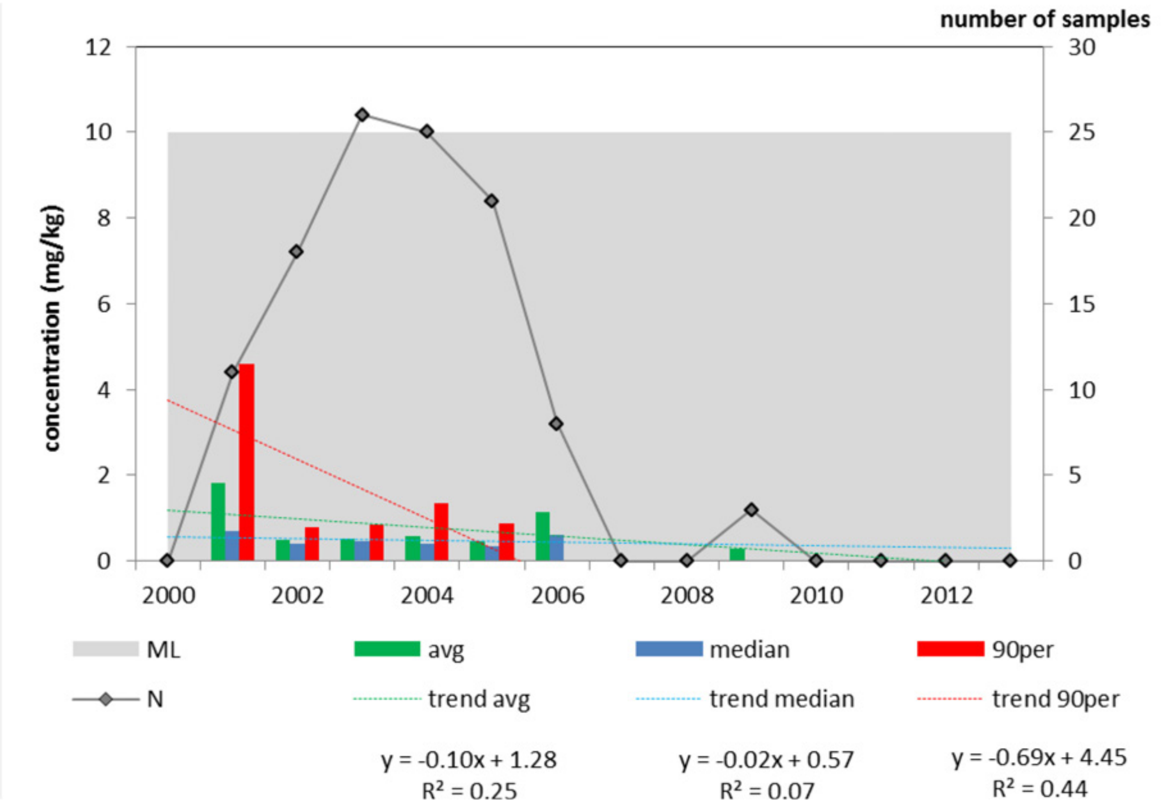

Figure 3-53 *Average, median and 90 percentile concentration of lead in complementary bovine feed; 2000-2013; N = 112; ML = 10 mg/kg.*

Complementary ruminant feed

RASFF does not report alerts or notifications for this product group. The current study did not contain samples of complementary feed for ruminants exceeding the ML. Between 2000 and 2006 the average lead concentration decreased significantly (Figure 3-3).

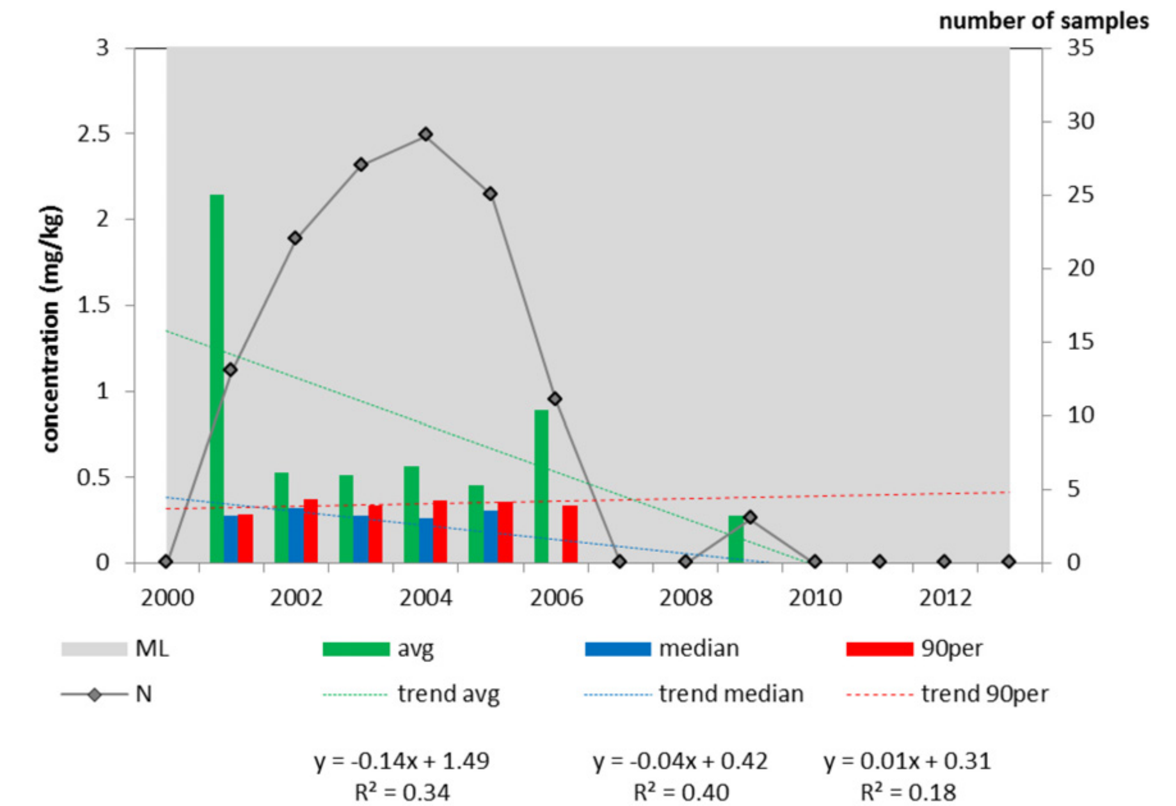

Figure 3-54 *Average, median and 90 percentile concentration of lead in complementary ruminant feed; 2000-2013; N = 130; ML = 10 mg/kg.*

In the other subgroups of complementary feed (pigs, poultry, sheep, goats) the number of samples between 2000-2013 was relatively low and no significant trends could be detected (data not shown).

Complementary mineral feed

RASFF reported four notifications regarding lead in mineral mixes (Table Sup3-5). Two in 2002 were notified by the Netherlands (33.4 and 63.9 mg/kg). One of those samples (33.4) was present in the dataset of the current study as well. The other sample (63.9 mg/kg) was present as well but classified as complementary bovine feed in this dataset. The sample notified by Germany in mineral feed from the United Kingdom, via the Netherlands (306 mg/kg) was not present in the current dataset.

In the current dataset 14 samples had a lead concentration exceeding the ML. In 2012 and 2013 five samples were between 30 and 39 mg/kg. This concerned samples of Actionine Phil 75 (natural minerals for binding toxins). If the product had been classified as feed additives belonging to the functional groups of binders and anti-caking agents (ML = 30 mg/kg) the concentrations still would be above the ML. Furthermore, when those samples would have been excluded from the group of complementary mineral feed, the increase of the average, median and 90 percentile concentrations between 2007 and 2013 would still be significant (data not shown).
In fact there is no ML for mycotoxin binders. They should probably have been classified as "Other feed additives". In that case there would not be a ML and those samples would not have been noticed in this dataset.

Table Sup3-32 *RASFF alerts and notifications related to lead in complementary mineral feed.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
mineral mix, general	4	15	306	15

(More details in Table Sup5-2).

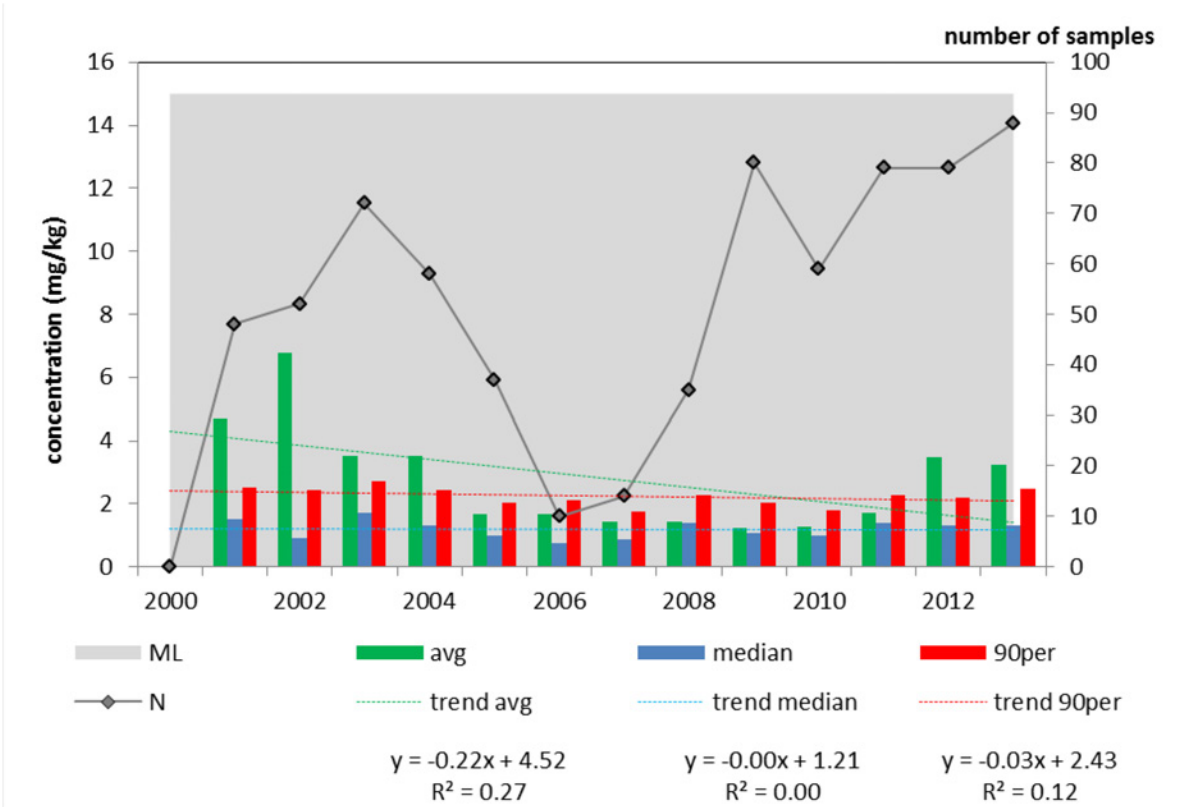

Figure 3-55 *Average, median and 90 percentile concentration of lead in complementary mineral feed; 2000-2013; N = 711; ML = 15 mg/kg.*

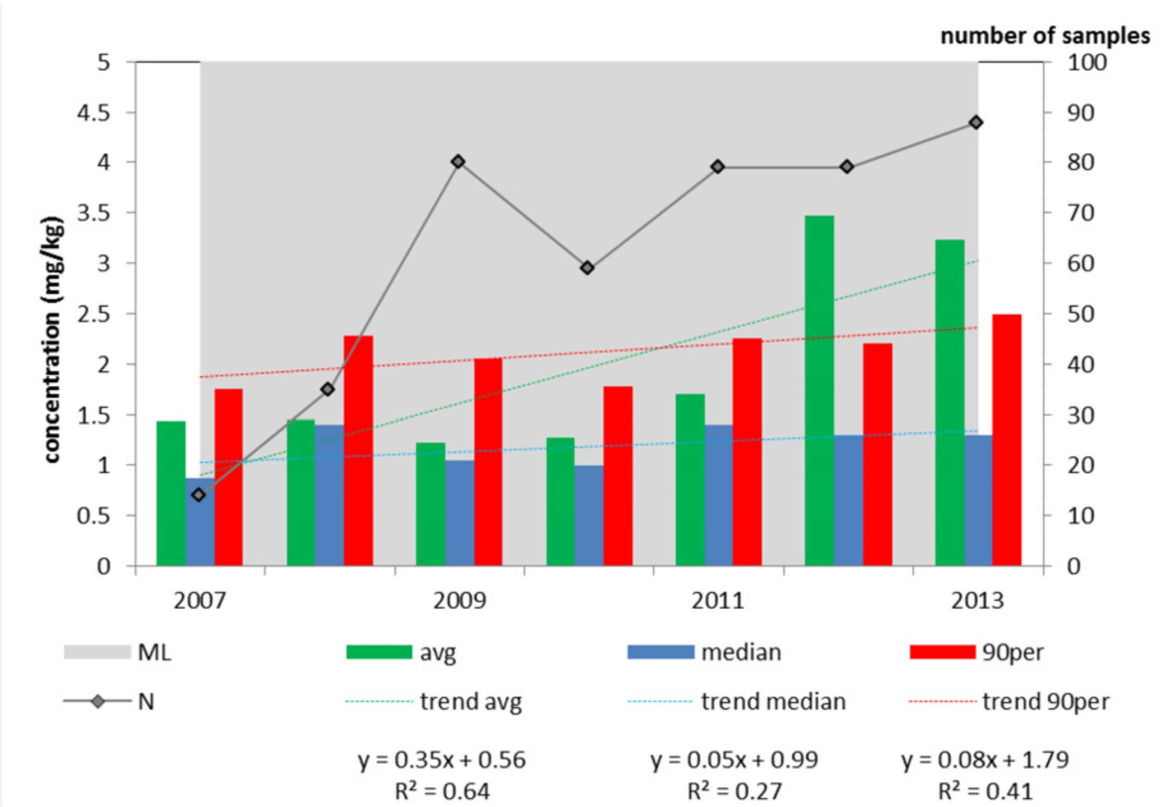

Figure 3-56 *Average, median and 90 percentile concentration of lead in complementary mineral feed; 2007-2013; N = 434; ML = 15 mg/kg.*

The largest part of category complementary mineral feed consists of mineral mix for bovines (350 out of 711 samples). In 2002 three samples (out of 27) exceeded the ML with lead concentrations of 28.7, 33.4 and 92.5 mg/kg.

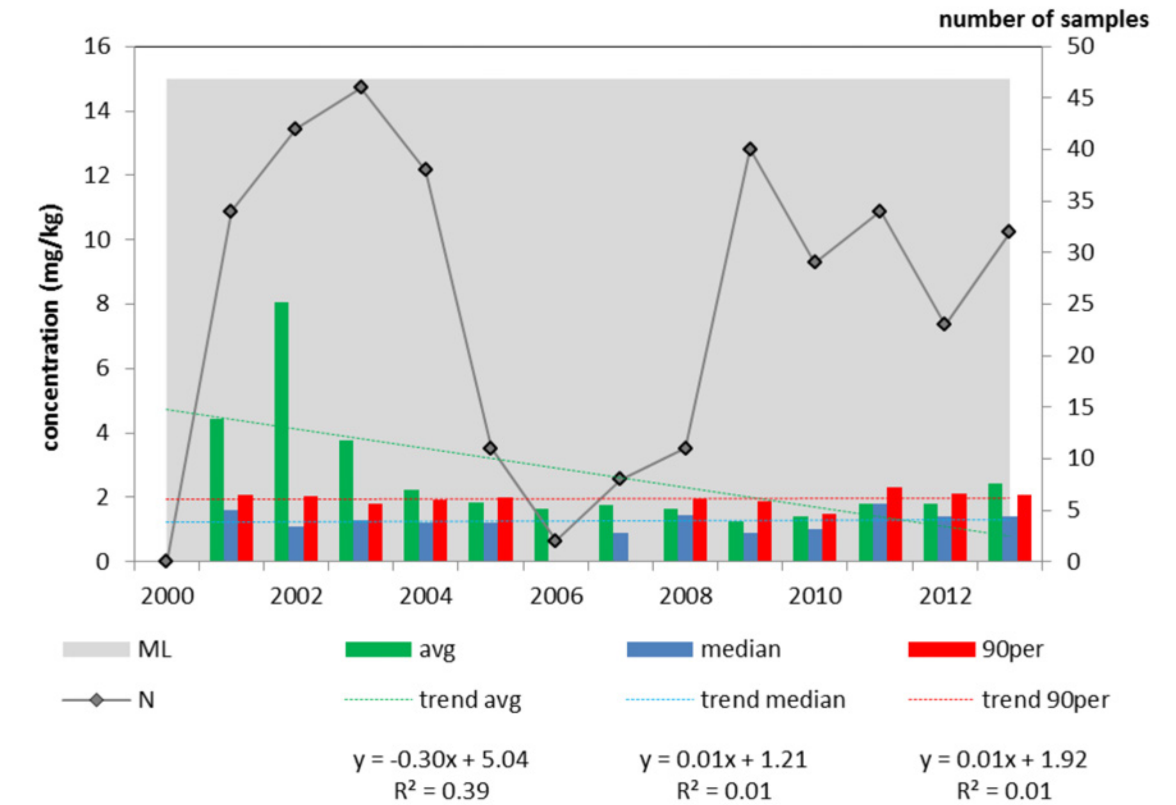

Figure 3-57 *Average, median and 90 percentile concentration of lead in complementary mineral feed for bovines; 2000-2013; N = 350; ML = 15 mg/kg.*

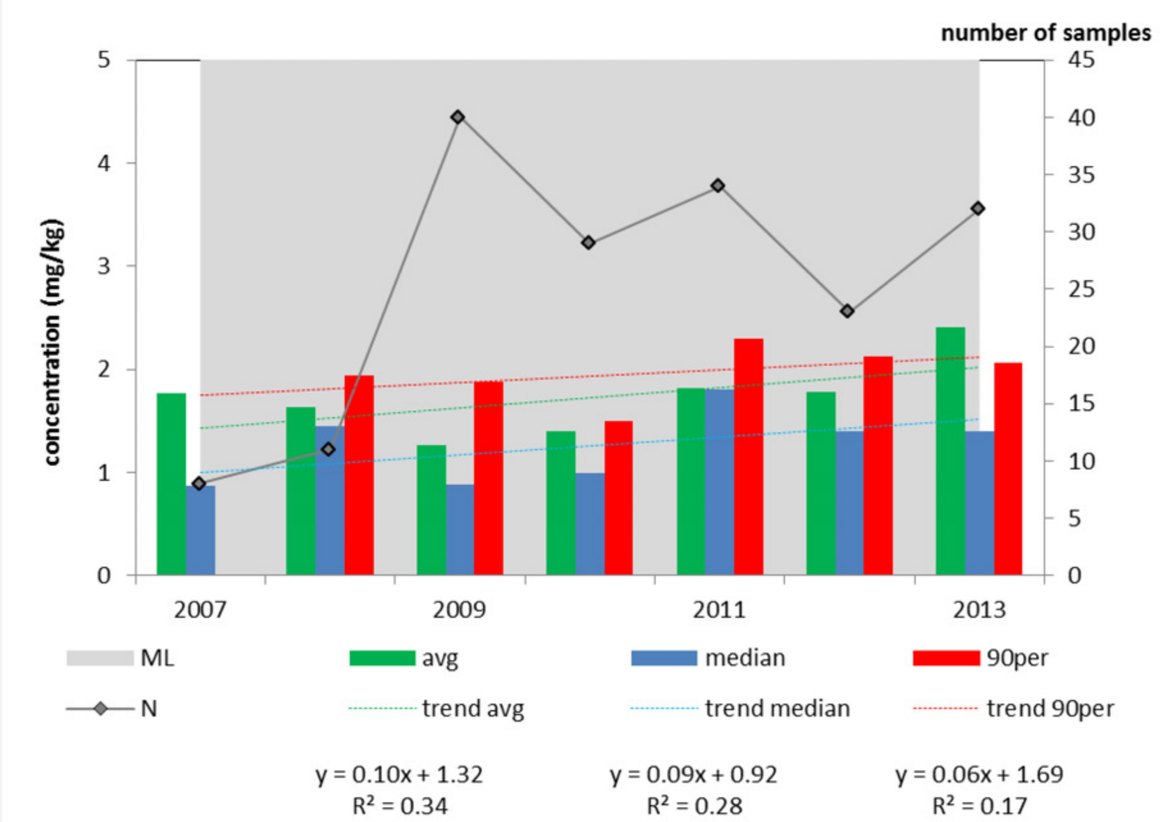

Figure 3-58 *Average, median and 90 percentile concentration of lead in complementary mineral feed for bovines; 2007-2013; N = 169; ML = 15 mg/kg.*

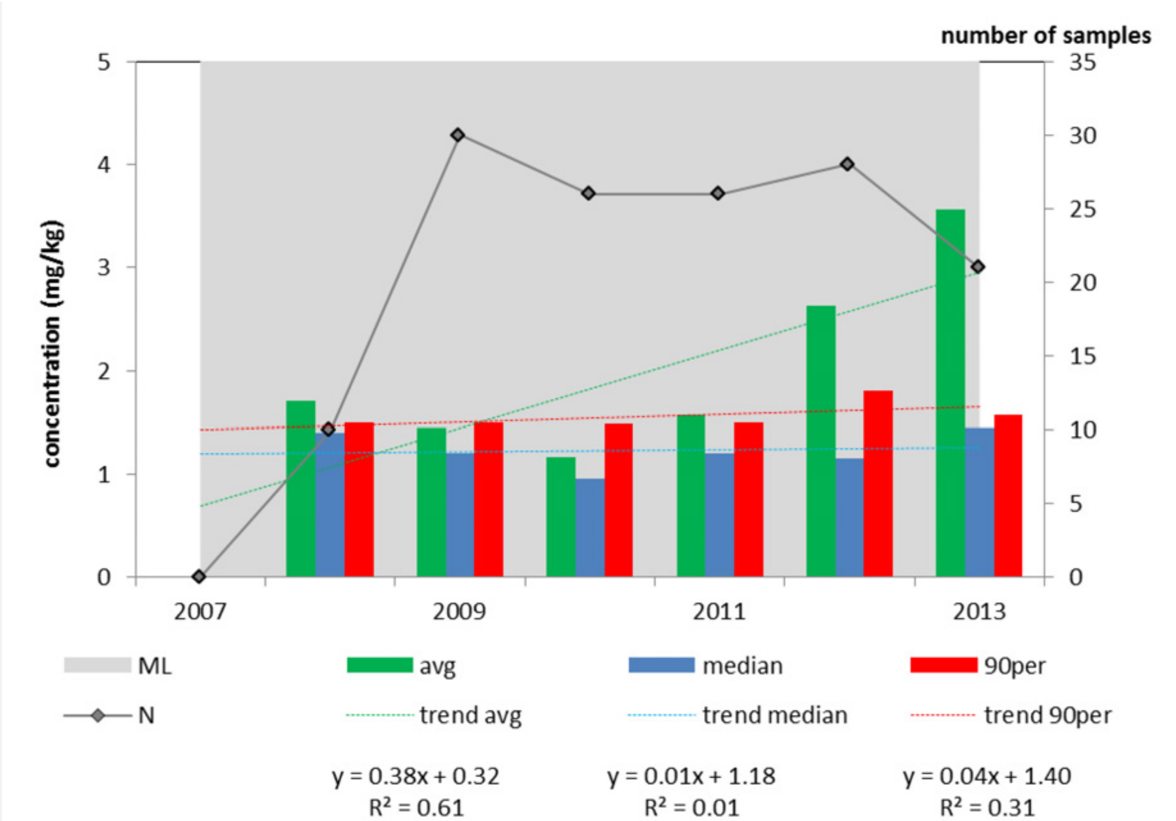

Figure 3-59 *Average, median and 90 percentile concentration of lead in complementary mineral feed for ruminants (unspecified); 2007-2013; N = 141; ML = 15 mg/kg.*

Pre-mixtures

In RASFF one notification regarding pre-mixtures can be found, notified by Netherlands in 2002 (Table Sup3-6). This sample was present in the current dataset but classified as mineral mix for bovines. The concentration (92.5 mg/kg) does not exceed the ML for pre-mixtures (200 mg/kg) but it does exceed the ML for complementary mineral feed (15 mg/kg). In the dataset of pre-mixtures no samples exceeded the ML. The average concentration declined significantly between 2000 and 2013 (Figure 3-9) and remains below the ML for complementary mineral feed. This was relevant information since there could be more samples that were classified as premix but in fact should have been classified as complementary mineral feed. Most (561) premix samples, with a lead content above the LOQ, have lead concentrations below 15 mg/kg, but some (19) have a concentration between 15 and 46 mg/kg. Between 2007 and 2013 the average lead concentration in pre-mixtures increased significantly (Figure 3-10) but with an average lead concentration in that period of only 2% of the ML.

Table Sup3-33 *RASFF alerts and notifications related to lead in pre-mixtures.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
premix, general	1	92.5	92.5	200

(More details in Table Sup5-2).

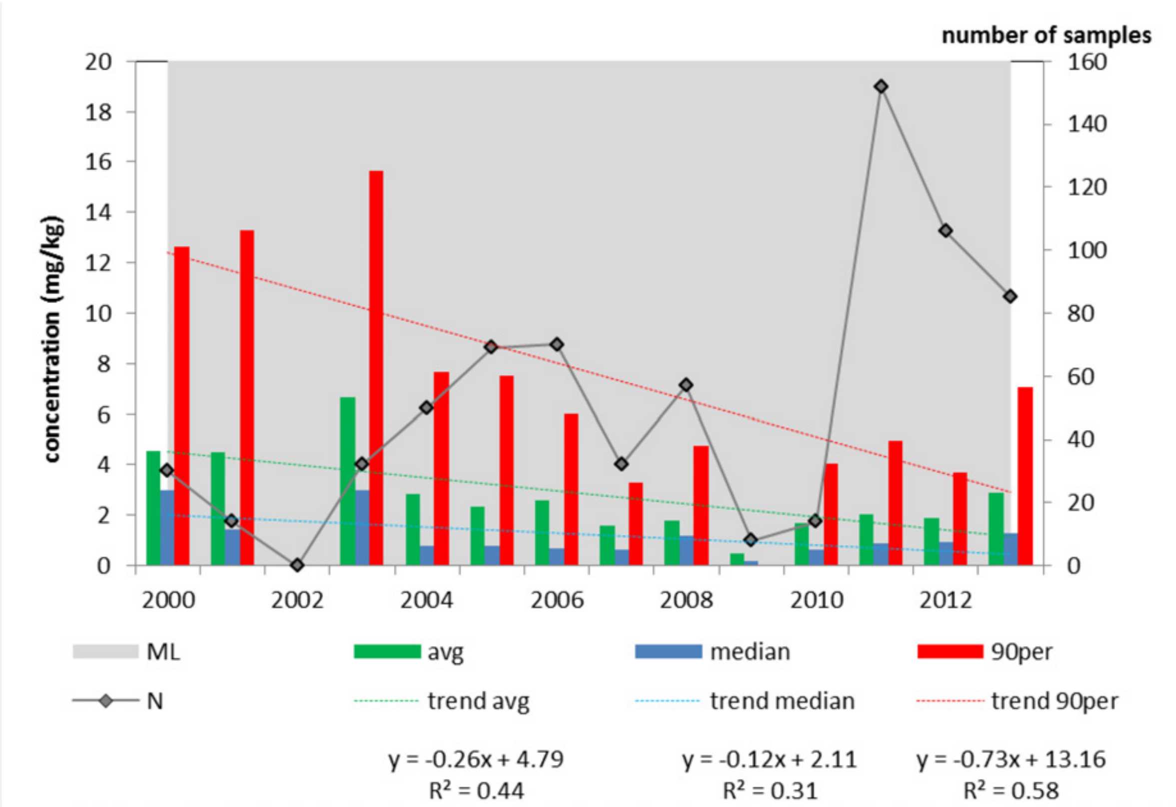

Figure 3-60 *Average, median and 90 percentile concentration of lead in pre-mixtures; N = 719; ML = 200 mg/kg.*

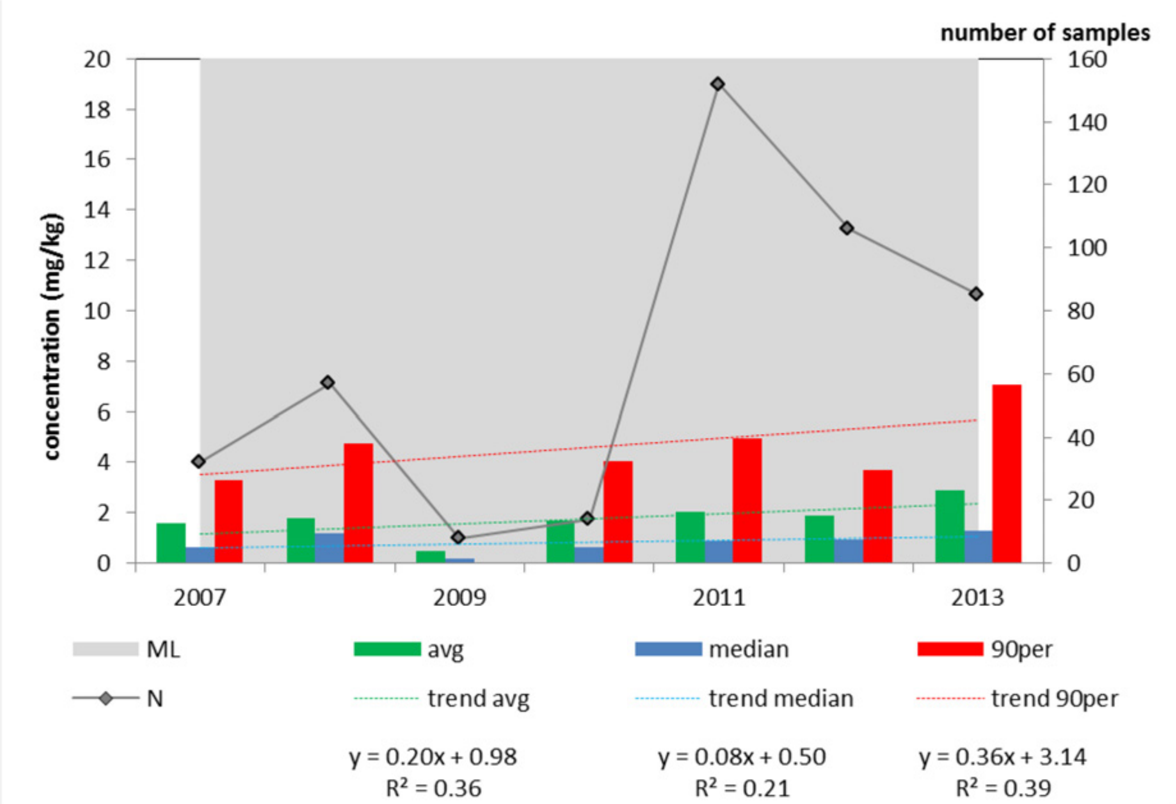

Figure 3-61 *Average, median and 90 percentile concentration of lead in pre-mixtures between 2007 and 2013; N =454; ML = 200 mg/kg.*

Complete feed
In RASFF three notifications concerned lead in complete feed (Table Sup3-7). The notification regarding pet food involves pet food from the Netherlands, with raw material from the United Kingdom (2013). The other two were from Spain (pigs) and Germany (poultry). The pet food sample from 2013 was not present in the current dataset. Only one sample exceeds the ML: complete feed for pigs in 2000 with 8.1 mg/kg lead from unknown origin.

Table Sup3-34 *RASFF alerts and notifications related to lead in complete feed.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
pig feed, complete	1	10	10	5
pet food	1	15.7	15.7	5
poultry feed	1	14.95	14.95	5

(More details in Table Sup5-2).

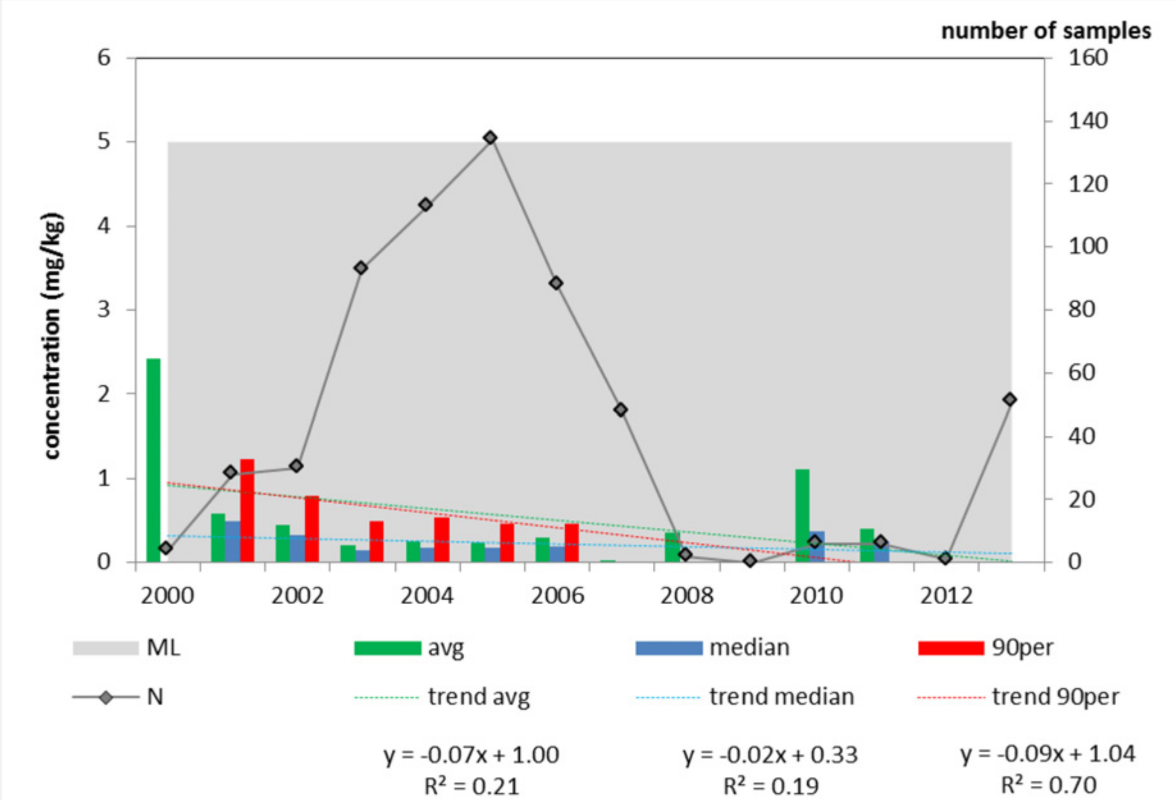

Figure 3-62 *Average, median and 90 percentile concentration of lead in complete feed; N = 604; ML = 10 mg/kg.*

In complete feed for pigs one sample from 2000 (out of four in total) of pig feed with a lead concentration of 8.1 caused a high average value. This strongly influences the trend (Figure 3-12). Furthermore, after 2006 the number of samples taken decreased to almost zero.

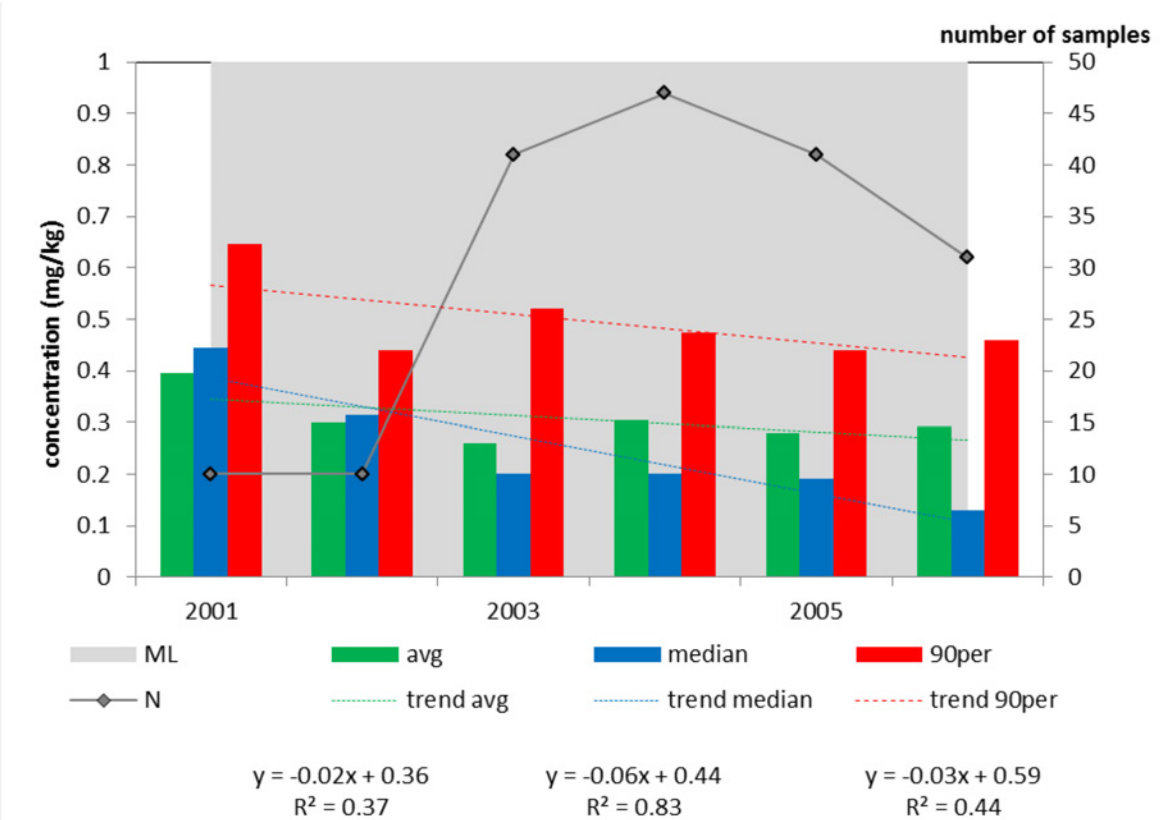

Figure 3-63 *Average, median and 90 percentile concentration of lead in complete feed for pigs; 2001-2006; N = 180; ML = 10 mg/kg.*

Feed materials (excl. forage, phosphates and calcareous marine algae, calcium carbonate, calcium and magnesium carbonate and yeasts)

RASFF reported five notification regarding feed materials (Table Sup3-5). One notification (bone meal from Italy, 2013) originates from the Netherlands. This sample was not present in the current dataset. Two samples exceeding the ML were present in this dataset: duck weed (2008, 12 and 14 mg/kg).

Table Sup3-35 *RASFF alerts and notifications related to lead in feed materials with the exception of forage, phosphates and calcareous marine algae, calcium carbonate, calcium and magnesium carbonate and yeasts.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
bone meal	1	46.3	46.3	10
palm kernel expeller	1	1.7	15	10
rice protein	1	22	22	10
sugar beet pulp	1	383	383	10
sunflower seed meal	1	1.5	43.5	10

(More details in Table Sup5-2).

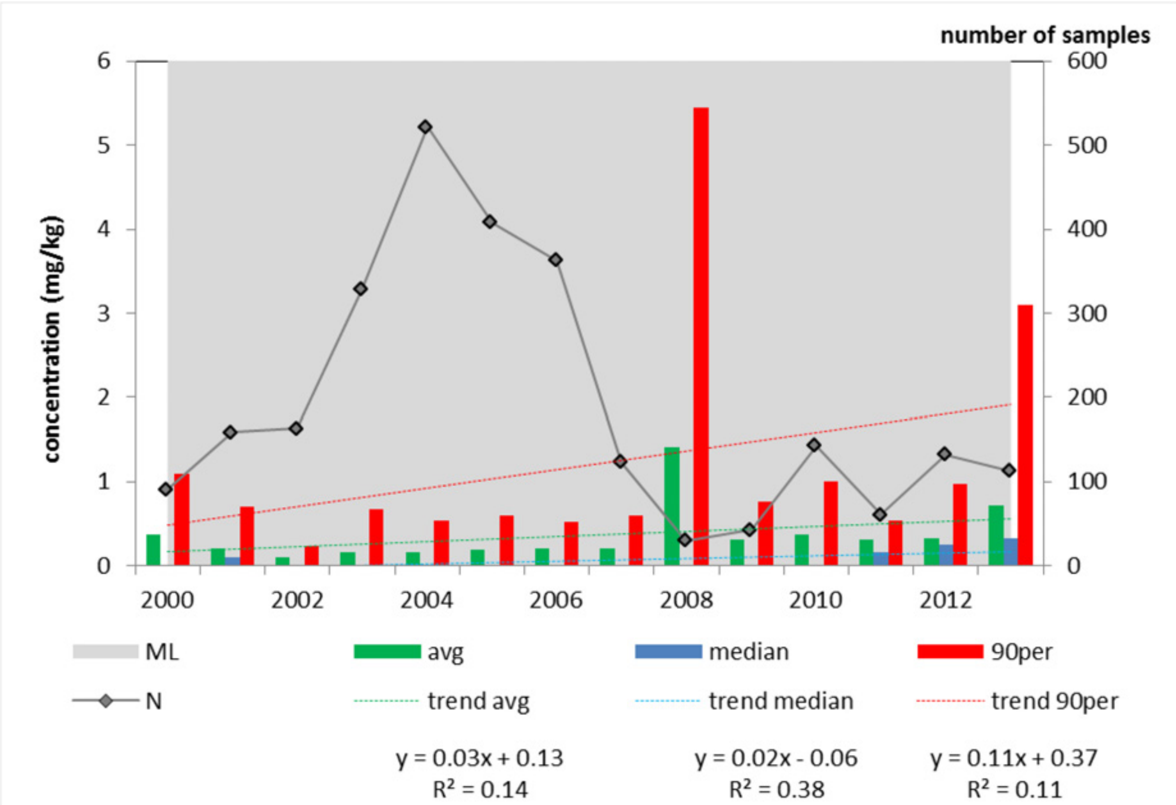

Figure 3-64 *Average, median and 90 percentile concentration of lead in feed materials with the exception of forage, phosphates and calcareous marine algae, calcium carbonate, calcium and magnesium carbonate and yeasts; N = 2679; ML = 10 mg/kg.*

Of the 2679 feed material samples (excl. forage, phosphates and calcareous marine algae, calcium carbonate, calcium and magnesium carbonate and yeasts) 2097 samples were feed materials of vegetable origin.

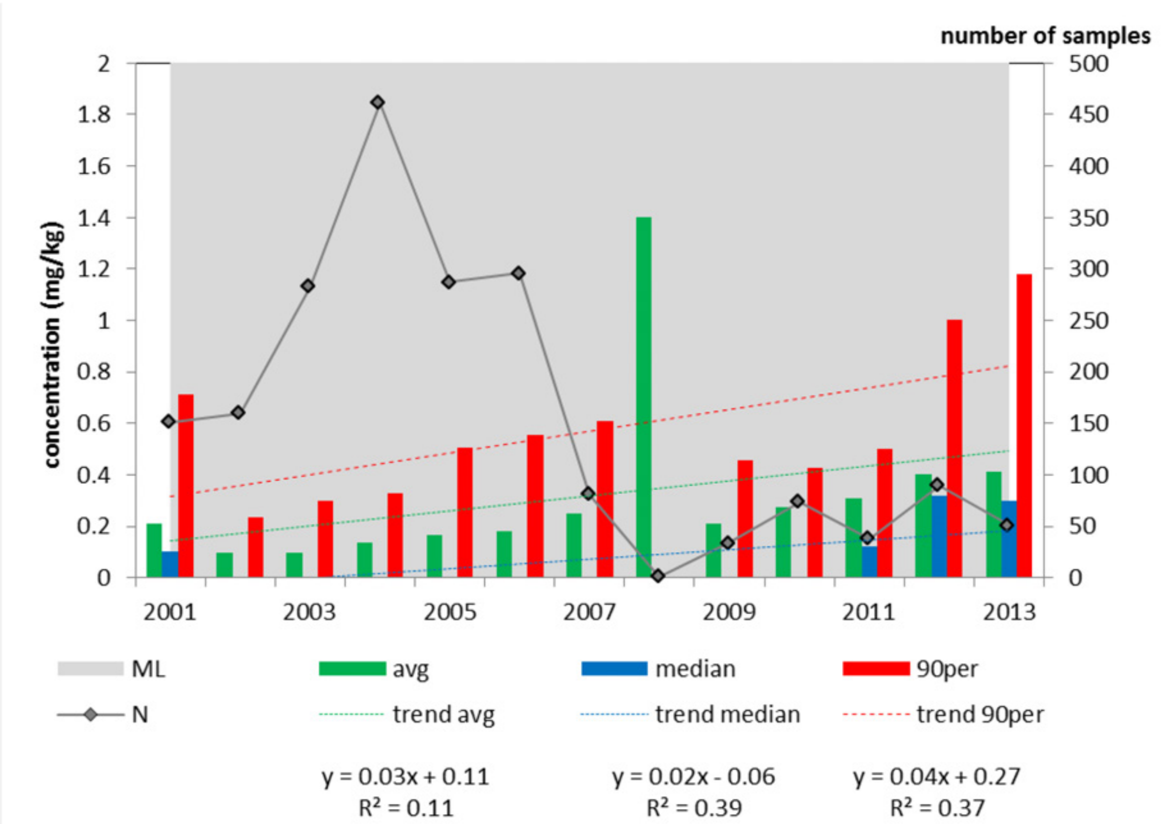

Figure 3-65 *Average, median and 90 percentile concentration of lead in feed materials of vegetable origin; N = 2097; ML = 10 mg/kg.*

For soya bean expeller/extracted, (Figure 3-15).between 2007 and 2013 only four samples were reported. This is justified because the concentrations are very low.

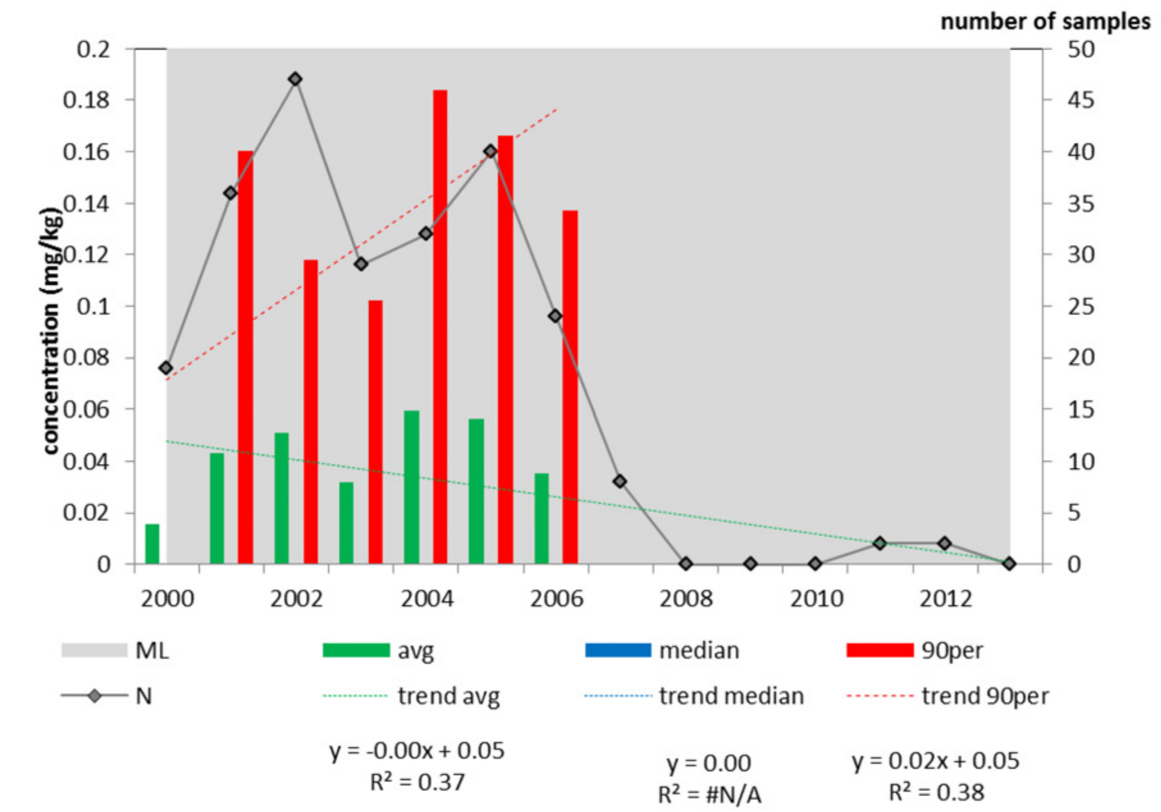

Figure 3-66 *Average, median and 90 percentile concentration of lead in soya expeller/extracted; N = 239; ML = 10 mg/kg.*

Another substantial subgroup of feed materials was fishmeal (222 samples between 2002 and 2013). No samples exceeded the ML. Between 2007 and 2013 the concentrations remained well below the ML with a highest value of 3.8 mg/kg (2010, Denmark) and the other values below 1 mg/kg.

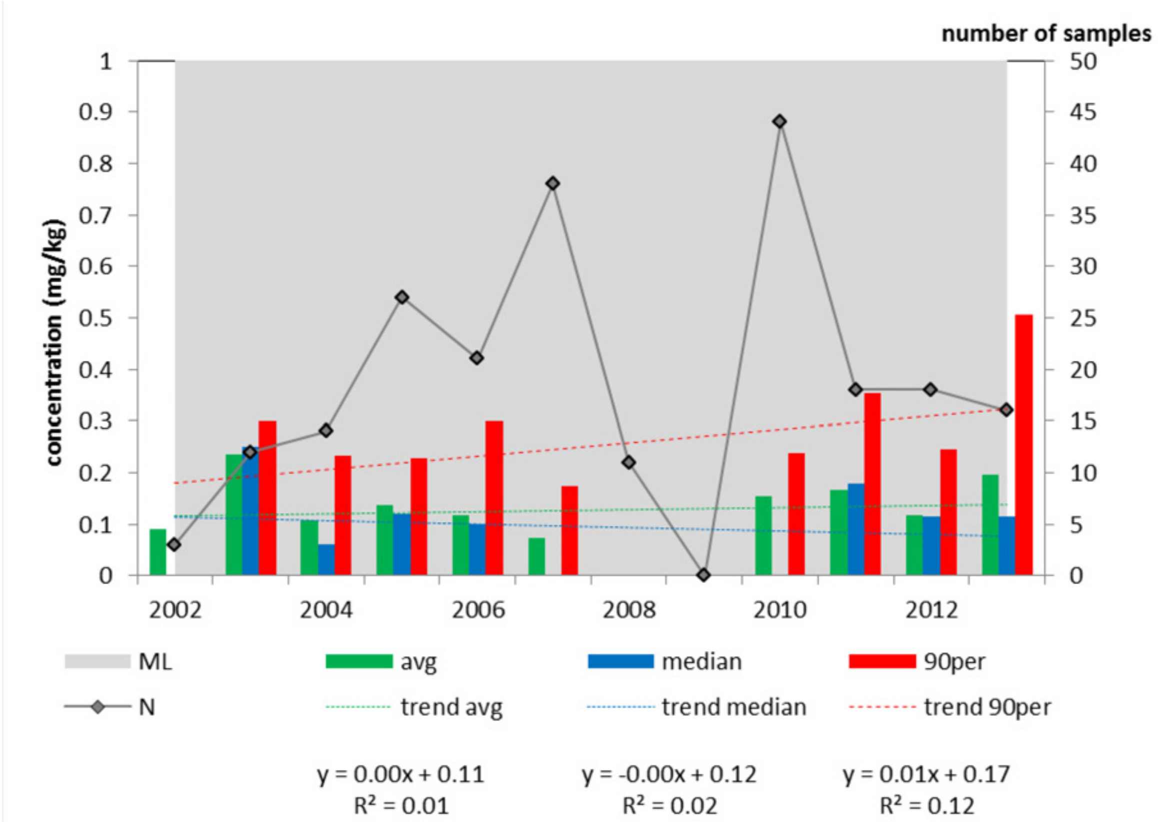

Figure 3-67 *Average, median and 90 percentile concentration of lead in fish meal between 2002 and 2013; N = 222; ML = 10 mg/kg.*

Forage

Forage includes products intended for animal feed such as hay, silage, fresh grass, etc. No RASFF alerts were reported for this product group. In the current study no forage samples have been reported with lead concentration concentrations exceeding the ML. Average concentrations are well below the ML and have decreased significantly in the period from 2000 – 2013. Presumably this is caused by the fact that environmental pollution has decreased due to the ban of leaded fuels (EFSA, 2013).

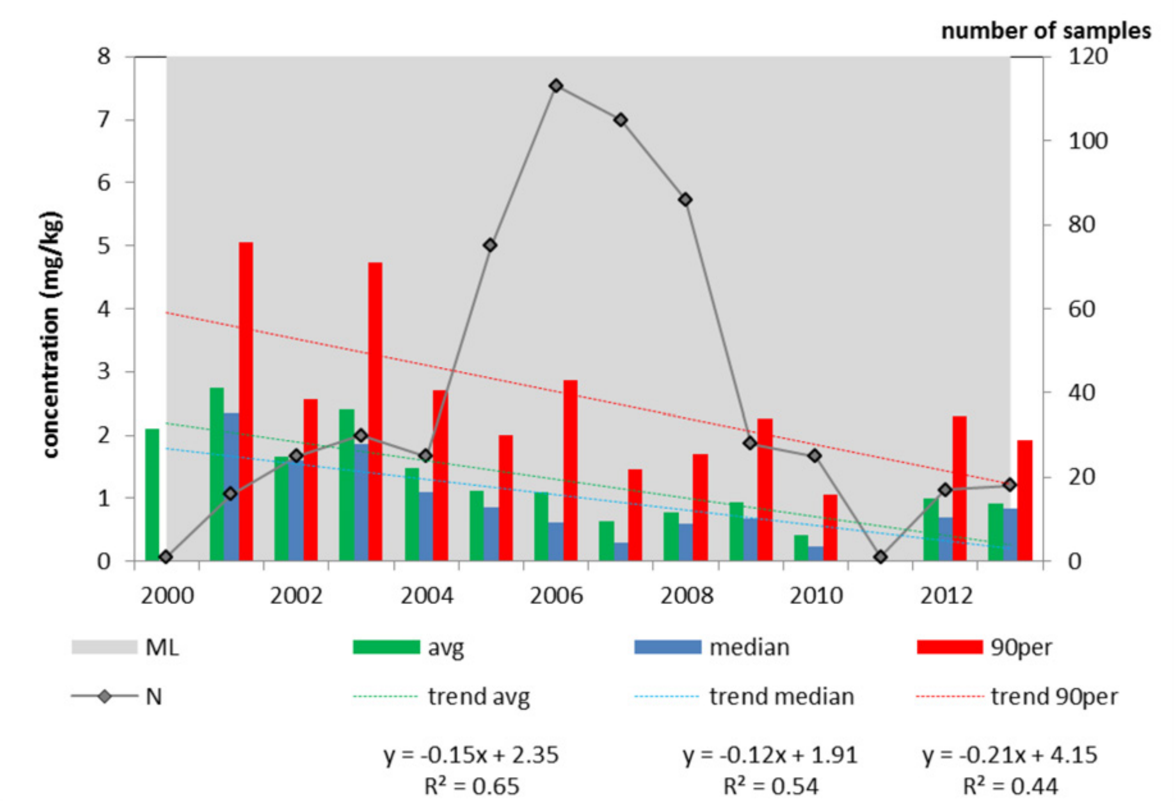

Figure 3-68 *Average, median and 90 percentile concentration of lead in forage; N = 565; ML = 30 mg/kg.*

Phosphates and calcareous marine algae
RASFF reported two notifications regarding phosphates and calcareous marine algae, not related to the Netherlands. In the current study none of the samples exceeded the ML.

Table Sup3-36 *RASFF alerts and notifications related to lead in phosphates and calcareous marine algae.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
dicalcium phosphate	1	39.5	39.5	15
mono-calcium phosphate	1	23.7	23.7	15

(More details in Table Sup5-2).

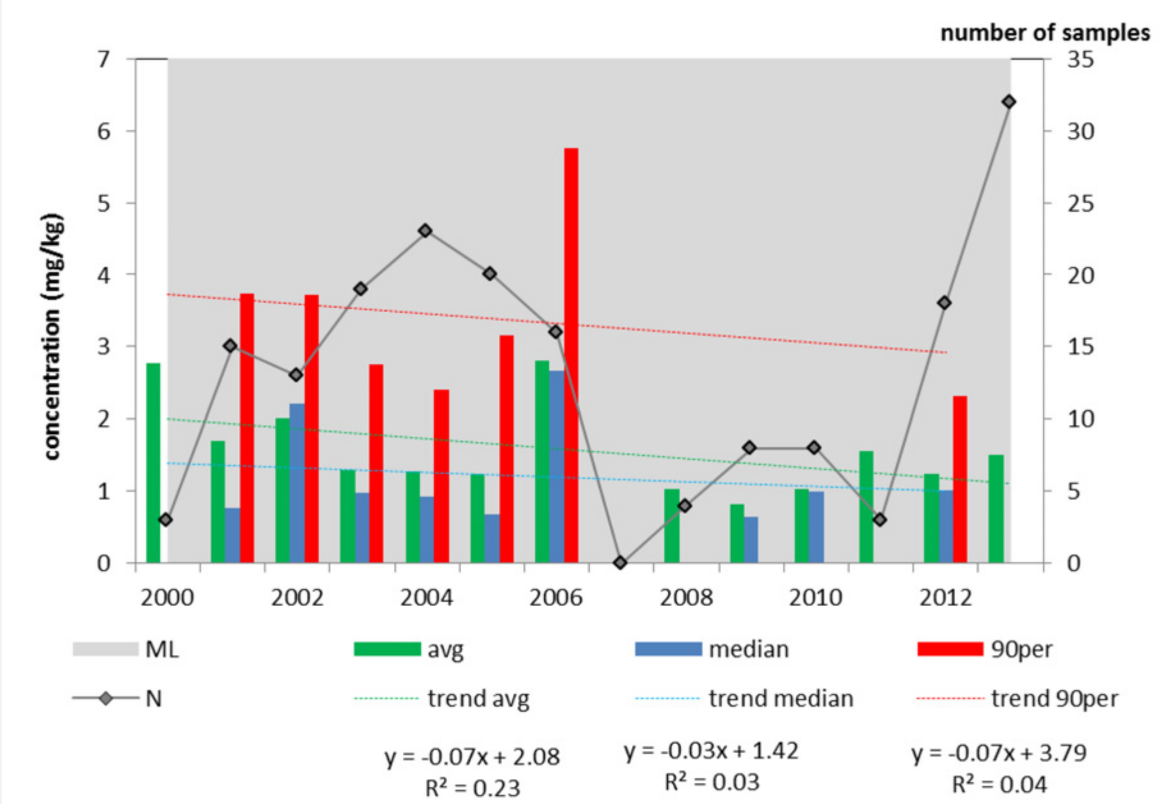

Figure 3-69 *Average, median and 90 percentile concentration of lead in phosphates and calcareous marine algae; 2003-2013; N = 182; ML = 15 mg/kg.*

Calcium carbonate; calcium and magnesium carbonate

No RASFF alerts were reported for this product group. The only samples with lead concentrations exceeding the ML in the current study were calcium carbonate, reported in 2003 (21, 30 and 31 mg/kg) and 2004 (23 mg/kg). This was not enough for a relevant trend analysis.

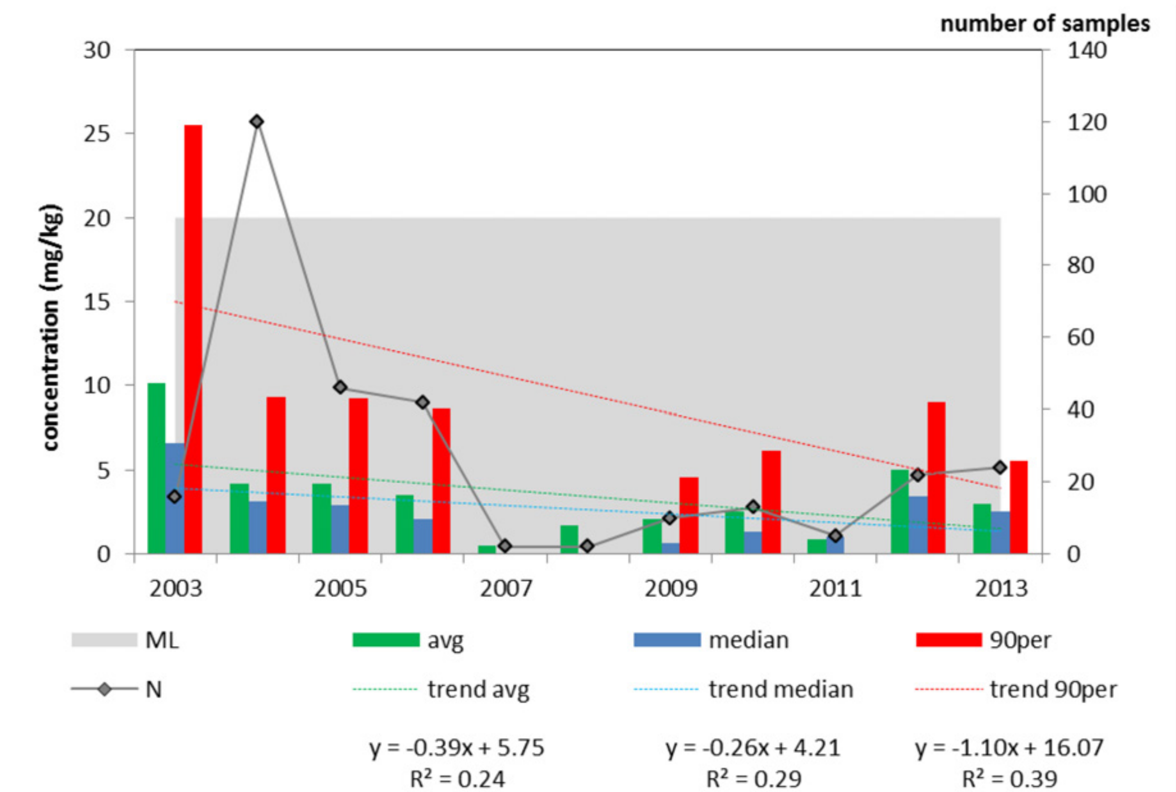

Figure 3-70 *Average, median and 90 percentile concentration of lead in calcium carbonate; 2003-2013; N = 302; ML = 20 mg/kg.*

Yeasts
No RASFF alerts were reported for this product group. Since in the current study only three samples were analysed (2005, 2010, 2011, all below the LOQ) no trend analysis could be performed.

Feed additives belonging to the functional group of compounds of trace elements (excl. zinc oxide, manganous oxide, ferrous carbonate, cupric carbonate).

RASFF reported two notifications regarding trace elements (Table Sup3-10), none of them related to the Netherlands. In the current study no samples exceeded the ML.

Table Sup3-37 *RASFF alerts and notifications related to lead in feed additives belonging to the functional group of compounds of trace elements (excl. zinc oxide, manganous oxide, ferrous carbonate, cupric carbonate).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
copper sulphate	1	196	196	100
iron oxide	1	339	339	100

(More details in Table Sup5-2).

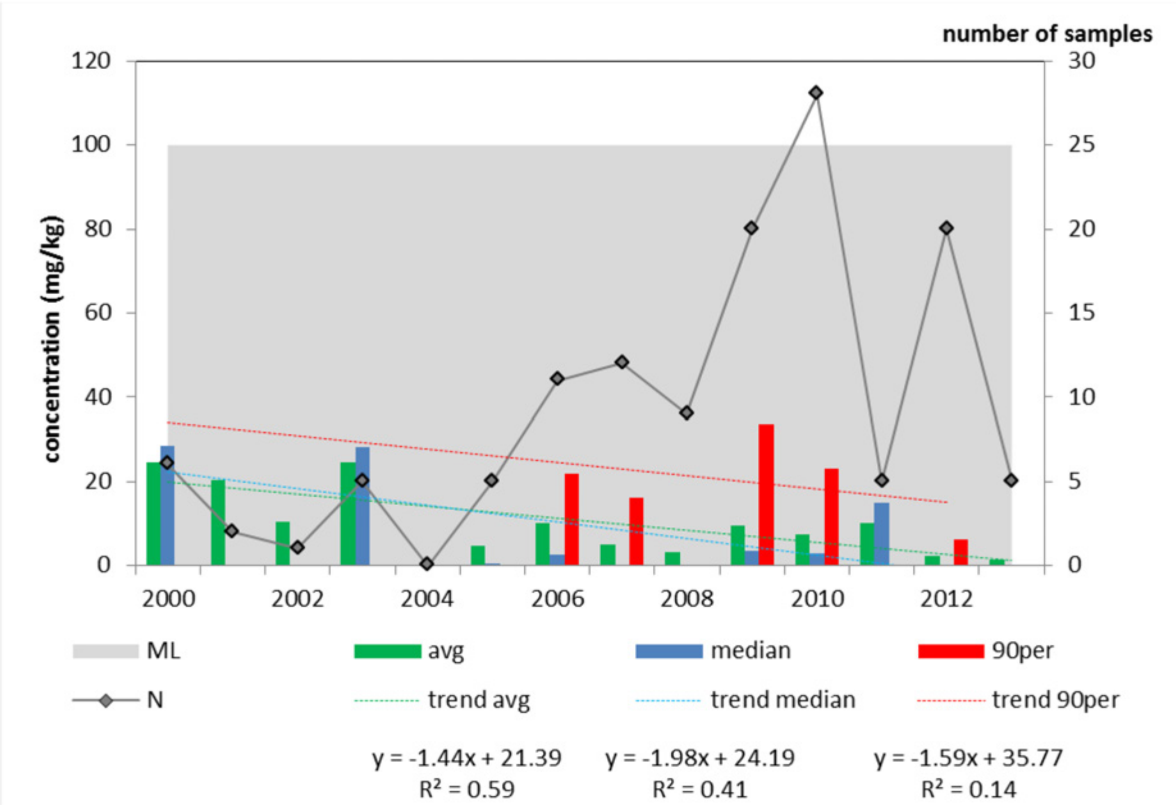

Figure 3-71 *Average, median and 90 percentile concentration of lead in feed additives belonging to the functional group of compounds of trace elements (excl. zinc oxide, manganous oxide, ferrous carbonate, cupric carbonate); N = 129; ML = 100 mg/kg.*

Zinc oxide

Table Sup3-38 *RASFF alerts and notifications related to lead in zinc oxide.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
zinc oxide	4	571	134000	400

(More details in Table Sup5-2).

RASFF reported four incidents with very high lead concentrations in zinc oxide from Turkey, India and Portugal, none of them related to the Netherlands. In the current study no samples exceeded the ML.

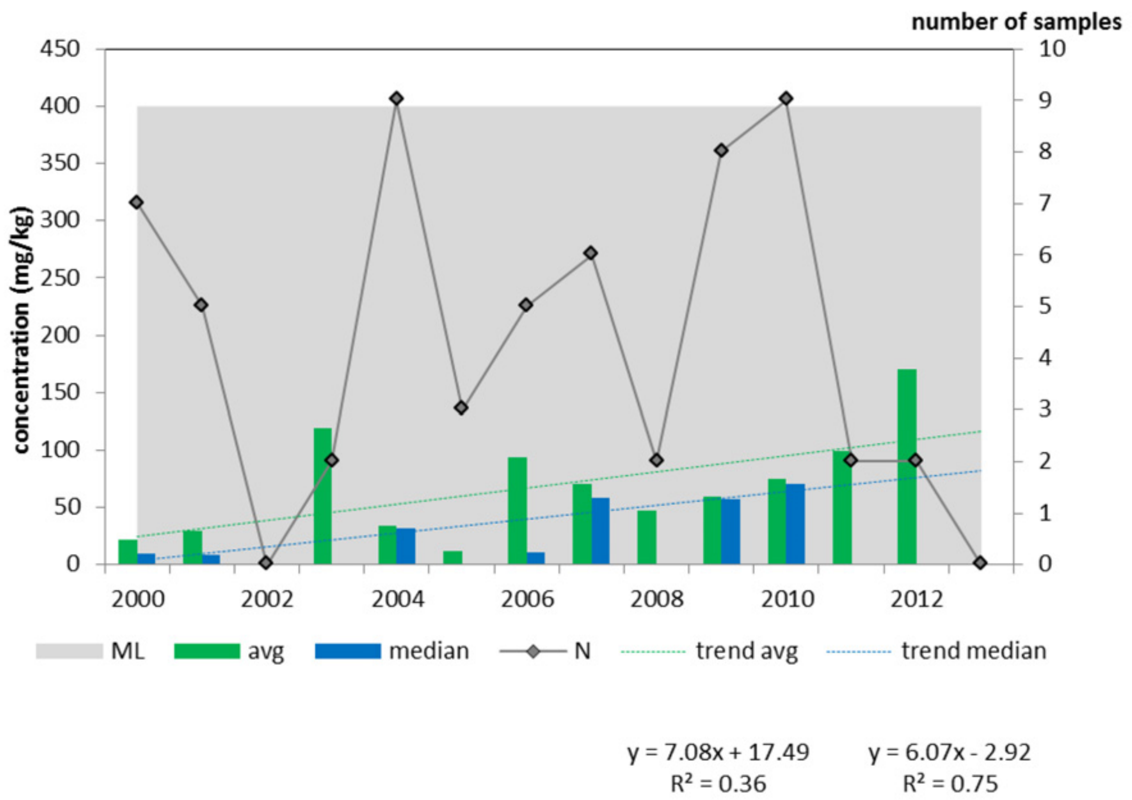

Figure 3-72 *Average and median concentration of lead in zinc oxide; N = 60; ML = 400 mg/kg.*

Manganous oxide, ferrous carbonate, cupric carbonate

Table Sup3-39 *RASFF alerts and notifications related to lead in manganous oxide, ferrous carbonate, cupric carbonate.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
manganese oxide	1	292	292	200

(More details in Table Sup5-2).

RASFF reported one alert regarding manganese oxide (from Brazil, reported by Austria, Table Sup3-12). In the current study only sixteen samples from this group were analysed between 2000 and 2013, all manganese oxide. None of those samples exceeded the ML for lead.

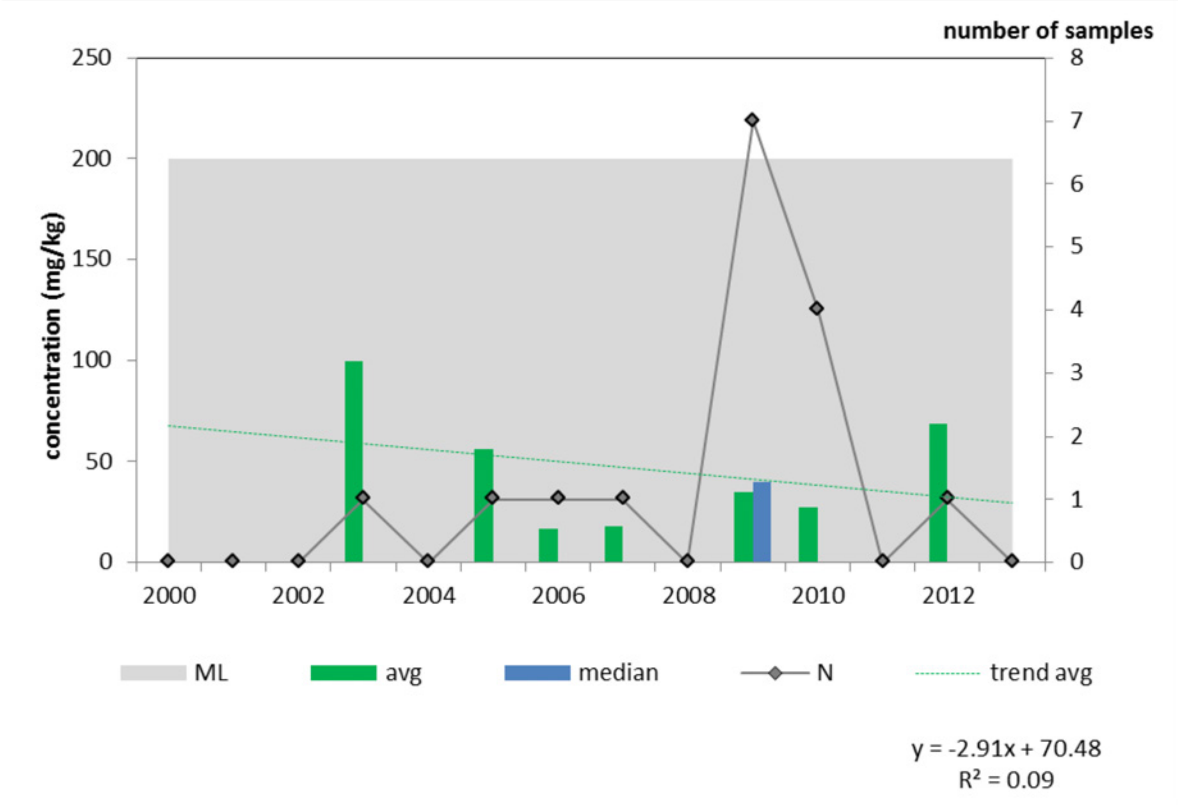

Figure 3-73 *Average and median concentration of lead in manganous oxide, ferrous carbonate, cupric carbonate; N = 16; ML = 200 mg/kg.*

Feed additives belonging to the functional groups of binders and anti-caking agents (excl. clinoptilolite of volcanic origin; natrolite-phonolite)

RASFF reported one notification regarding this feed group (Table Sup3-13). It concerns sepiolite from Spain, reported by Belgium in 2008. In the current study 14 samples (out of 273) exceeded the ML between 2002 and 2013, 12 of them before 2007. None of those samples were as high as the sample reported by RASFF.

Table Sup3-40 *RASFF alerts and notifications related to lead in feed additives belonging to the functional groups of binders and anti-caking agents (excl. clinoptilolite of volcanic origin; natrolite-phonolite).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
sepiolite	1	105.8	105.8	30

(More details in Table Sup5-2).

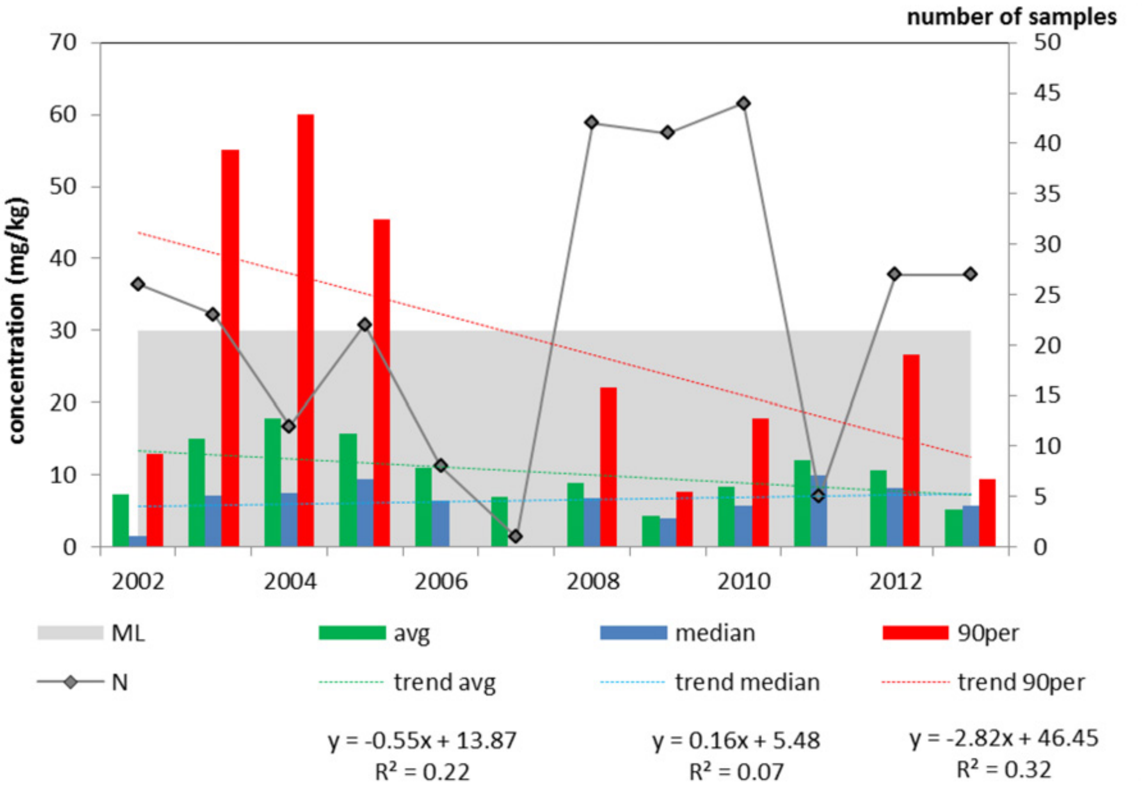

Figure 3-74 *Average, median and 90 percentile concentration of lead in feed additives belonging to the functional groups of binders and anti-caking agents (excl. clinoptilolite of volcanic origin; natrolite-phonolite); 2002-2013; N = 278; ML = 30 mg/kg.*

Sepiolite

Sepiolite is one of the products from the group groups of binders and anti-caking agents. No samples were reported for 2000-2003 so only 2004-2013 is shown. No samples of sepiolite with lead concentrations exceeding the ML were found in this study.

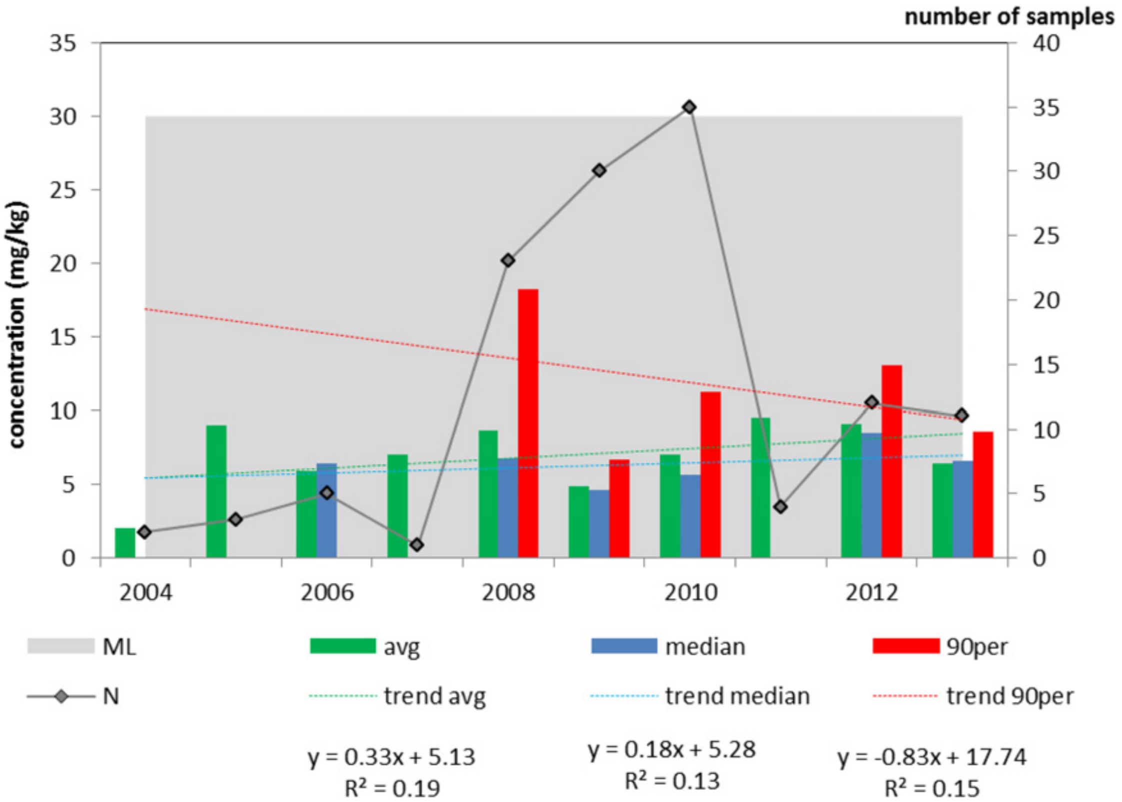

Figure 3-75 *Average, median and 90 percentile concentration of lead in sepiolite; 2004-2013; N = 126 ML = 30 mg/kg.*

Clay minerals (unspecified)

Clay minerals are part of group of binders and anti-caking agents. They were not always specified further (into sepiolite, kaolinite, clinoptilolite, etc.). In this study it was assumed that clinoptilolite of volcanic origin or natrolite-phonolite would have been specified because the ML is higher (60 mg/kg) than the ML for the other binders and anti-caking agents (30 mg/kg). Therefore the ML of 30 mg/kg has been used for the group clay minerals (unspecified). In this group 7 samples were reported with lead concentrations exceeding the ML of 30 mg/kg, 2 in 2004, 3 in 2005, 1 in 2006 and 2012. No samples were reported for 2000-2003 so only 2004-2013 was shown (Figure 3-25).

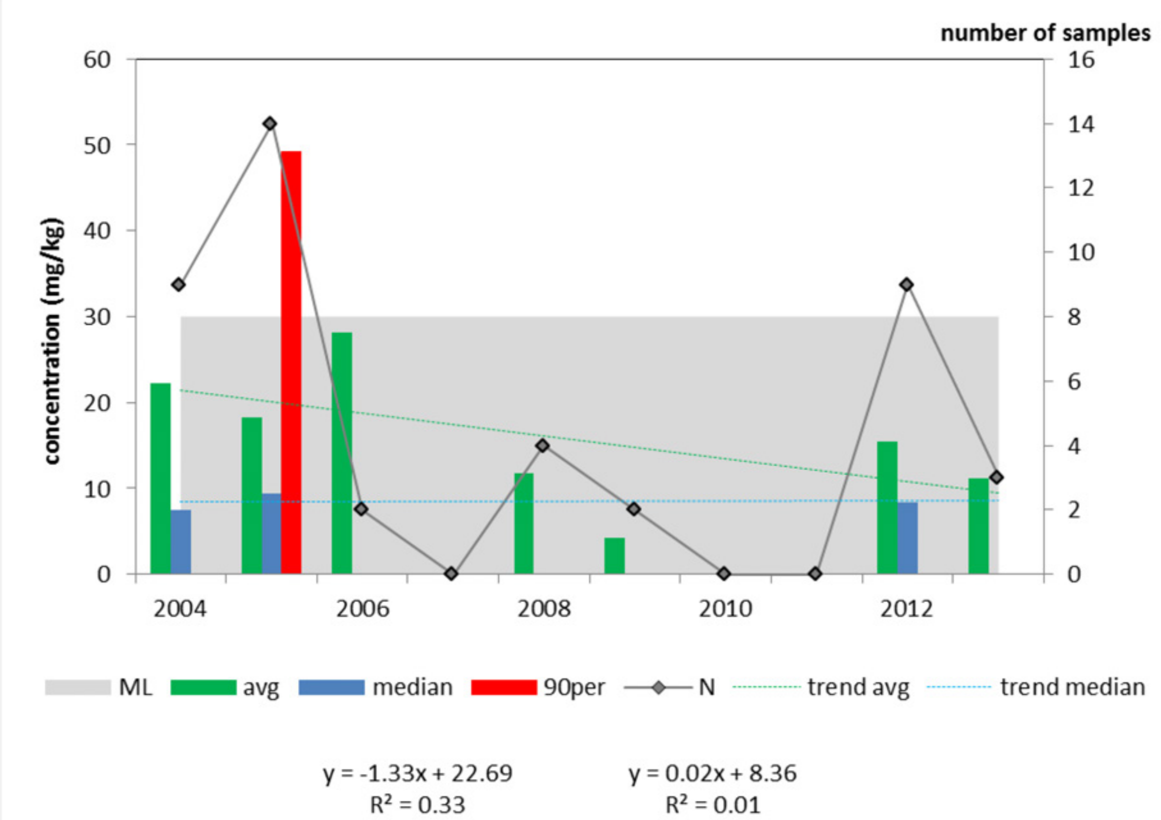

Figure 3-76 *Average, median and 90 percentile concentration of lead in clay minerals (unspecified); 2004-2013; N = 43; ML = 30 mg/kg.*

Clinoptilolite of volcanic origin; natrolite-phonolite

Clinoptilolite of volcanic origin; natrolite-phonolite are part of group of binders and anti-caking agents, but have an ML different from the rest of the group (60 i.s.o. 30 mg/kg). In this study none of the samples analysed (between 2007 and 2013, all clinoptolite) exceeded this ML. RASFF reported no notification regarding this feed additive either.

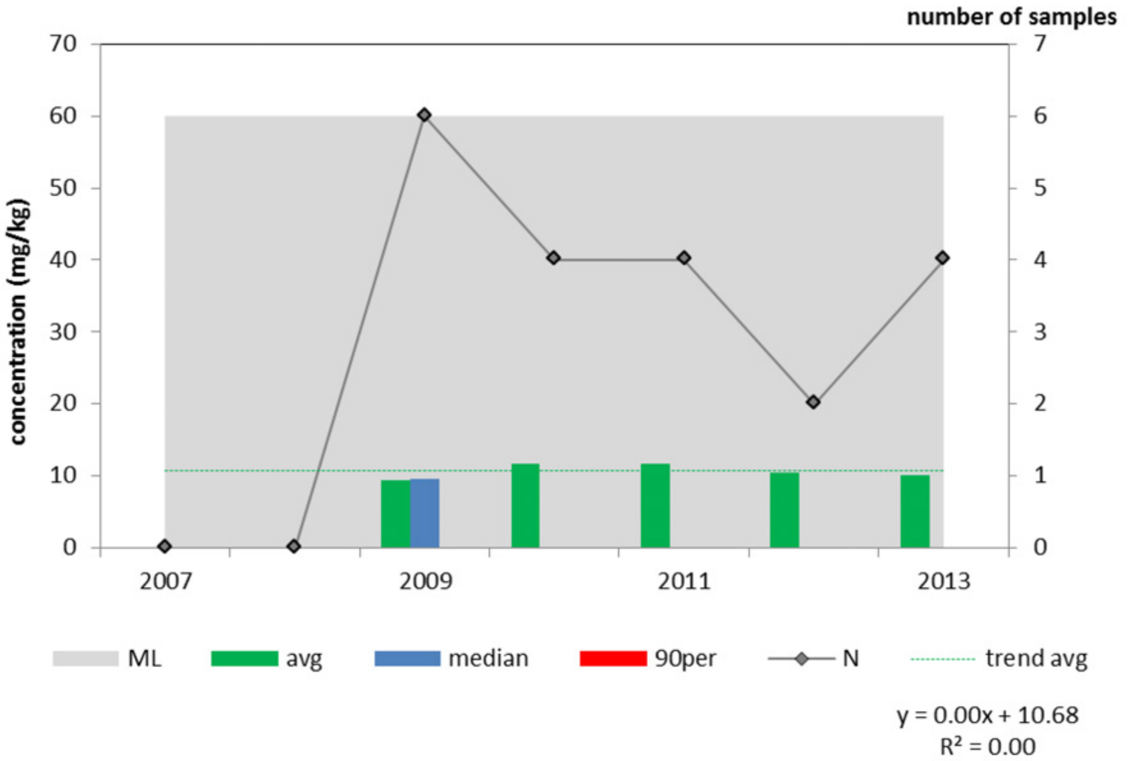

Figure 3-77 *Average, median and 90 percentile concentration of lead in clinoptilolite of volcanic origin; natrolite-phonolite; N = 20; ML = 60 mg/kg.*

Other feed additives

For other feed additives, for example vitamins, there were no MLs for lead. No RASFF notifications were reported. In most samples the concentration was below 3 mg/kg (14 samples) or below the LOQ (89 samples), except for Myco-AD (a feed additive to bind mycotoxins; 2011 26 mg/kg), choline chloride (2011, 33 mg/kg) and calcium propionate (2013, 34 mg/kg).

Figure 3-78 *Average, median and 90 percentile concentration of lead in other feed additives; N = 156; no ML.*

Annex 4 Supplemental information mercury

Maximum levels for mercury in animal feed and feed materials

Directive 2002/32/EC, amended by Regulation (EU) No 744/2012 describes the maximum mercury concentration allowed in feeds and feed materials since 2012 (Table Sup4-1). The highest concentrations were allowed in fish, other aquatic animals and products derived thereof. The lowest MLs were defined for compound feeds and feed materials. Compared to the previous trend analysis report (Adamse et al, 2009, the differentiation in maximum levels between complete (0.1 mg/kg) and complementary feed (0.2 mg/kg) was withdrawn. The maximum level for compound feed for dogs, cats and fur animals decreased in 2012 from 0.4 mg/kg to 0.3 mg/kg and limits for mineral feed and compound feed for fish were added.

Table Sup4-41 *Maximum levels for mercury(4) in animal feed and feed materials according to Directive 2002/32/EC, amended by Regulation (EU) No 744/2012.*

Products intended for animal feed	Maximum content in mg/kg (ppm) relative to a feed with a moisture content of 12%
Feed materials	0.1
with the exception of:	
— fish, other aquatic animals and products derived thereof,	0.5
— calcium carbonate; calcium and magnesium carbonate (10).	0.3
Compound feed	0.1
with the exception of:	
— mineral feed,	0.2
— compound feed for fish,	0.2
— compound feed for dogs, cats and fur animals.	0.3

(4) The maximum levels refer to total mercury.

(10) Calcium and magnesium carbonate refers to the natural mixture of calcium carbonate and magnesium carbonate as described in Commission Regulation (EU) No 575/2011 of 16 June 2011 on the Catalogue of feed materials (OJ L 159, 17.6.2011, p. 25).

Overall trends in percentage of samples exceeding the LOQ or the ML

For the calculation of the percentage of samples exceeding the ML the maximum levels valid since 2012 were used. Between 2000 and 2013 only 10 samples (out of 4906 samples) exceeded the ML. For another 1116 samples (feed additives and pre-mixtures) no ML was set (Table Sup4-2) Between 2007- and 2013 4 out of 1549 samples (with ML) exceeded the ML (Table Sup4-3).

Table Sup4-42 *Samples exceeding the ML or the LOQ for mercury (2000-2013).*

Product	N Total	N > LOQ	N > ML	% > LOQ	% > ML
Feed materials, with the exception of:	2929	459	3	16	0.1
— fish, other aquatic animals and products derived thereof	306	270	0	88	0.0
— calcium carbonate; calcium and magnesium carbonate	126	38	0	30	0.0
Compound feed, with the exception of:	716	75	3	11	0.4
— compound feed for dogs, cats and fur animals	60	5	1	8	1.7
— mineral feed	713	206	1	29	0.1
— compound feed for fish	2	2	0	100	0.0
Feed additives -> no ML	585	210	-	36	-
Pre-mixtures -> no ML	585	165	-	28	-
Total	**6022**	**1430**	**8**		

Table Sup4-43 *Samples exceeding the ML or the LOQ for mercury (2007-2013).*

Product	N Total	N > LOQ	N > ML	% > LOQ	% > ML
Feed materials, with the exception of:	684	117	1	17	0.1
— fish, other aquatic animals and products derived thereof	198	180	0	91	0.0
— calcium carbonate; calcium and magnesium carbonate	65	15	0	23	0.0
Compound feed, with the exception of:	59	6	1	10	1.7
— compound feed for dogs, cats and fur animals	56	5	1	9	1.8
— mineral feed	434	101	0	23	0
— compound feed for fish	0	0	0	0	0
Feed additives -> no ML	467	153	-	33	-
Pre-mixtures -> no ML	441	122	-	28	-
Total	**2404**	**699**	**3**		

Results mercury

Feed materials (excl. fish, other aquatic animals and products derived thereof and calcium carbonate; calcium and magnesium carbonate)

The RASFF alert about mercury in yeast did not originate from the Netherlands but from Germany (Table Sup4-4). The one sample of yeast in the current dataset had a mercury concentration below the LOQ. The high 90 percentile in 2000 was cause by ten samples (out of 85) of potato pulp of 0.1 mg/kg, equal to the ML for feed materials. In 2012 a sample of grass meal with a concentration of 0.228 mg/kg exceeded the ML.

Table Sup4-44 *RASFF alerts and notifications related to lead in feed materials (excl. fish, other aquatic animals and products derived thereof and calcium carbonate; calcium and magnesium carbonate).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
yeast	1	0.14	0.16	-

(More details in Table Sup5-4).

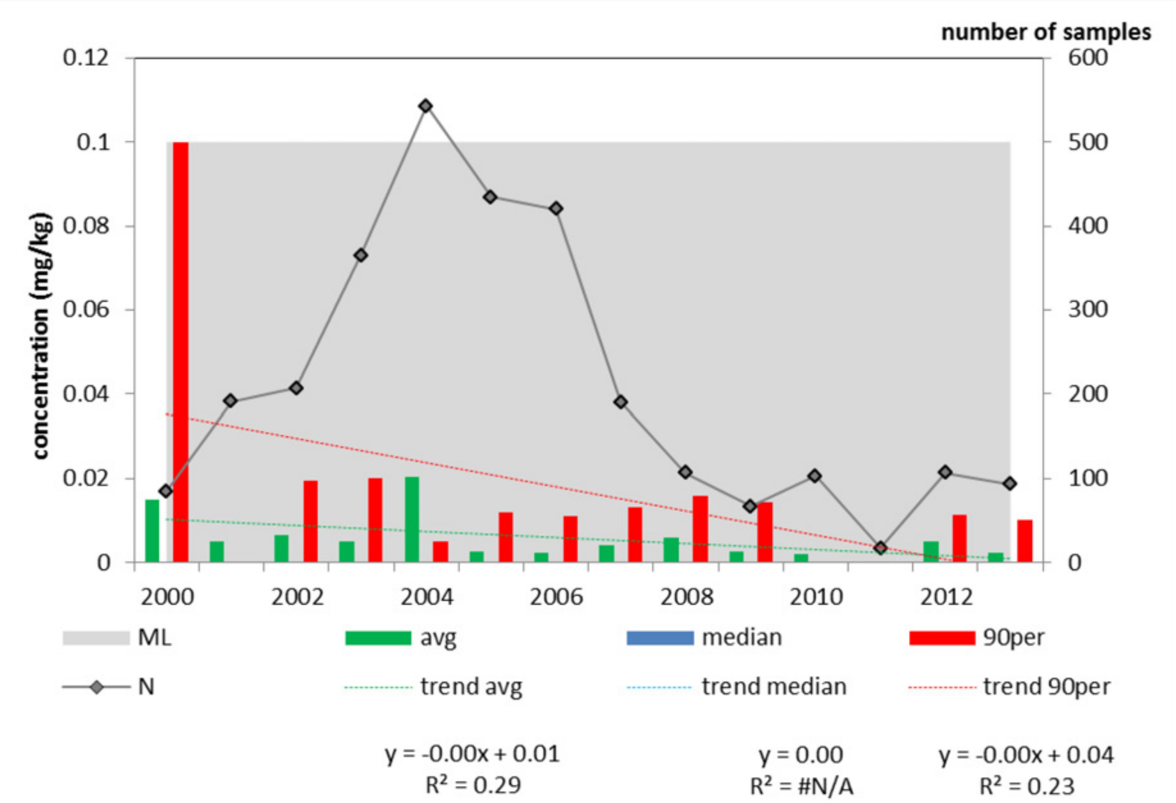

Figure 4-79 *Average, median and 90 percentile concentration of mercury in feed materials (excl. fish, other aquatic animals and products derived thereof and calcium carbonate; calcium and magnesium carbonate); 2000-2013; N = 2929; ML = 0.1 mg/kg.*

In the previous trend analysis report (Adamse et al., 2009), covering the period 2000-2006, several feed materials of plant origin were studied separately. Most did not contain any or hardly any mercury. No significant trends were observed and the advice was that in general it would not be necessary to analyse feed materials of vegetable origin very frequently. Only after obvious calamities this would be warranted. After 2006 the number of feed material of plant origin samples analysed for mercury dropped considerably (Figure 4-2). The high 90 percentile in 2000 was caused by potato pulp as explained above. Only three samples exceeded the ML: two samples of wheat in 2004 (country of origin unknown, both 5 mg/kg[2]) and one sample of grass meal from 2012 from the Netherlands (0.228 mg/kg). Therefore there was no added value in analysing the trends for separate plants again for the period 2000-2013.

[2] Both samples were also reported on the PDV site. However, the unit for both samples were probably reported incorrectly and the value should have been 0.005 mg/kg (Adamse, 2009).

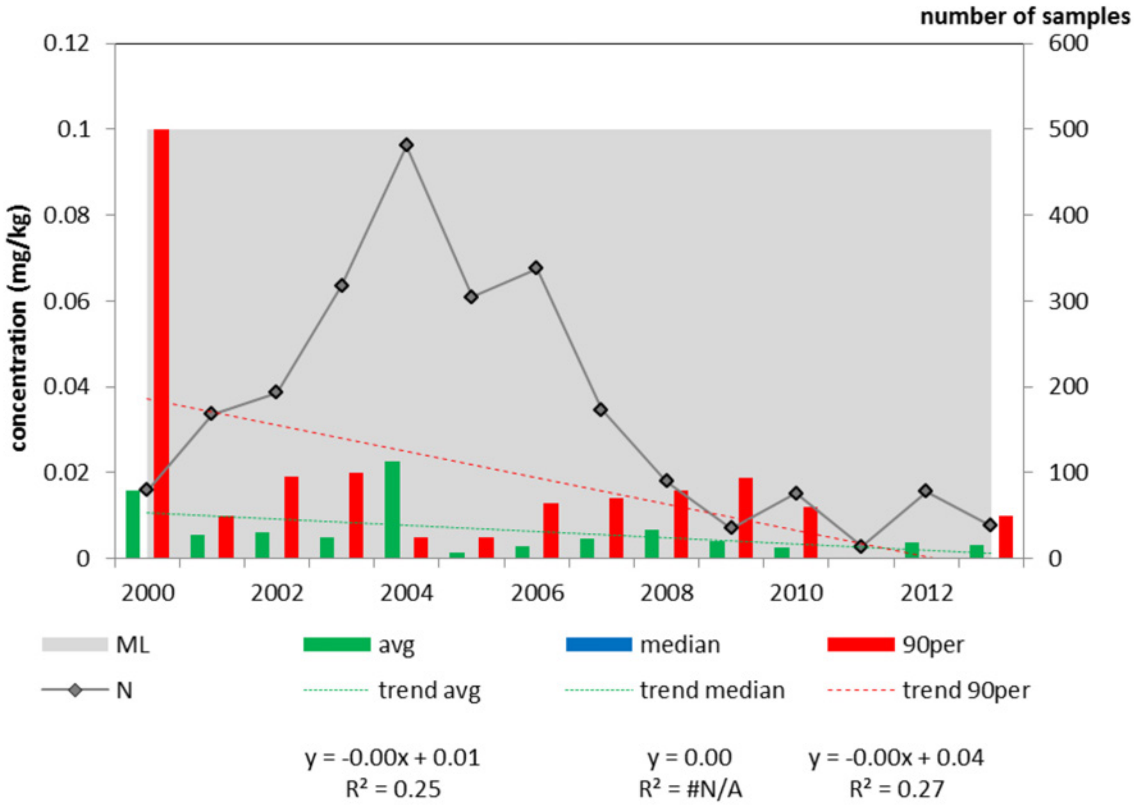

Figure 4-80 *Average, median and 90 percentile concentration of mercury in feed materials from plant origin; 2000-2013; N = 2387; ML = 0.1 mg/kg.*

The previous report stated that potato pulp fibres should be analysed for at least a few more years, especially to check the mercury levels. In 2000 and 2001 relatively high levels of mercury were detected (just below the ML) (Figure 4-3). However, in the period 2007-2013 only 71 samples were analysed, most of them (43) in 2010. The mercury concentration was below the LOQ in 64 samples and around 0.02 or 0.03 mg/kg in the other 7 samples.

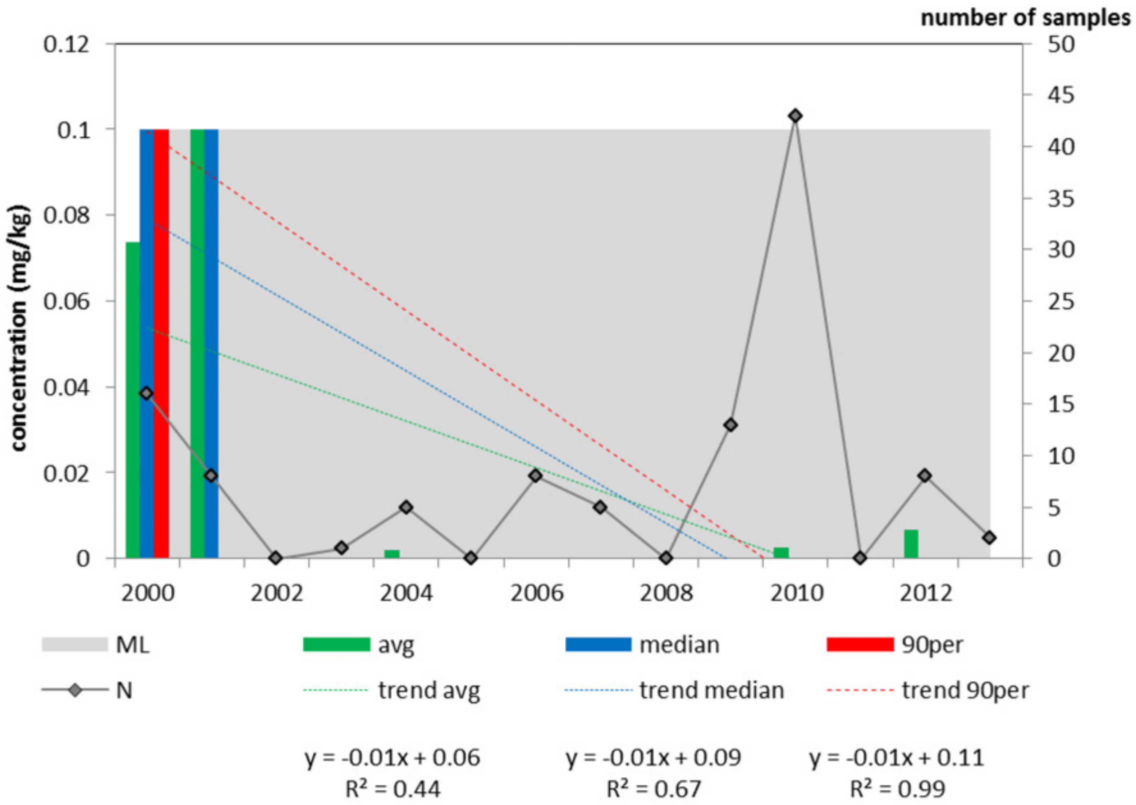

Figure 4-81 *Average, median and 90 percentile concentration of mercury in potato products; 2000-2013; N = 109; ML = 0.1 mg/kg.*

Fish, other aquatic animals and products derived thereof.

Table Sup4-45 *RASFF alerts and notifications related to mercury in fish, other aquatic animals and products derived thereof.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
fish meal	3	0.73	1.14	0.5
shark cartilage powder	1	0.87	0.87	0.5

(More details in Table Sup5-4).

RASFF includes 4 notifications related to mercury in fish, other aquatic animals and products derived thereof (Table Sup4-5). The notifications were not reported by the Netherlands. The products originate from Spain (2 samples of fish meal), Guatemala (fish meal) and New Zealand (shark cartilage powder) and the mercury concentrations were well above the ML. In the current study no samples of fish and other aquatic animals exceeded the ML.

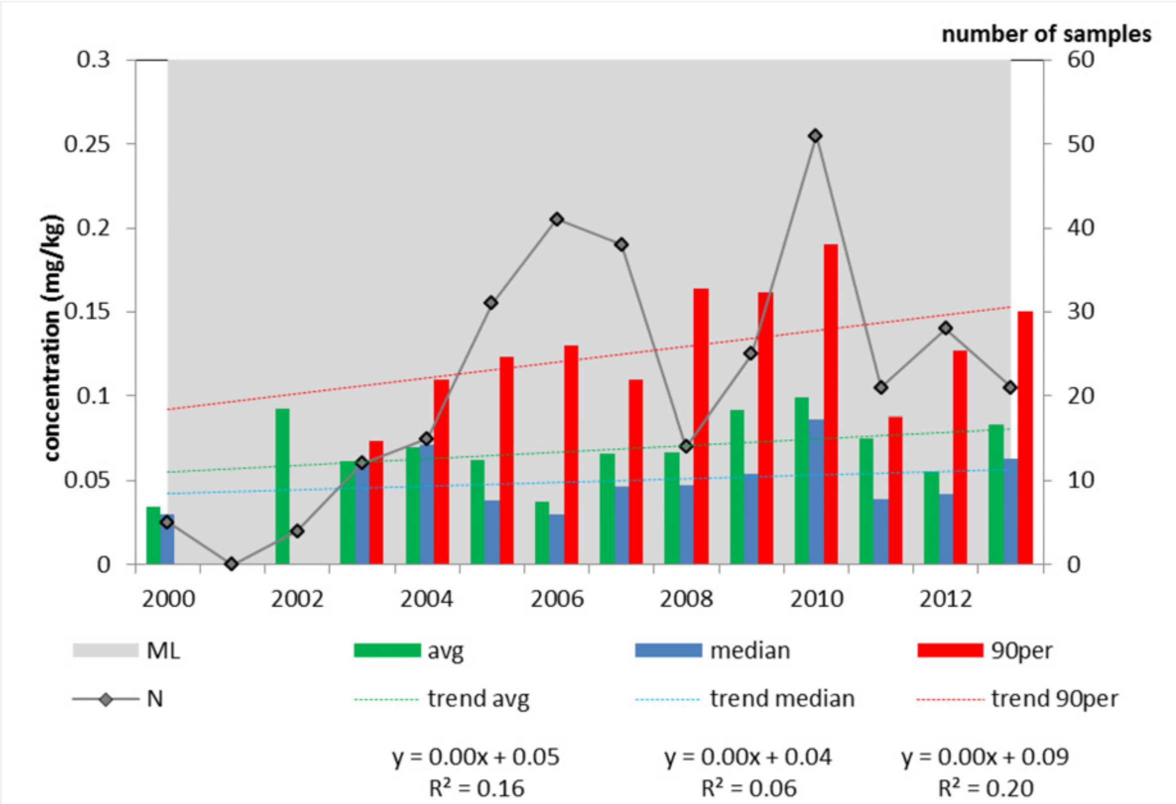

Figure 4-82 *Average, median and 90 percentile concentration of mercury in fish, other aquatic animals and products derived thereof; 2000-2013; N = 306; ML = 0.5 mg/kg.*

The largest part of the category "fish, other aquatic animals and products derived thereof" consists of fish meal. In the 2009 report a decrease of the average mercury concentration was observed after 2003.

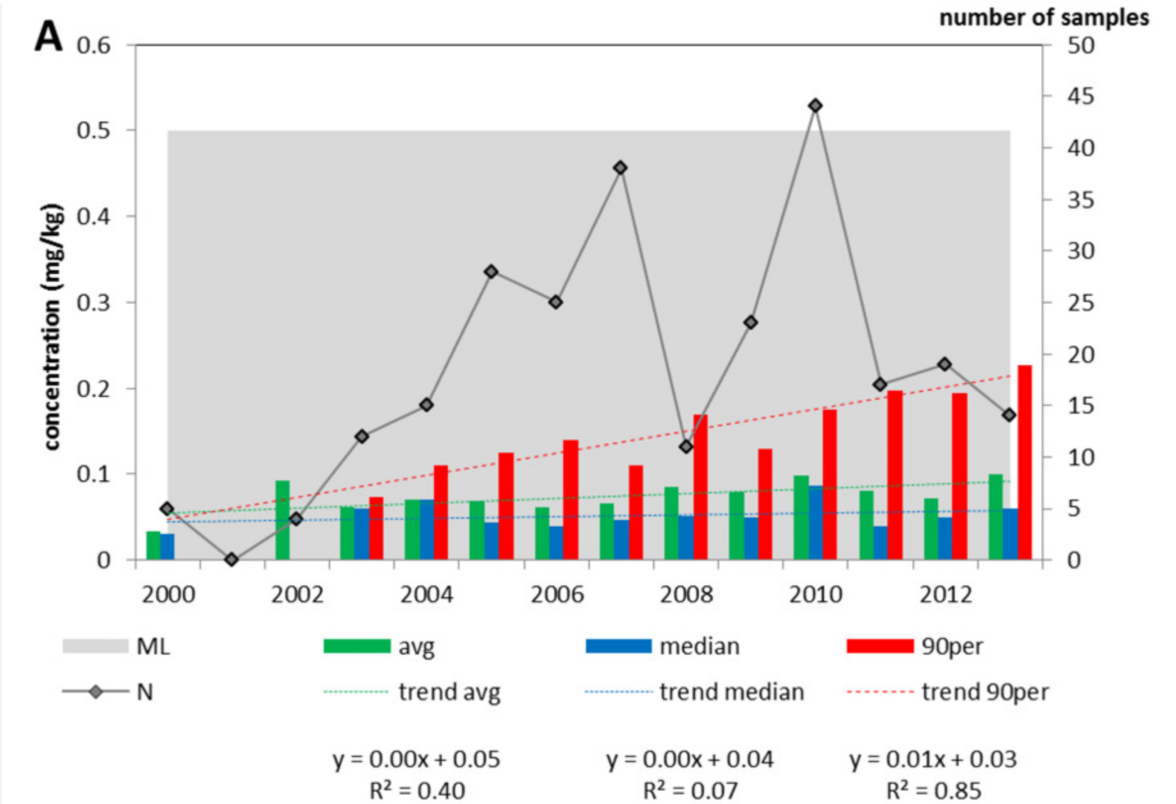

Figure 4-83 *Average, median and 90 percentile concentration of mercury in fish meal; 2000-2013; N = 255; ML = 0.5 mg/kg.*

Most fish meal in this report originates from unknown countries (89 samples) and Peru (61 samples). The highest concentrations reported were 0.49 and 0.41 mg/kg from Spain and 0.47 from France. Those concentrations were close to the ML of 0.5 mg/kg. RASFF also reports about two samples of fish meal from Spain with high levels (Table Sup4-5). However, those samples were from 2013 whereas the samples with high mercury content from the current dataset were from 2010 and 2011.

The highest individual concentration reported in the samples from Peru (Figure 4-6) was 0.22 mg/kg (in 2010), well below the ML of 0.5 mg/kg. Other countries where fish meal in this monitoring dataset originates from were Denmark (33 samples), EU[3] (21 samples), Germany (14 samples), Norway (9 samples) and several other countries with only one or two samples. The average mercury concentration in the samples from Denmark (Figure 4-7) and Norway (data not shown) decreased significantly. The average concentrations in the samples originating from EU[4] increased significantly (Figure 4-8). This, together with the samples from Spain and France, contributed to the increase of the mercury concentrations in fish meal of all countries of origin (Figure 4-5). Another 18 samples were reported with the Netherlands as country of origin. This was most likely not correct and should be considered of unknown origin.

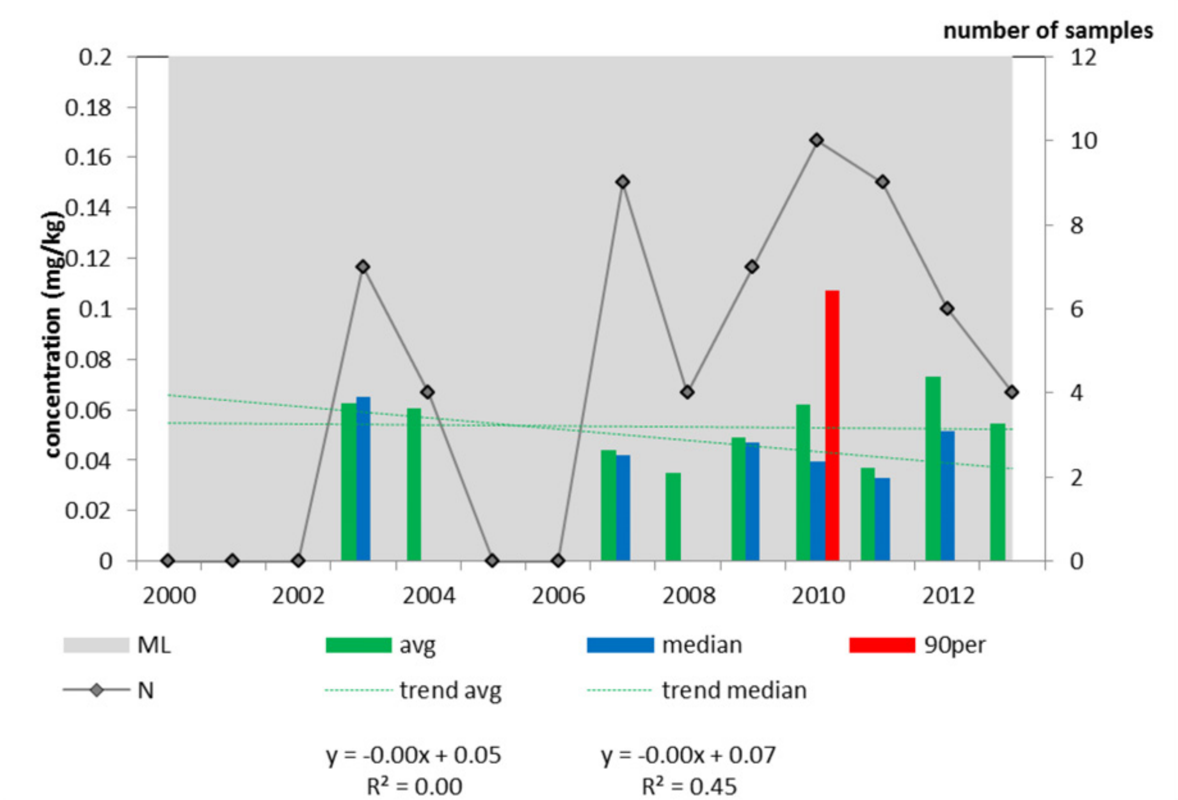

Figure 4-84 *Average, median and 90 percentile concentration of mercury in fish meal originating from Peru; 2000-2013; N = 60; ML = 0.5 mg/kg.*

3 Specified as EU, not a collection of several EU countries.
4 Specified as EU, not a collection of several EU countries.

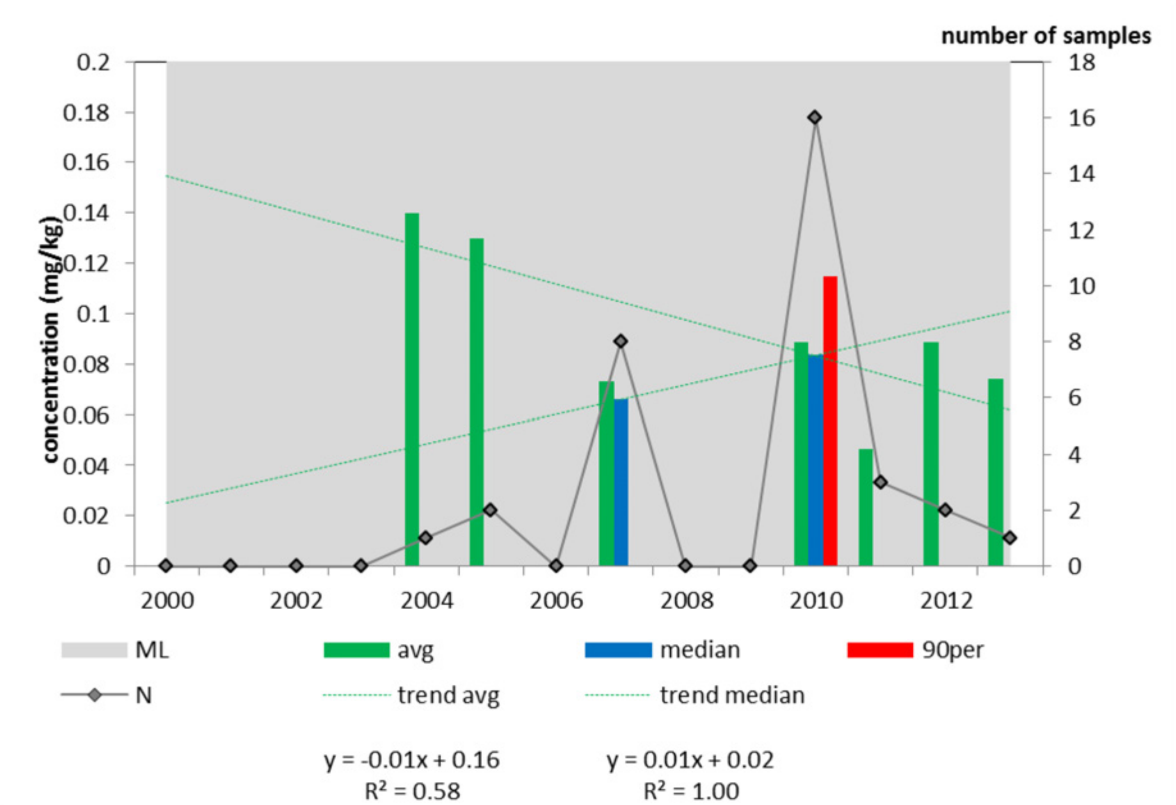

Figure 4-85 *Average, median and 90 percentile concentration of mercury in fish meal originating from Denmark; 2000-2013; N = 33; ML = 0.5 mg/kg.*

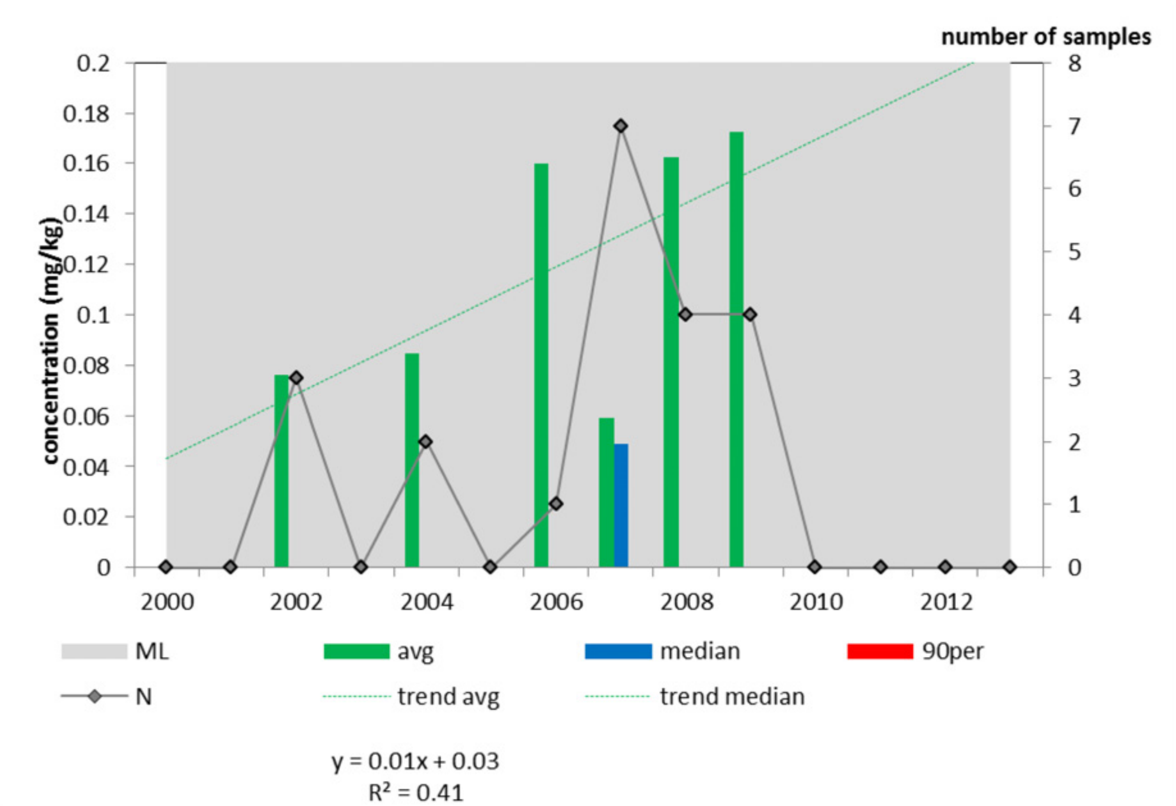

Figure 4-86 *Average, median and 90 percentile concentration of mercury in fish meal originating from EU[5]; 2000-2013; N = 21; ML = 0.5 mg/kg.*

5 Specified as EU, not a collection of several EU countries.

Calcium carbonate, calcium and magnesium carbonate.
RASFF does not report incidents regarding calcium carbonate, calcium and magnesium carbonate. In the current dataset, no samples were available before 2003 (Figure 4-9). Between 2003 and 2013 there were no samples that exceed the ML for mercury.

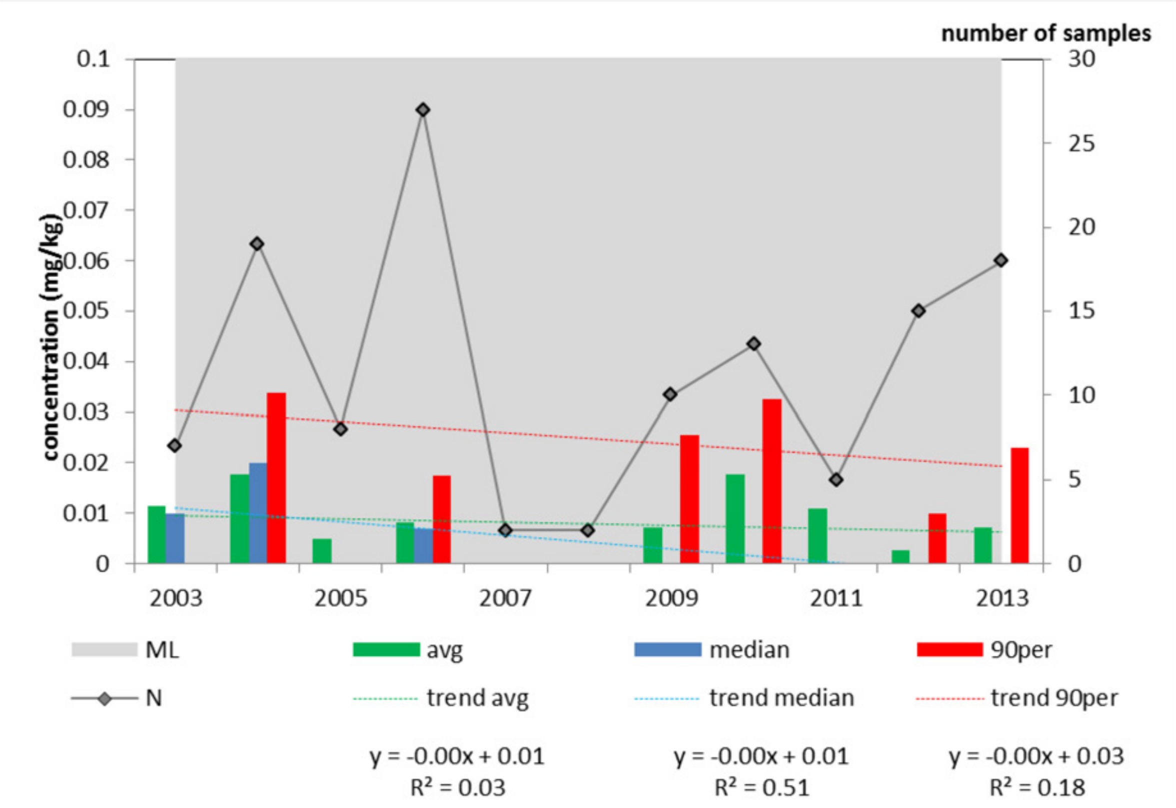

Figure 4-87 *Average, median and 90 percentile concentration of mercury in calcium carbonate, calcium and magnesium carbonate; 2003-2013; N = 126; ML = 0.3 mg/kg.*

Compound feed (excl. mineral feed, compound feed for fish, dogs, cats and fur animals)
RASFF reported about two incidents regarding compound feed (Table Sup4-6), one about complete feed without a specific target animal defined, one about compound feed for pigs. The notifications do not relate to the Netherlands. In the Dutch dataset from this report there were similar samples with a mercury concentration exceeding the ML: in 2001 complementary bovine feed (1.2 mg/kg), in 2004 artificial milk feed (0.16 mg/kg), in 2006 start feed pigs for slaughter (0.12 mg/kg) and in 2010 complete feed, general (0.37 mg/kg). There were no significant trends (Figure 4-10).

Table Sup4-46 *RASFF alerts and notifications related to mercury in compound feed (excl. mineral feed, compound feed for fish, dogs, cats and fur animals).*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
complete feed, general	1	0.24	0.24	0.1
pig feed, complete	1	0.22	0.22	0.1

(More details in Table Sup5-4).

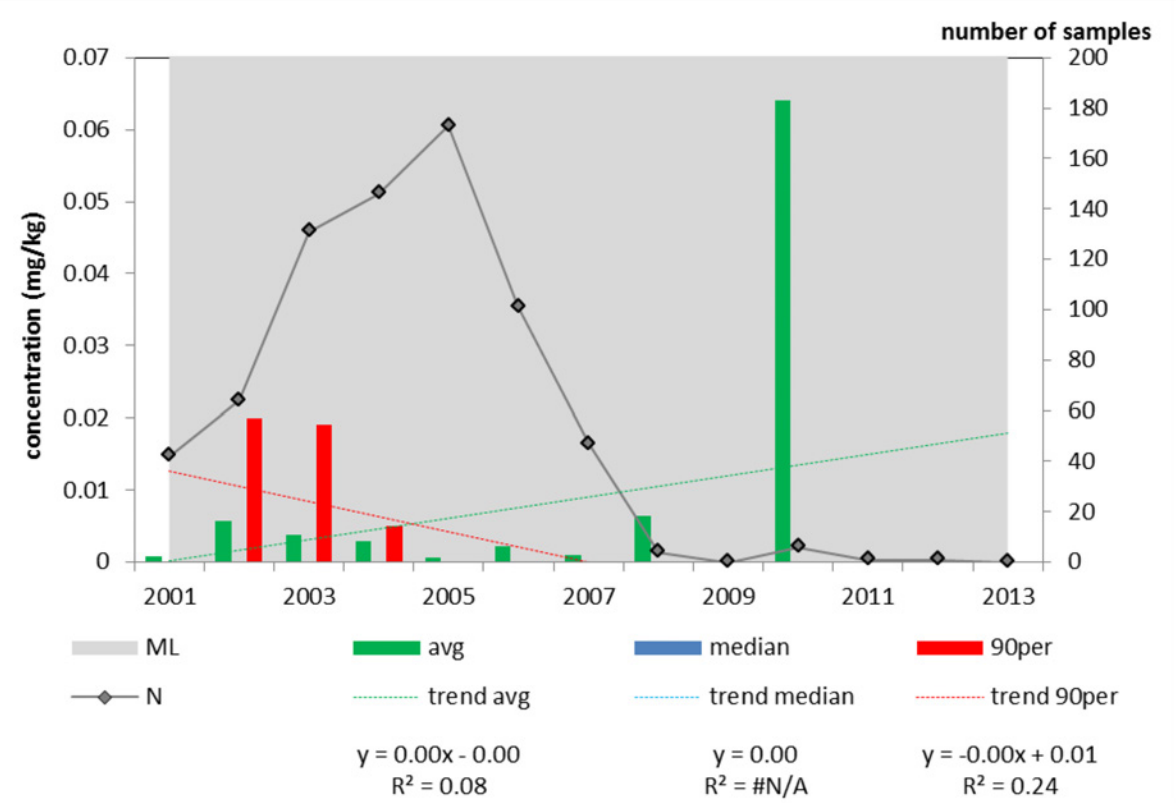

Figure 4-88 *Average, median and 90 percentile concentration of mercury in compound feed (excl. mineral feed, compound feed for fish, dogs, cats and fur animals); 2000-2013; N = 716; ML = 0.1 mg/kg.*

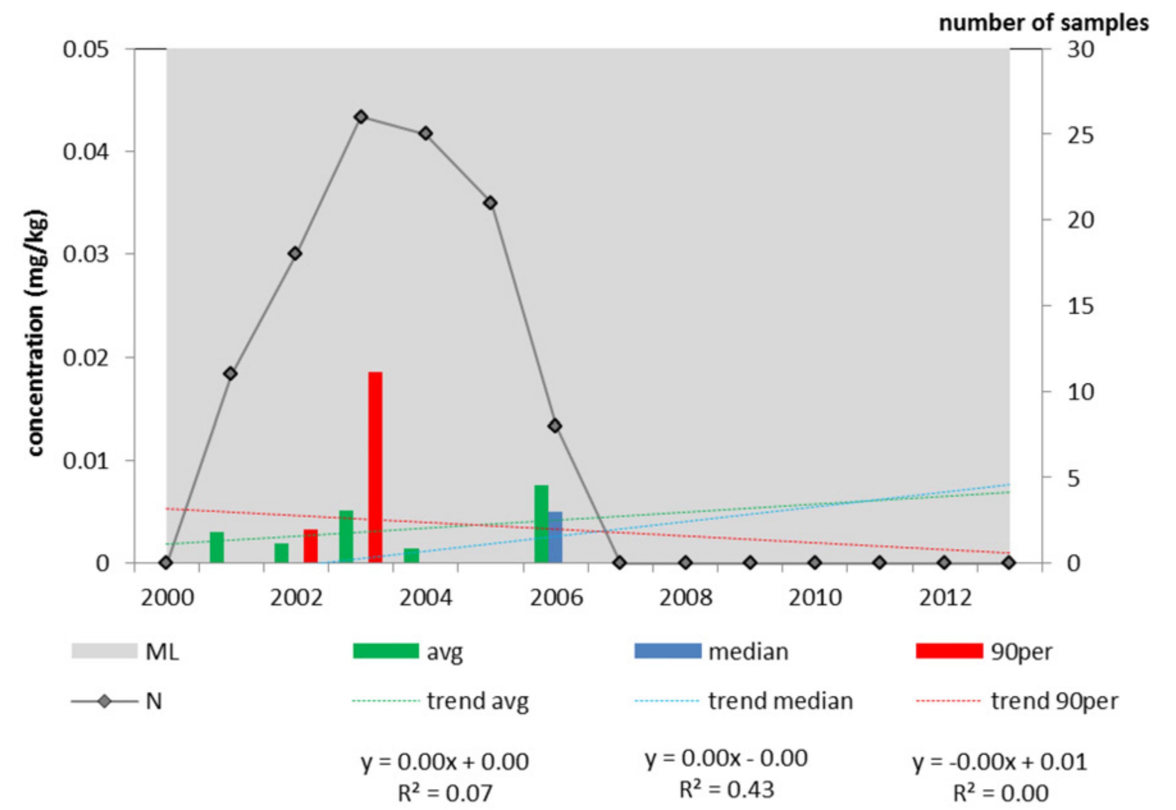

Figure 4-89 *Average, median and 90 percentile concentration of mercury in complementary bovine feed; 2000-2013; N = 109; ML = 0.1 mg/kg.*

In compound feed for pigs the mercury concentrations were low, except one sample (startfeed pigs for slaughter, 0.12 mg/kg) in 2006 where the concentration exceeds the ML (Figure 4-12).

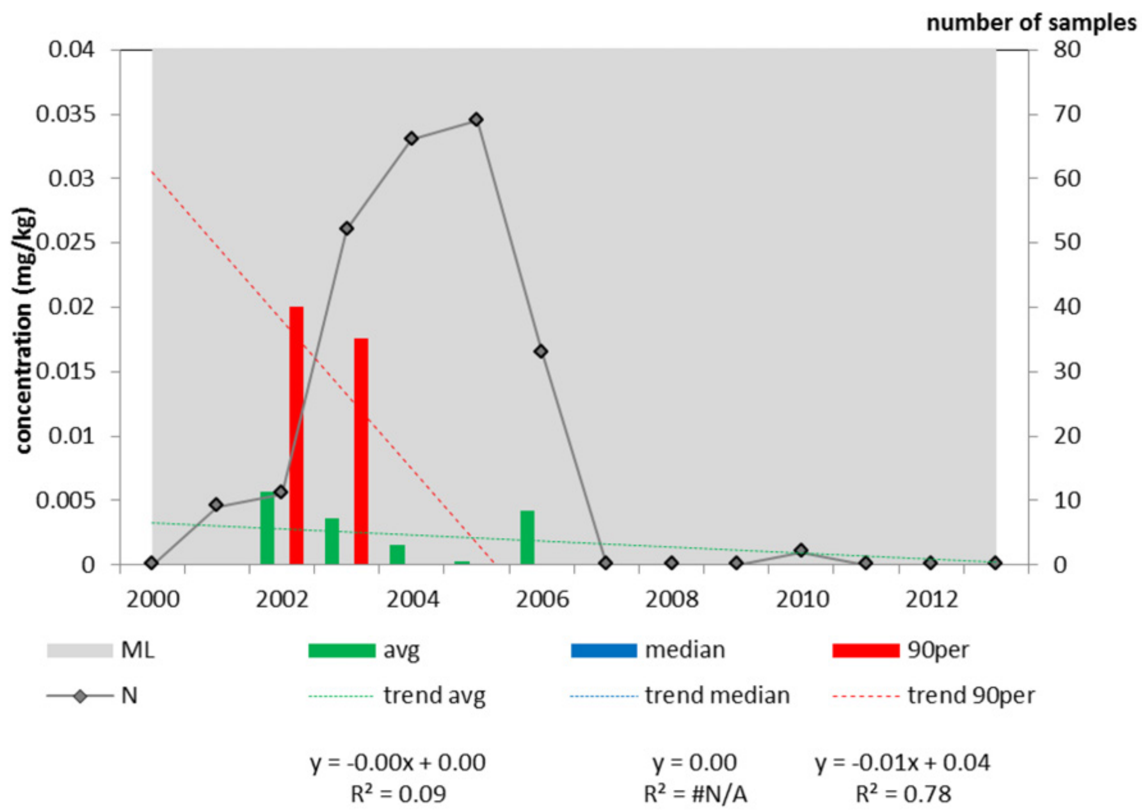

Figure 4-90 *Average, median and 90 percentile concentration of mercury in compound feed for pigs; 2000-2013; N = 242; ML = 0.1 mg/kg.*

In compound feed for poultry the mercury concentrations were low (Figure 4-13).

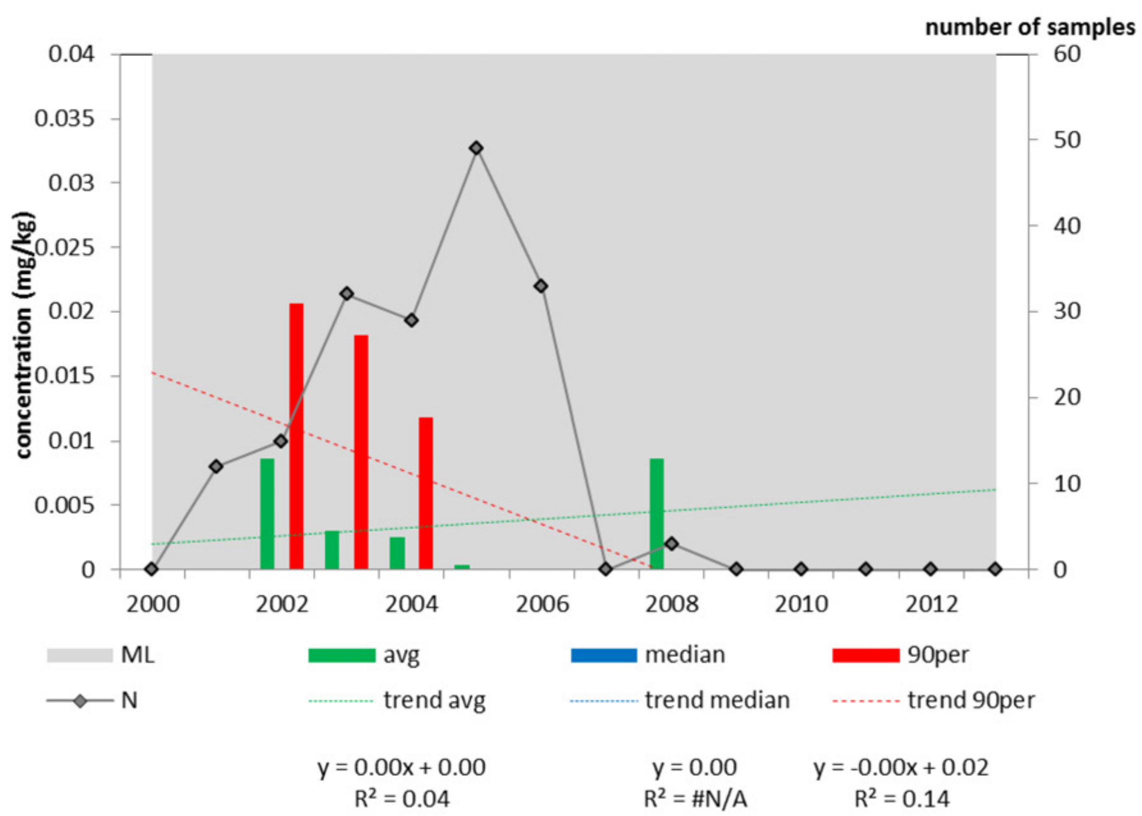

Figure 4-91 *Average, median and 90 percentile concentration of mercury in compound feed for poultry; 2000-2013; N = 173; ML = 0.1 mg/kg.*

Mineral feed

RASFF contains one notification regarding mercury in mineral feed: mineral mix for poultry in 2013 with 0.34 mg/kg mercury (Table Sup4-7). This feed originated from Germany and was reported by the Czech Republic in 2013. This sample exceeded the MRL of 0.2 mg/kg. In the current dataset one of the samples taken between 2000 and 2013 exceeded the ML (mineral mix for bovines in 2001, 1.2 mg/kg). The average concentration remained well below the ML and decreased significantly between 2000 and 2013.

Table Sup4-47 *RASFF alerts and notifications related to mercury in mineral feed.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
mineral mix, poultry	1	0.34	0.34	0.2

(More details in Table Sup5-4).

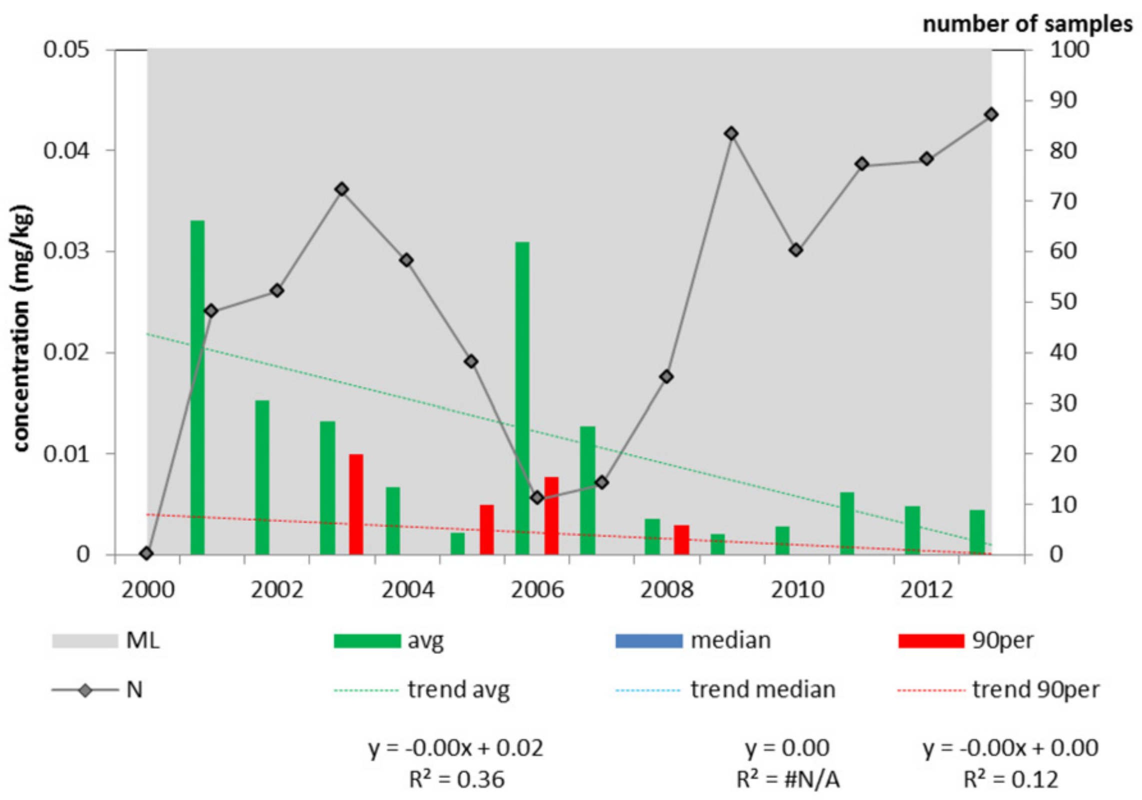

Figure 4-92 *Average, median and 90 percentile concentration of mercury in mineral feed; 2000-2013; N = 713; ML = 0.2 mg/kg.*

Compound feed for fish

RASFF reported one incident concerning fish feed: shrimp feed from Belgium notified by Belgium in 2012 containing a mercury concentration twice the value of the ML (Table Sup4-8). In the current dataset only two samples of fish feed have been reported, in 2003 and 2005, 0.087 and 0.012 mg/kg respectively. Both below the ML. It was not possible to perform a trend analysis.

Table Sup4-48 *RASFF alerts and notifications related to mercury in compound feed for fish.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
shrimp feed	1	0.21	0.21	0.1

(More details in Table Sup5-4).

Compound feed for dogs, cats and fur animals

RASFF reported four incidents concerning pet food (Table Sup4-9), all related to feed from Thailand reported in 2012 by Italy and Germany. In the current dataset only 60 samples were analysed. Most of them (50) in 2013 (Figure 4-15). Fifty percent of the samples concerned cat feed, 32 samples, all from 2013. It was quite likely that the sudden increase in the number of samples taken in 2013 was triggered by the RASFF alerts. Only three samples of cat feed contained mercury levels above the LOQ (0.19, 0.067 and 0.022 mg/kg), none of them exceeded the ML of 0.3 mg/ml. However, one sample of pet food (without target animal specified) from 2013 did exceed the ML with a mercury concentration of 0.46 mg/ml. Due to the low number of samples it was not possible to perform a relevant trend analysis.

Table Sup4-49 *RASFF alerts and notifications related to mercury in compound feed for dogs, cats and fur animals.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
cat feed	3	0.43	2.11	0.3
pet food	1	0.43	0.43	0.3

(More details in Table Sup5-4).

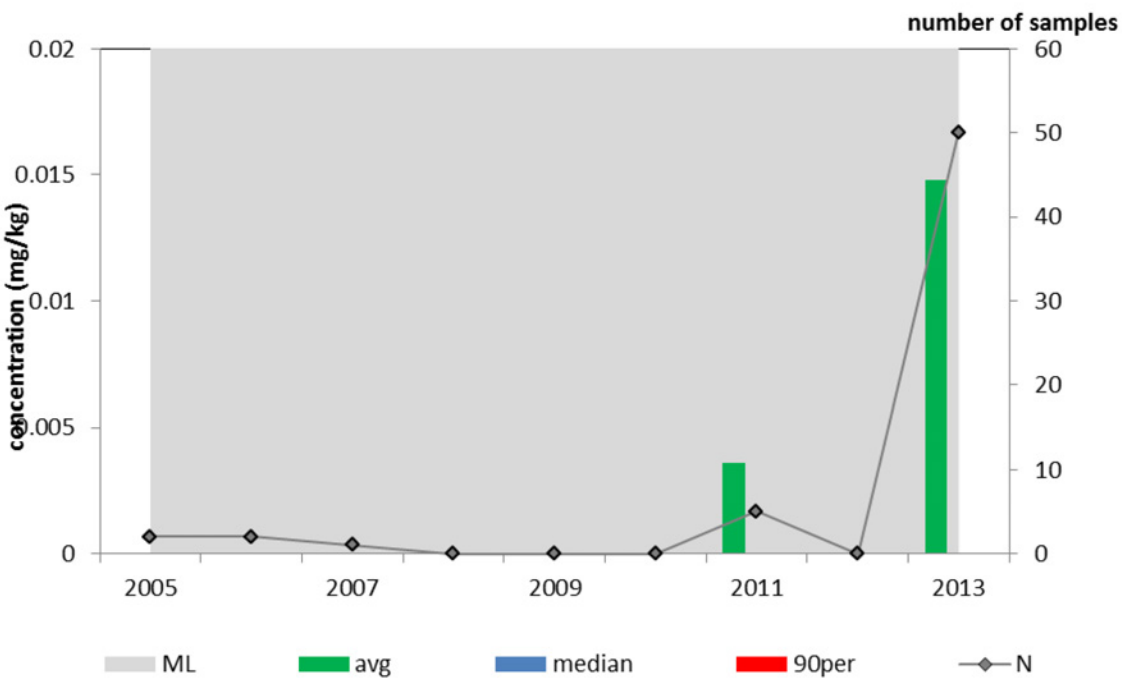

Figure 4-93 *Average, median and 90 percentile concentration of mercury in compound feed for dogs, cats and fur animals; 2000-2013; N = 60; ML = 0.3 mg/kg.*

Feed additives

RASFF shows one notification regarding feed additives, 0.38 mg/kg mercury in vitamin preparation from India, reported by the United Kingdom in 2011 (Table Sup4-10). In the current study only 30 samples from feed additives belonging to the category vitamins and pro-vitamins were present in the dataset, all below the LOQ. Because there was no maximum level defined for mercury in feed additives it was not possible to calculate the number of incidences (N > ML).

Table Sup4-50 *RASFF alerts and notifications related to mercury in feed additives.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
vitamin	1	0.38	0.38	-

(More details in Table Sup5-4).

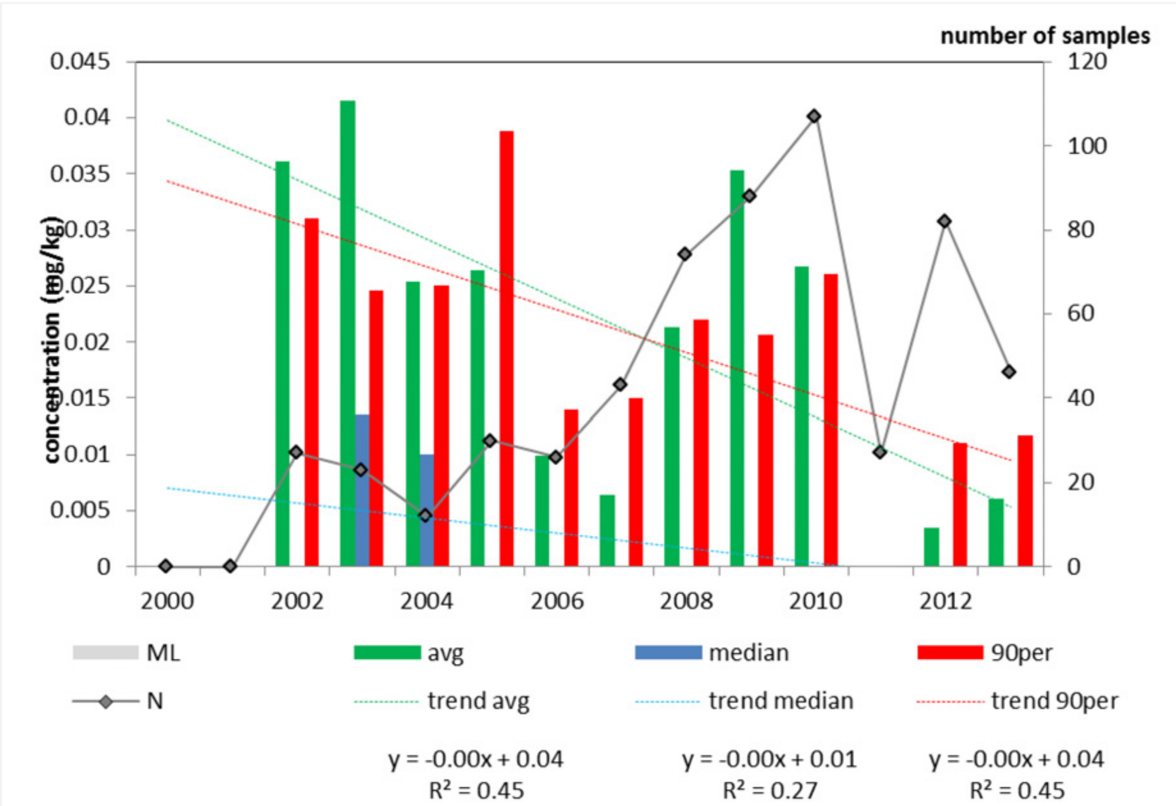

Figure 4-94 *Average, median and 90 percentile concentration of mercury in feed additives; 2000-2013; N = 585; no ML*

The largest group of products belonging to the category feed additives were the feed additives belonging to the functional group of binders and anti-caking agents, i.e. clay minerals like bentonite, kaolinite and sepiolite.

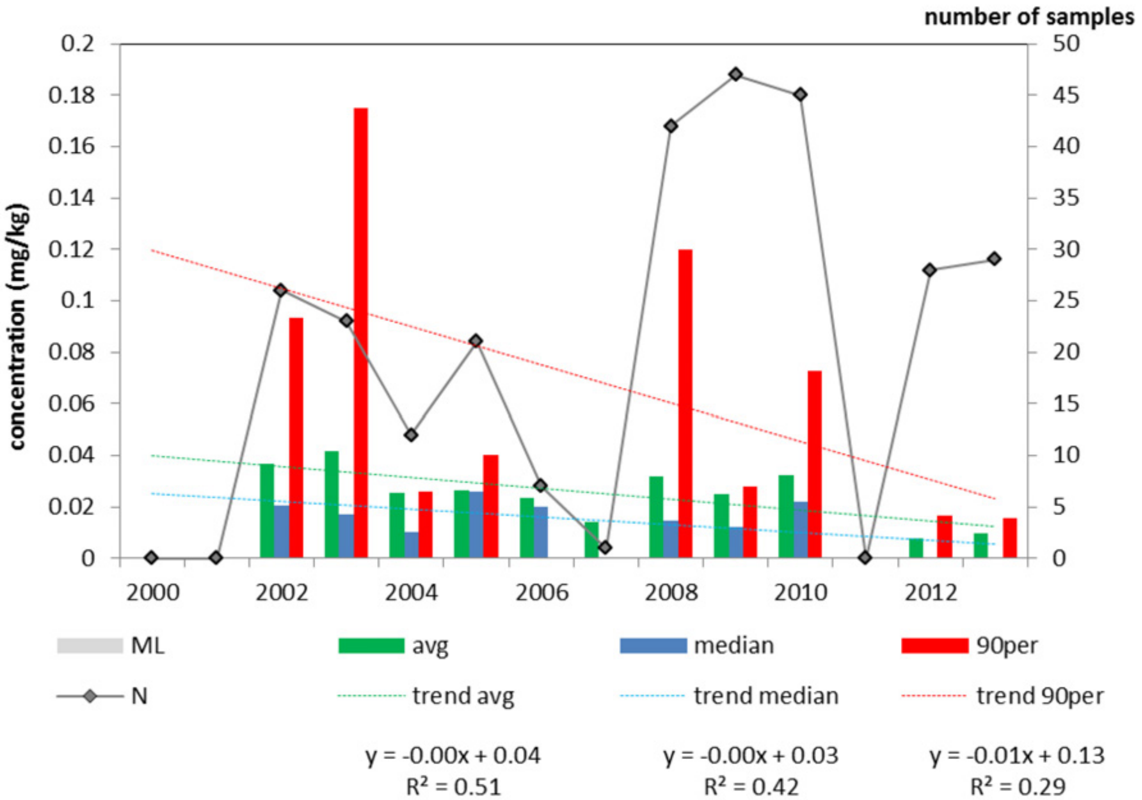

Figure 4-95 *Average, median and 90 percentile concentration of mercury in clay minerals; 2000-2013; N = 281; no ML.*

More than forty percent of the samples from clay minerals were samples of sepiolite (118 of 281) (Figure 4-18). The number of samples per year varied considerably. The average mercury concentration in kaolinite increased significantly (Figure 4-19). However, the number of samples taken per year was quite low and after 2010 no kaolinite samples were present in the dataset. This makes a trend unreliable.

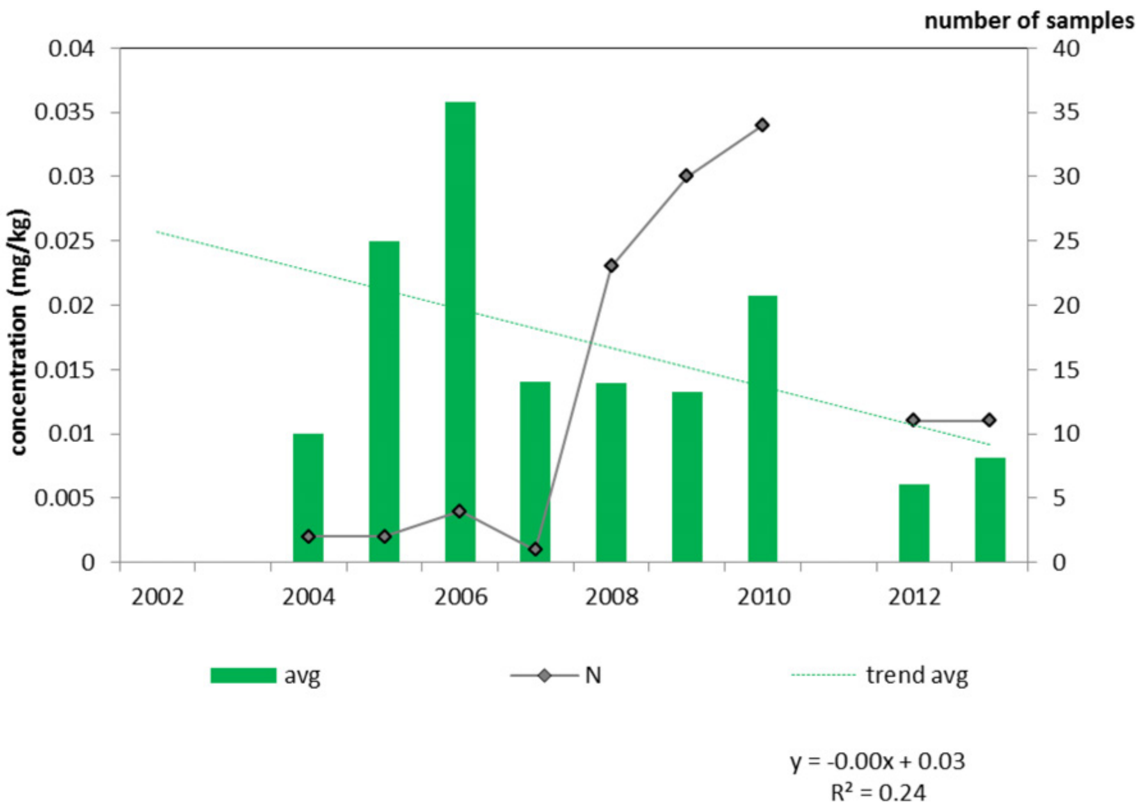

Figure 4-96 *Average, median and 90 percentile concentration of mercury in sepiolite; 2000-2013; N = 118; no ML.*

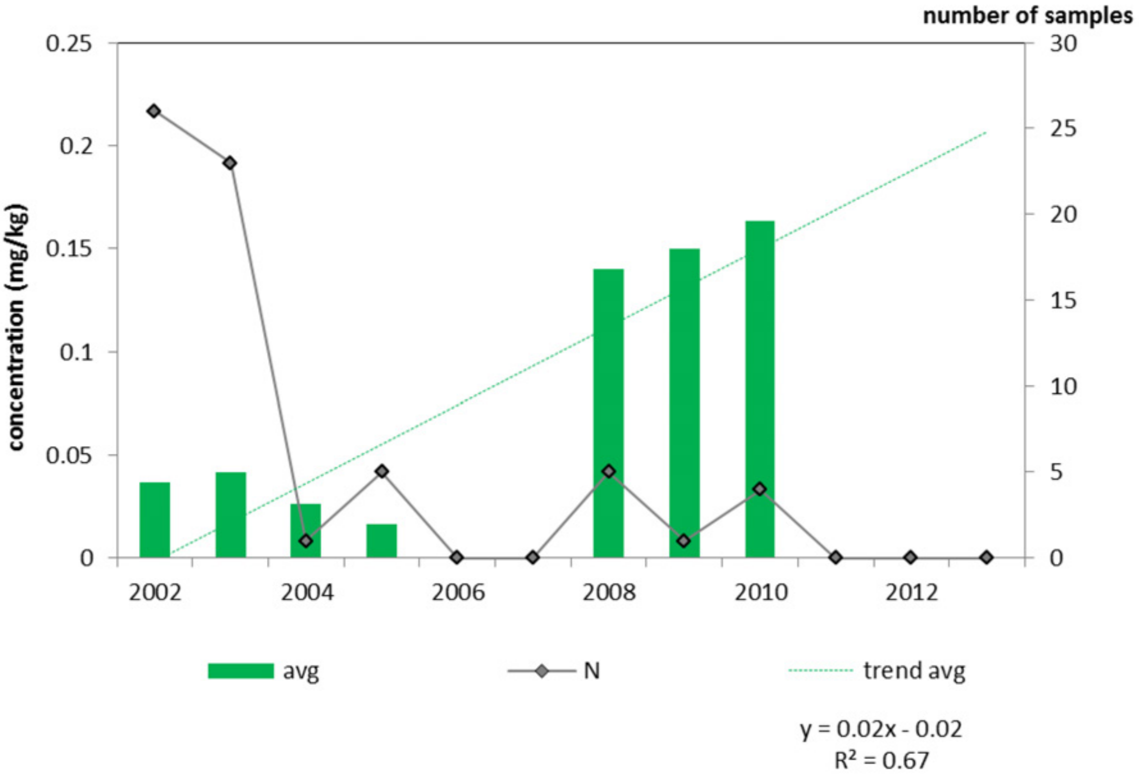

Figure 4-97 *Average, median and 90 percentile concentration of mercury in kaolinite; 2000-2013; N = 65; no ML.*

Another group of products belonging to the category feed additives were the feed additives belonging to the functional groups of trace elements. This group consists of samples from copper chelate, copper mix, copper sulphate, copper supplement, iron carbonate, iron oxide, iron sulphate, iron supplement manganese, zinc acetate, zinc chelate, zinc oxide, zinc sulphate, zinc supplement (Figure 4-20). The highest concentrations reported were in manganese oxide (0.53 mg/kg in 2009) and copper sulphate (0.33 mg/kg in 2010).

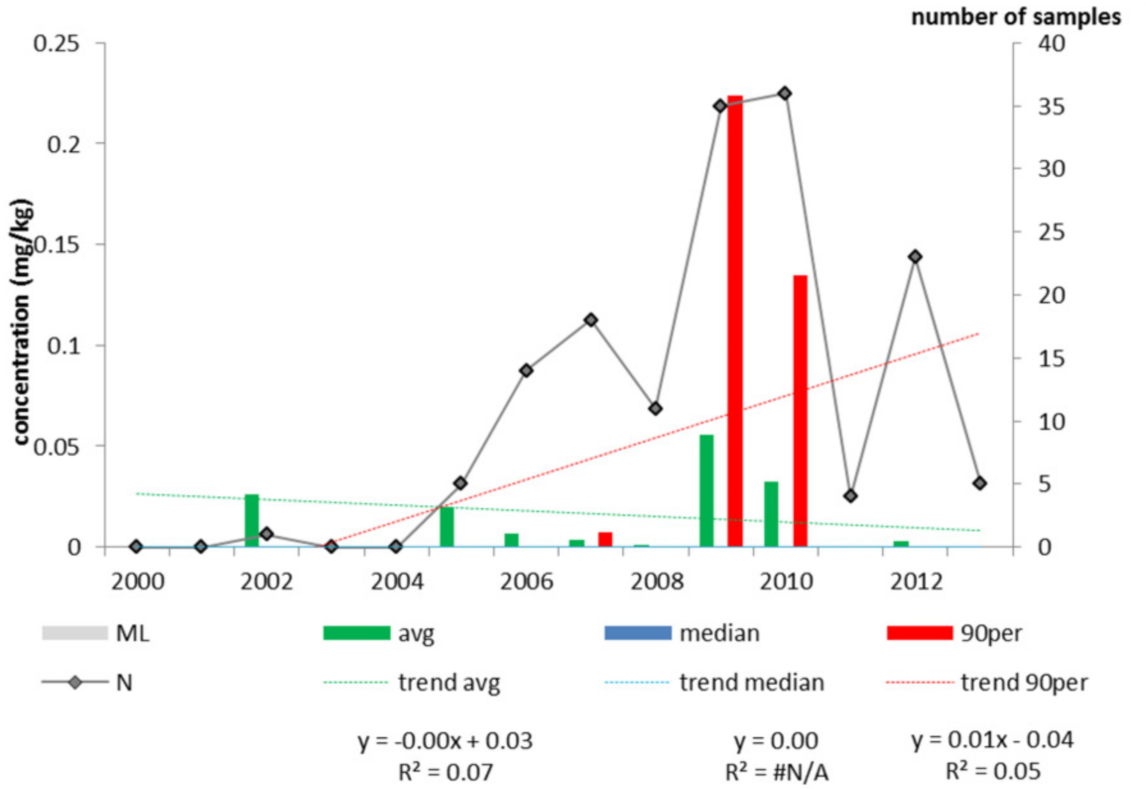

Figure 4-98 *Average, median and 90 percentile concentration of mercury in trace elements; 2000-2013; N = 152; no ML.*

Pre-mixtures

Since no ML has been set for mercury for this group no % > ML could be determined (Figure 4-21). Two relatively high concentrations in 2006 (0.82 and 0.57 mg/kg) caused a high 90 percentile concentration in that year, but the individual (not shown) or average mercury concentrations in the entire period studied did not exceed 1 mg/kg, much lower than the concentration reported in the RASFF notification (Table Sup4-11).

Table Sup4-51 *RASFF alerts and notifications related to mercury in pre-mixtures.*

Product	Number of notifications	Reported min. concentration (mg/kg)	Reported max. concentration (mg/kg)	Legal max. concentration (mg/kg)
premix	1	17.8	17.8	-

(More details in Table Sup5-4).

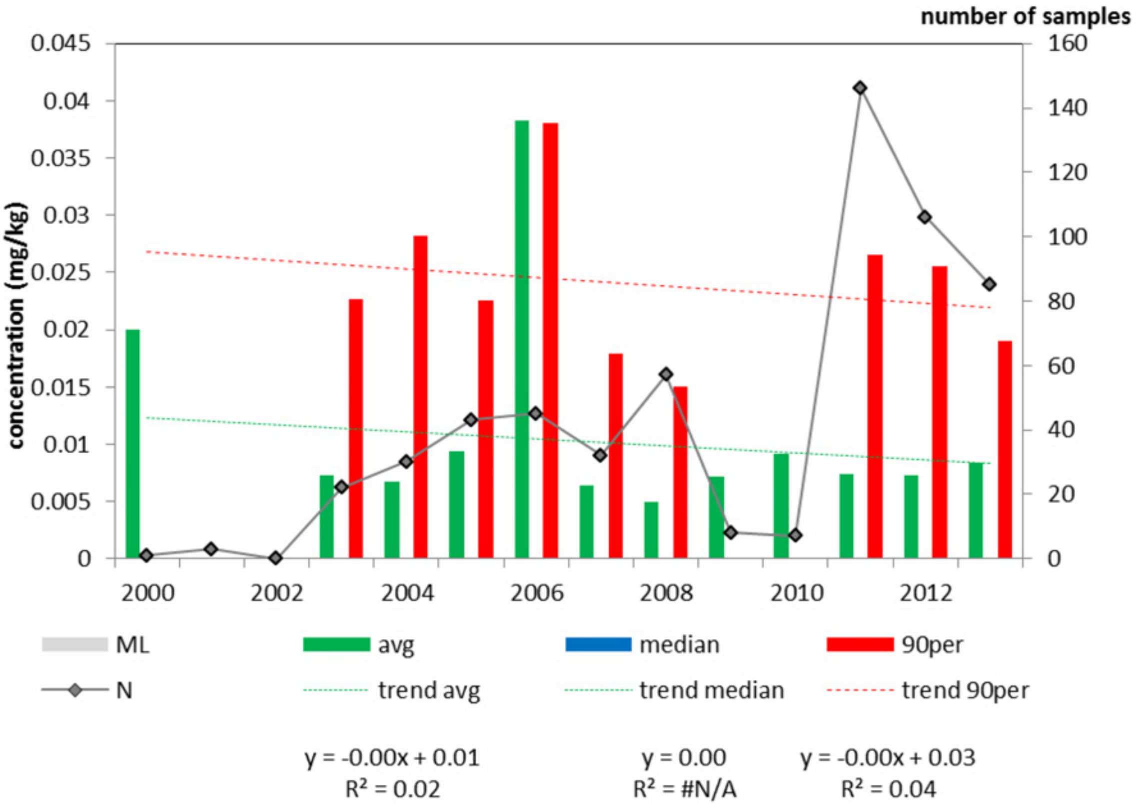

Figure 4-99 *Average, median and 90 percentile concentration of mercury in pre-mixtures; 2000-2013; N = 585; no ML.*

Annex 5 Supplemental information RASFF notifications

RASFF notifications arsenic

Table Sup5-52 *RASFF notifications arsenic.*

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
complementary feed	feed horse, complementary	2006.0206	alert	Germany	Austria	6.7	mg/kg	4	arsenic (6.7 mg/kg - ppm) in complementary feed for horses from Germany
complementary feed	feed horse, complementary	2005.AJZ	information	France	Germany	8.7	mg/kg	4	arsenic (8.7 mg/kg - ppm) and lead (52.0 mg/kg - ppm) in complementary feed for horses from France
complementary feed	pig feed, general, complementary	2013.0037	alert	Austria	Austria	12.4	mg/kg	4	arsenic (12.4 mg/kg - ppm) in peat for piglets from Austria
complete feed[6]	cat feed, complete	2011.1419	alert	Thailand	Italy	7	mg/kg	2	arsenic (7.0 mg/kg - ppm) in tuna with rice feed for cats from Thailand
complete feed[4]	cat feed, complete	2012.AOQ	border rejection	Thailand	Italy	6.03	mg/kg	2	arsenic (6.03 mg/kg - ppm) in canned cat food from Thailand
complete feed[4]	cat feed, complete	2011.COJ	border rejection	Thailand	Italy	6.7	mg/kg	2	arsenic (6.7 mg/kg - ppm) in feed for cats from Thailand
complete feed[4]	cat feed, complete	2012.BQN	border rejection	Thailand	Germany	7.1	mg/kg	2	arsenic (7.1 mg/kg - ppm) in canned cat food from Thailand
complete feed[4]	cat feed, complete	2012.0146	information for attention	Thailand	Italy	5.79	mg/kg	2	arsenic (5.79 mg/kg - ppm) in feed for cats from Thailand

[6] Possibly containing fish, other aquatic animals and products derived thereof and/or seaweed meal and feed materials derived from seaweed. This was not always clear from the description.

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
complete feed[4]	dog food	2012.BCY	border rejection	Thailand	France	7.138	mg/kg	2	arsenic (7.138 mg/kg - ppm) in canned feed for dog or cat from Thailand
complete feed[4]	dog food	2011.COK	border rejection	Thailand	Italy	8.5	mg/kg	2	arsenic (8.5 mg/kg - ppm) in feed for dogs from Thailand
complete feed[4]	petfood	2012.BIX	border rejection	Thailand	United Kingdom	7	mg/kg	2	arsenic (7.0 mg/kg - ppm) in canned feed from Thailand
complete feed[4]	petfood	2012.BMP	border rejection	Thailand	Italy	7	mg/kg	2	arsenic (7.0 mg/kg - ppm) in fish for animal nutrition from Thailand
complete feed[4]	petfood	2011.COO	border rejection	Thailand	Italy	11	mg/kg	2	arsenic (11 mg/kg - ppm) in pet food from Thailand
complete feed[4]	petfood	2012.BDA	border rejection	Vietnam	France	7.401	mg/kg	2	arsenic (7.401 mg/kg - ppm) in canned pet food from Vietnam
complete feed[4]	petfood	2011.1731	information for attention	Thailand	Italy	7.6	mg/kg	2	arsenic (7.6 mg/kg - ppm) in rice with tuna from Thailand
complete feed for fish and fur animals	fish feed	2003.202	alert	Denmark	Germany	6.9	mg/kg	10	arsenic (6.9 mg/kg - ppm) in complete feed for fish (production animals)
complete feed for fish and fur animals	shrimp feed	2011.0408	information for attention	Belgium	Belgium	7.4	mg/kg	10	arsenic (7.4 mg/kg - ppm) in shrimp feed from Belgium
complete feed for fish and fur animals	shrimp feed	2012.1410	information for attention	Belgium	Belgium	11	mg/kg	10	arsenic (11 mg/kg - ppm) and mercury (0.21 mg/kg - ppm) in complementary feed for shrimp from Belgium
cupric sulphate pentahydrate; cupric carbonate; di copper chloride trihydroxide; ferrous carbonate	copper sulphate	2012.0219	information for follow-up	Poland	Belgium	52; 54; 73	mg/kg	50	arsenic (52; 54; 73 mg/kg - ppm) in copper sulphate from Poland
cupric sulphate pentahydrate; cupric carbonate; di copper chloride trihydroxide; ferrous carbonate	copper sulphate	2011.0488	information for follow-up	Poland	Belgium	126	mg/kg	50	arsenic (126 mg/kg - ppm) in copper sulphate from Poland

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
feed materials	apple, dried	2011.1811	alert	Poland	Austria	23.2	mg/kg	2	arsenic (23.2 mg/kg - ppm) in dried apple pomace from Poland
feed materials	apple, dried	2011.1812	alert	Poland	Austria	24	mg/kg	2	arsenic (24 mg/kg - ppm) in dried apple pomace from Poland
feed materials	sunflower seed feed meal	2012.1770	information for follow-up	Spain	Spain	1.78-23.7	mg/kg	2	arsenic (1.78-23.7 mg/kg - ppm) and lead (1.5-43.45 mg/kg - ppm) in sunflower meal from Spain
feed materials	yeast	2011.1296	alert	Brazil	Germany	23.1	mg/kg	2	arsenic (23.1 mg/kg - ppm) in yeasts for feed use (Saccharomyces Cerevisiae) from Brazil
feed materials	yeast	2011.1639	information for follow-up	Brazil	Belgium	3.2	mg/kg	2	arsenic (3.2 mg/kg - ppm) in yeasts for feed use from Belgium, with raw material from Brazil
fish, other aquatic animals and products derived thereof	fish meal	2012.AZM	border rejection	Vietnam	France	7.054	mg/kg	25	arsenic (7.054 mg/kg - ppm) in fishmeal from Vietnam
fish, other aquatic animals and products derived thereof	mussel grist	2002.344	alert	Netherlands	Germany	24	mg/kg	25	arsenic (24 mg/kg - ppm) in Single feed - mussel grist
fish, other aquatic animals and products derived thereof	oyster shells	2009.1007	information	Netherlands	Belgium	22	mg/kg	25	arsenic (22 mg/kg - ppm) in oyster shells from the Netherlands
magnesium oxide; magnesium carbonate	magnesium oxide/magnesite	2003.316	alert	Spain	Germany	8.51	mg/kg	20	arsenic (8.51 mg/kg - ppm) in magnesium oxide - calcined magnesite
magnesium oxide; magnesium carbonate	magnesium oxide/magnesite	2011.1624	alert	Austria	Cyprus	56.5	mg/kg	20	arsenic (56.5 mg/kg - ppm) in magnesium oxide from Austria
meal made from grass, from dried lucerne and from dried clover, and dried sugar beet pulp and dried molasses sugar beet pulp	sugar beet pulp	2009.0726	alert	Austria	United Kingdom	6	mg/kg	4	arsenic (6 mg/kg - ppm) and lead (383 mg/kg - ppm) in unmolassed sugar beet pulp pellets from Austria

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
mineral feed	mineral mix, general	2002.BJL	information	Argentina	Italy	25 above the legal limit	mg/kg	12	arsenic (25 above the legal limit mg/kg - ppm) in additives - mineral for animal feed
mineral feed	mineral mix, general	2012.1052	information for follow-up	Poland	Ireland	5.9	mg/kg	12	arsenic (5.9 mg/kg - ppm) and lead (15 mg/kg - ppm) in complementary mineral feed for cattle, sheep and goats from Poland
mineral feed	mineral mix, general	2012.0204	information for follow-up	France	Germany	18.2	mg/kg	12	arsenic (18.2 mg/kg - ppm) in mineral feed from France, via Belgium
palm kernel expeller	palm kernel expeller	2011.1057	alert	Malaysia	Netherlands	220	mg/kg	4	arsenic (220 mg/kg - ppm) in palm kernel expeller from Malaysia, via Germany
palm kernel expeller	palm kernel expeller	2011.BQE	border rejection	Malaysia	Netherlands	134	mg/kg	4	arsenic (134 mg/kg - ppm) in palm kernel expeller from Malaysia
palm kernel expeller	palm kernel expeller	2011.1376	information for follow-up	Indonesia & Malaysia	United Kingdom	41.8	mg/kg	4	arsenic (41.8 mg/kg - ppm) in palm kernel expeller from Indonesia and Malaysia
palm kernel expeller	palm kernel expeller	2011.1150	information for follow-up	Malaysia	United Kingdom	7.24; 8.08	mg/kg	4	arsenic (7.24; 8.08 mg/kg - ppm) in palm kernel expeller from Malaysia
phosphates and calcareous marine algae	dicalcium phosphate ; [calcium hydrogen orthophosphate]	2009.1375	information	China	Spain	12.9	mg/kg	10	arsenic (12.9 mg/kg - ppm) in dicalcium phosphate from China
phosphates and calcareous marine algae	monocalciumphosphate	2004.233	alert	Germany	Denmark	12	mg/kg	10	arsenic (12 mg/kg - ppm) in monocalciumphosphate
seaweed meal and feed materials derived from seaweed	algae	2012.0273	information for follow-up	France	Austria	80	mg/kg	40	arsenic (80 mg/kg - ppm) in sea algae meal from France
zinc oxide; manganous oxide; cupric oxide	manganese oxide	2012.1210	information for attention	India	Denmark	110	mg/kg	100	arsenic (110 mg/kg - ppm) in manganese oxide from India

RASFF notifications lead

Table Sup5-53 *RASFF notifications lead.*

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
complementary feed	feed horse, complementary	2005.AJZ	information	France	Germany	52	mg/kg	10	arsenic (8.7 mg/kg - ppm) and lead (52.0 mg/kg - ppm) in complementary feed for horses from France
complementary feed	pig feed, general, complementary	2003.052	alert	Spain	Italy	281,4 + 165,29	mg/kg	10	lead (281,4 + 165,29 mg/kg - ppm) in Complementary feed for pigs
complete feed	feed poultry, general	2002.BBR	information	Germany	Germany	14,95	mg/kg	5	lead (14,95 mg/kg - ppm) in Feed for fattening poultry - complete
complete feed	petfood	2013.0498	information for follow-up	United Kingdom	Netherlands	15.7	mg/kg	5	lead (15.7 mg/kg - ppm) in pet food from the Netherlands, with raw material from the United Kingdom
complete feed	pig feed, general, complete	2006.CCG	information	Spain	Spain	10	mg/kg	5	lead (10 mg/kg - ppm) in feeding stuff for pigs from Spain
feed additives belonging to the functional group of compounds of trace elements	copper sulphate	2007.0402	alert	Russia	Ireland	196	mg/kg	100	lead (196 mg/kg - ppm) in copper sulphate from the Russian Federation via the Netherlands
feed additives belonging to the functional group of compounds of trace elements	iron oxide	2010.1047	alert	France	Belgium	339	mg/kg	100	lead (339 mg/kg - ppm) in iron oxide from France, via the Netherlands
feed additives belonging to the functional groups of binders and anti-caking agents	sepiolite	2008.1484	information	Spain	Belgium	105.8	mg/kg	30	lead (105.8 mg/kg - ppm) in sepiolite from Spain

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
feed materials	bone meal	2013.0583	information for follow-up	Italy	Netherlands	46.3	mg/kg	10	lead (46.3 mg/kg - ppm) in processed animal proteins of dear (venison meal - cat. 3) from Italy
feed materials	palm kernel expeller	2013.0589	information for attention	Malaysia	Germany	15; 2.5; 1.6; 1.4; 2.0; 2.2	mg/kg	10	high content of lead (15; 2.5; 1.6; 1.4; 2.0; 2.2 mg/kg - ppm) in palm kernel expeller from Malaysia
feed materials	rice protein	2008.1065	information	Pakistan	Germany	22	mg/kg	10	lead (22 mg/kg - ppm) in single feed - rice protein from Pakistan, via Belgium
feed materials	sugar beet pulp	2009.0726	alert	Austria	United Kingdom	383	mg/kg	10	arsenic (6 mg/kg - ppm) and lead (383 mg/kg - ppm) in unmolassed sugar beet pulp pellets from Austria
feed materials	sunflower seed feed meal	2012.1770	information for follow-up	Spain	Spain	1.5-43.45	mg/kg	10	arsenic (1.78-23.7 mg/kg - ppm) and lead (1.5-43.45 mg/kg - ppm) in sunflower meal from Spain
manganous oxide, ferrous carbonate, cupric carbonate	manganese oxide	2006.0900	alert	Brazil	Austria	292	mg/kg	200	lead (292 mg/kg - ppm) in manganese(II)oxide from Brazil via Germany
mineral feed	mineral mix, general	2002.184	alert	Netherlands	Netherlands	33,4	mg/kg	15	lead (33,4 mg/kg - ppm) in Mineralsmix
mineral feed	mineral mix, general	2002.185	alert	Netherlands	Netherlands	63,9	mg/kg	15	lead (63,9 mg/kg - ppm) in Mineralsmix
mineral feed	mineral mix, general	2012.1052	information for follow-up	Poland	Ireland	15	mg/kg	15	arsenic (5.9 mg/kg - ppm) and lead (15 mg/kg - ppm) in complementary mineral feed for cattle, sheep and goats from Poland
mineral feed	mineral mix, general	2012.0144	information for follow-up	United Kingdom	Germany	306	mg/kg	15	lead (306 mg/kg - ppm) in mineral feed from the United Kingdom, via the Netherlands

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
phosphates and calcareous marine algae	dicalcium phosphate ; [calcium hydrogen orthophosphate]	2004.BKN	information	Belgium	Spain	39.5	mg/kg	15	lead (39.5 mg/kg - ppm) in dehydrated dicalcium phosphate
phosphates and calcareous marine algae	monocalciumphosphate	2011.BWK	border rejection	China	Greece	23.7	mg/kg	15	high content of lead (23.7 mg/kg - ppm) in mono-calcium phosphate from China
pre-mixtures	premix	2002.131	alert	Netherlands	Netherlands	92,5	mg/kg	200	lead (92,5 mg/kg - ppm) in Premix of Minerals
zinc oxide	zinc oxide	2004.CQP	information	Turkey	France	5739; 7451; 4279; 4201; 4031; 4993	mg/kg	400	lead (5739; 7451; 4279; 4201; 4031; 4993 mg/kg - ppm) in zinc monoxide
zinc oxide	zinc oxide	2009.1648	information	India	Austria	799	mg/kg	400	lead (799 mg/kg - ppm) in zinc oxide from India
zinc oxide	zinc oxide	2006.0870	alert	Portugal	Spain	134000	mg/kg	400	lead (134 g/kg) in zinc oxide from Portugal
zinc oxide	zinc oxide	2007.BKD	information	Turkey	Greece	571	mg/kg	400	dioxins (22.64; 020 ng/kg - ppt) and lead (571 mg/kg - ppm) in zinc oxide from Turkey

RASFF notifications cadmium

Table Sup5-54 *RASFF notifications cadmium.*

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
pre-mixtures	premix, fish	2005.AXC	information	Norway	Norway	500 to 11500	mg/kg	15	cadmium (500 to 11500 mg/kg - ppm) in mineral pre-mixture for fish from Norway
pre-mixtures	premix, poultry	2014.0062	information for attention	Belgium	Belgium	160	mg/kg	15	cadmium (160 mg/kg - ppm) in poultry feed additive from Belgium
phosphates	dicalcium phosphate ; [calcium hydrogen orthophosphate]	2009.0248	alert	Portugal	Spain	12.4	mg/kg	10	cadmium (12.4 mg/kg - ppm) in dicalcium phosphate from Portugal
phosphates	dicalcium phosphate ; [calcium hydrogen orthophosphate]	2008.1675	information	Slovenia	Austria	15.4	mg/kg	10	cadmium (15.4 mg/kg - ppm) in dicalcium phosphate from Slovenia
phosphates	dicalcium phosphate ; [calcium hydrogen orthophosphate]	2005.AXL	information	Israel	Cyprus	16.7	mg/kg	10	cadmium (16.7 mg/kg - ppm) in di-calcium phosphate from Israel
phosphates	monocalciumphosphate	2007.AAR	information	Turkey	Greece	19.5	mg/kg	10	cadmium (19.5 mg/kg - ppm) in monocalcium phosphate from Turkey
mineral feed	mineral mix, general	2010.0817	information	India	Belgium	25	mg/kg	5	cadmium (25 mg/kg - ppm) in dietary minerals from India, via Germany
feed materials of vegetable origin	celery	2014.0925	information for follow-up	Poland	Germany	2.71	mg/kg	1	cadmium (2.71 mg/kg - ppm) in celery stalks from Poland
feed materials of mineral origin	calcium carbonate; [limestone]	2011.1171	information for attention	Spain	Spain	6.3	mg/kg	2	cadmium (6.3 mg/kg - ppm) in calcium carbonate from Spain
feed materials of mineral origin	calcium carbonate; [limestone]	2012.1144	information for follow-up	Germany	Germany	20.6	mg/kg	2	arsenic (20.6 mg/kg - ppm) and cadmium (4.1 mg/kg - ppm) in feed lime from Germany

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
feed materials of animal origin	lobster shell powder	2006.AOQ	information	El Salvador	Norway	4.95; 4.30	mg/kg	2	cadmium (4.95; 4.30 mg/kg - ppm) in lobster shell in powder form from El Salvador
feed materials of animal origin	squid meal	2009.0019	information	Peru	Belgium	2.5; 3.2	mg/kg	2	cadmium (2.5; 3.2 mg/kg - ppm) in squid meal from Peru
feed materials of animal origin	fish meal	2009.0446	information	Spain	Spain	3.86	mg/kg	2	cadmium (3.86 mg/kg - ppm) in fish meal from Spain
feed materials of animal origin	squid	2011.0849	information for attention	Argentina	France	13.764	mg/kg	2	cadmium (13.764 mg/kg - ppm) in frozen whole squid (Ilex argentinus) from Argentina
feed materials of animal origin	fish meal	2013.1305	information for attention	Ecuador	Netherlands	3	mg/kg	2	cadmium (3 mg/kg - ppm) in tuna meal from Ecuador, via Germany
feed materials of animal origin	fish meal	2014.0057	information for attention	Spain	Italy	2.81; 3.90	mg/kg	2	cadmium (2.81; 3.90 mg/kg - ppm) in fish meal from Spain
feed materials of animal origin	fish meal	2013.1570	information for follow-up	Argentina	Italy	4.03	mg/kg	2	cadmium (4.03 mg/kg - ppm) in fish meal from Argentina, via Lithuania
feed materials of animal origin	fish meal	2012.1308	information for follow-up	Spain	Greece	6.1; 4.7	mg/kg	2	cadmium (6.1; 4.7 mg/kg - ppm) in fish meal from Spain
feed additives belonging to the functional group of compounds of trace elements	zinc sulphate	2006.0075	alert	China	France	3.7-7.6%	%	10	cadmium (3.7-7.6%) in zinc sulphate from China
feed additives belonging to the functional group of compounds of trace elements	zinc sulphate	2002.144	alert	China	Belgium	88.677 (8,9%)	mg/kg	10	cadmium (88677 (8,9%) µg/kg - ppb) in Zincsulphate monohydrate
feed additives belonging to the functional group of compounds of trace elements	zinc sulphate	2007.0314	alert	China	Norway	16; 13.4; 12.1	mg/kg	10	cadmium (16; 13.4; 12.1 mg/kg - ppm) in zinc sulphate 35% from Germany, raw material from China
feed additives belonging to the functional group of compounds of trace elements	zinc sulphate	2007.0196	alert	Slovakia	Latvia	966	mg/kg	10	cadmium (966 mg/kg - ppm) in zinc sulphate from the Slovak Republic via Poland

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
feed additives belonging to the functional group of compounds of trace elements	zinc sulphate	2005.AWR	information	China	Norway	11; 17	mg/kg	10	cadmium (11 / 17 mg/kg - ppm) in zinc sulphate mono feed grade to be used as pre-mixture from China
feed additives belonging to the functional group of compounds of trace elements	zinc sulphate	2010.1677	information	Italy	France	15.7; 16.8	mg/kg	10	cadmium (15.7; 16.8 mg/kg - ppm) in zinc sulphate from Italy
feed additives belonging to the functional group of compounds of trace elements	zinc sulphate	2012.1688	information for follow-up	China	Belgium	23.5	mg/kg	10	cadmium (23.5 mg/kg - ppm) in zinc sulphate from China
feed additives belonging to the functional group of compounds of trace elements	zinc sulphate	2012.1588	information for follow-up	China	Belgium	49.7	mg/kg	10	cadmium (49.7 mg/kg - ppm) in zinc sulphate from China
cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate	zinc oxide	2009.BSC	border rejection	China	Greece	480	mg/kg	30	cadmium (480 mg/kg - ppm) in zinc oxide from China
cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate	manganese oxide	2006.APF	information	China	Cyprus	45	mg/kg	30	cadmium (45 mg/kg - ppm) in manganese oxide from China
cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate	zinc oxide	2008.0746	information	China	Bulgaria	357,454; 349,173	mg/kg	30	cadmium (357,454; 349,173 mg/kg - ppm) in zinc oxide from China
cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate	manganese oxide	2011.0171	information for follow-up	Brazil	Germany	41	mg/kg	30	cadmium (41 mg/kg - ppm) in manganese(II)oxide from Brazil, via the Netherlands
cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate	zinc oxide	2013.0777	information for follow-up	Turkey	Belgium	52	mg/kg	30	cadmium (52 mg/kg - ppm) in zinc oxide from Turkey, via Denmark

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
complementary feed	feed bovine animal, complementary	2013.1293	information for follow-up	Germany	Germany	1.43	mg/kg	0.5	cadmium (1.43 mg/kg - ppm) in complementary feed for cattle from Germany
complementary feed	complementary feed, general	2014.0924	information for follow-up	United Kingdom	Sweden	1.08	mg/kg	0.5	cadmium (1.08 mg/kg - ppm) in complementary feed from the United Kingdom

RASFF notifications mercury

Table Sup5-55 *RASFF notifications mercury.*

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
compound feed	pig feed, general, complete	2003.BFN	information	Germany	Germany	0.22 (DS	mg/kg	0.1	mercury (0.22 (DS) mg/kg - ppm) in complete feed for fattening pigs (meal)
compound feed	complete feed, general	2009.0040	information	France	Spain	0.24	mg/kg	0.1	mercury (0.24 mg/kg - ppm) in complete feed from France
compound feed	shrimp feed	2012.1410	information for attention	Belgium	Belgium	0.21	mg/kg	0.1	arsenic (11 mg/kg - ppm) and mercury (0.21 mg/kg - ppm) in complementary feed for shrimp from Belgium
mineral feed,	mineral mix, poultry	2013.1220	information for follow-up	Germany	Czech Republic	0.344	mg/kg	0.2	mercury (0.344 mg/kg - ppm) in mineral feed for poultry from Germany
fish, other aquatic animals and products derived thereof,	fish meal	2013.0800	information for follow-up	Spain	Italy	0.73	mg/kg	0.5	mercury (0.73 mg/kg - ppm) in fish meal from Spain
compound feed for dogs, cats and fur animals	cat feed, complementary	2012.1502	information for follow-up	Thailand	Germany	2.11 mg/kg dry matter	mg/kg	0.3	mercury (2.11 mg/kg dry matter) in complementary feed for cats from Thailand
feed materials	vitamin	2011.1674	information for attention	India	United Kingdom	0.383	mg/kg	0.1	mercury (0.383 mg/kg - ppm) in vitamin preparation from India
fish, other aquatic animals and products derived thereof,	fish meal	2013.BIA	border rejection	Guatemala	Spain	1.14	mg/kg	0.5	mercury (1.14 mg/kg - ppm) in fish meal from Guatemala
fish, other aquatic animals and products derived thereof,	shark cartilage powder	2013.1479	information for attention	New Zealand	Ireland	0.87	mg/kg	0.5	mercury (0.87 mg/kg - ppm) in shark cartilage powder from New Zealand
feed materials	yeast	2011.0089	information for follow-up	Russia	Germany	0.14; 0.159; 0.16	mg/kg	0.1	mercury (0.14; 0.159; 0.16 mg/kg dry matter) in yeast from ethanol production from Russia, via Latvia and via Lithuania

Product group EU	Product(s)	Reference	Notification type	Origin	Notified by	Value(s)	Unit	EU Limit	Subject
fish, other aquatic animals and products derived thereof,	fish meal	2013.0990	information for follow-up	Spain	Italy	0.79	mg/kg	0.5	mercury (0.79 mg/kg - ppm) in fish meal from Spain
feed materials	premix	2011.1128	information for attention	China	United Kingdom	17.8	mg/kg	0.1	mercury (17.8 mg/kg - ppm) in vitamin B2 premix from China, via Germany
compound feed for dogs, cats and fur animals	petfood	2012.ARL	border rejection	Thailand	Italy	0.43	mg/kg	0.3	mercury (0.43 mg/kg - ppm) in canned pet food from Thailand
compound feed for dogs, cats and fur animals	cat feed, complete	2012.0366	information for attention	Thailand	Italy	0.43	mg/kg	0.3	mercury (0.43 mg/kg - ppm) in cat food with tuna from Thailand
compound feed for dogs, cats and fur animals	cat feed, complete	2012.ANO	information for attention	Thailand	Italy	0.64	mg/kg	0.3	mercury (0.64 mg/kg - ppm) in cat food with tuna from Thailand

RIKILT Wageningen University & Research
P.O. Box 230
6700 AE Wageningen
The Netherlands
T +31 (0)317 48 02 56
www.wur.eu/rikilt

RIKILT report 2017.006

To explore the potential of nature to improve the quality of life

RIKILT Wageningen University & Research
P.O. Box 230
6700 AE Wageningen
The Netherlands
T +31 (0)317 48 02 56
www.wur.eu/rikilt

Report 2017.006

The mission of Wageningen University and Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to inding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 5,000 employees and 10,000 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.