EfW IPCN Public Hearing

14/5/18

Thank you commissioners for the opportunity to speak at this public hearing.
I will start by stating that I am opposed to this proposal and any similar version in the future.
As a society we are better than this and need to develop intelligent solutions that will enhance community and society rather than at their detriment.
I wish to talk to 3 issues:

1. Environment

From an environmental point of view - whenever humans decide to take over natural land and an ecosystem, we should consider doing it for a just and beneficial reason. The Cumberland Plain Woodland of this area is precious and shrinking rapidly due to development. A project of this kind which uses air dispersion from its own waste product effects not just the land it disturbs but the areas surrounding it. This project will affect the flora and fauna of Sydney as well as the human inhabitants. They live and breathe the same air.
A study has shown that POPs (Persistent Organic Pollutants) accumulate in the eggs and muscles of chickens (ref) which leads to entry and accumulation of these pollutants into the native ecosystem of the area. The exact effects of this are currently unclear but would present over time if the proposal was approved.

Now, we have human waste issues in Sydney, not dissimilar to the rest of the world.
And well thought systems need to be developed and implemented to fix this.
Incineration is not one of these solutions.
1.3 m Te of waste, now changed to 550 kTe of waste, **will be burnt – not recycled !**
This step alone interrupts the process of recycling in a significant way.
In has been suggested such incinerators disrupt the recycling economic model. Without putting significant cost on incineration to ensure the entrapped energy and value in the resource being burnt is valued recycling has no chance in competition. The environmental and health costs have been externalised to the community.
The waste paradigm needs to be changed. The government advertises for consumers to do more recycling and then claims we are reasonably good at it.
When you leave today by car, I am sure you will end up stopped near the side of a road on an on/off ramp - just look out your window at the waste that will caught in any grass near the kerb.
The waste problem is endemic and a solution to this overseas is product stewardship by manufacturer which leads to waste elimination by design. Incineration is not being pursued overseas any more.

2. Health

World class air quality standards are required in New South Wales.
As an example Hydrogen Fluoride (HF) is not even in the NSW air quality standards and yet in the EU standards is set at 1 ppm.
At this stage and given the identified cancer clusters around overseas incinerators I feel **more stringent standards on POPs need to be set** on particularly on **concentration (PPM)** and on **measuring/monitoring the smaller PM1 and PM2.5 particles** which particularly effect human respiratory health.
Given the proponent wishes to burn construction waste, this will include polystyrenes - like burnt in the Grenfell Tower disaster and were previously called EPS (Expanded Polystyrene). These are now manufactured with flame retardants in them (called XFLAM and PIR) which generate carcinogens on burning while trying to extinguish the self-generating flame.
Similarly, broadloom carpets will be burnt, which are basically plastic with colourants and adhesives.
These are being slowly replaced with carpet tile squares and Interface Carpets (ref) and the story of Ray Anderson are a case study in how the construction industry can move to a more sustainable footing for waste which can be streamed and recycled.

The industry needs to change to manufacturer product stewardship - incineration is not the solution.

Regarding the use of air dispersion as a primary method of waste disposal for exhaust chemical by-products, I appreciate that even the proponent has asked to use the EU standards (as they are using a European based company for the development).
Many fine particle (PM1 and PM2.5) pollutants will get through the planned filtration processes as technology cannot filter at this fine level while maintaining significant air flow. These fine particles will then settle out of the air flume, primarily close to the facility. The POPs previously referred to are known to accumulate in ecosystems whether it be human or natural.
Locations like Aldi, Woolworths and Lite N Easy that have distribution centres near the facility will become conduits for the further dispersion, contaminating wider areas of Sydney.

Aswell, we live in a researched and documented air basin where air in western Sydney circulates/lingers for days. It drifts towards the east and back to the west particularly when there is an area of high pressure off the east coast. Others have and will speak to the specifics of air quality and western Sydney, particularly in the Mount Druitt area to respiratory presentations to hospitals.
This is a well-known phenomenon with some good representative research and I table - Modelling Wind Fields: Hurley from the 1990's (attached).
Any activity/facility proposed in the future near domestic residence needs to provide live, transparent, independent air quality monitoring close to the facility.

With respect to human health, I wish to bring up one more significant issue. This goes to the process the community have been put through to stop the ludicrous proposal.
This process has been time consuming and I believe even a negative decision from this commission will not stop the ability for the proponent to reintroduce it at a later date.
Even the Federal Environment Minister has proposed energy from waste incineration as a solution to the wicked problem of waste management, which it is not. To achieve this, we need to ensure through legislation that it cannot be put in place in residential areas.

I also know that the opportune time to stop such unhealthy proposals is at the outset. I will bring the commission's attention to the recently completed court case in Queensland between Linc Energy and the Queensland Government. In this unfortunate situation only came to result after George Bender took his own life over the incident and trying to seek justice after government approval was given. Once approved, the regulation of these industries is very weak to non-existent (ref 1 and 2).

This current independent process, as referred to by the current government creates significant anxiety and stress on the public and only through a determined and significant resistance by the community are we at this point in time. The government needs to step up, re-apply the precautionary principle and only allow developments that benefit the community as well as the proponent. The same can be said for the NSW government's own proposals - I was in a Hawkesbury Council meeting last Tuesday where a community lady was brought to tears over the Western Sydney Corridor proposal that will decimate her family's planned life and dreams.
This dogmatic, uncaring attitude, particularly from people in the eastern side of Sydney to push onto the western side of the city is unjust.

3. Manufacturing Pragmatism

I have personally worked in the manufacturing industry for 30 years and hold a BE & MBA.
I have designed, build and maintained filtration systems during my time and am well aware of their limitations. As such, I can offer my submission without commenting to the need for pragmatism in a working environment.
Nowhere did I find in the proponent's submission a clear understanding on how they were going to maintain or manage a catastrophic failure of their filtration system.

I ask, filters will need replacing – How often? At what cost? At what frequency? Without independent feedback – how will the public know?
What will happen in the event of significant or catastrophic failures?
The same can be said for the combustion process. Overseas incinerators have been known to catch fire and feedstocks to burn outside the filtration capture zones.
It is clear that these systems should not just meet the legal requirement hurdles but clear them by a couple of orders of magnitude in model circumstances.

Summary:

In summary I ask the commissioners to reject this proposal for a toxic incinerator called an Energy from Waste Facility.
This current proposal is being legally considered in an almost vacuum of policy governing the issues and hazards that facility like this produce. Latest knowledge is many years advanced to policy and regulation and this needs to be remedied.
So I ask the commission to meet the community expectations and recommend to the Government that before any of these facilities are determined in the future:

1. The NSW Air Quality standards are re-written and improved to world best practice, that many known toxic chemicals have limits set and that air quality monitoring standards are set to provide live, online data available to the community from independent sources.
And that extra monitoring stations are mandatory near any significant facility that wishes to use air dispersion as a method of disposing of their chemicals, such as exhaust stacks.
Otherwise, the facility must have a closed circuit air system and re-use their own processed air waste.

2. The NSW Government undertake (in consultation with the Federal Government) a review of the construction standards of buildings in New South Wales with the primary goal of making redundant housing stock a deconstruction and reuse/recycle process rather than a demolition and disposal.
Product stewardship in the building industry needs to be on the builder.
A similar review should occur for the Commercial & Industrial waste sector

3. Legislation be passed that prohibits waste incineration near residential areas.

4. Finally, the current independent review process of planning is clearly putting significant pressure on communities and individuals in making them responsible to influence the decisions and proposals being made in their area. The angst and despair that occurs in the community creates issues of mental health and distrust with the government departments and politicians.
This process needs its own review to better protect individuals and a precautionary principle needs to be applied to the whole process.

INVITED

Modelling Wind Fields in MAQS

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Abstract MAQS is the Metropolitan Air Quality Study, a multi-million dollar scientific investigation of photochemical smog and fine particle pollution in the major urban and industrial area of New South Wales on the east coast of Australia, extending from Newcastle-Hunter Valley/Central Coast/Sydney/Illawarra-Wollongong. As part of a consultancy for MAQS, we have extended and applied the detailed prognostic numerical air pollution transport and dispersion model, LADM, to several simulations of local and inter-regional air pollution events for the region. The investigation has highlighted (i) the large uncertainty in specifying surface synoptic meteorological data on high pollution days, (ii) the ability of LADM to predict well the local winds and temperatures, even without assimilation of observational data, (iii) the need to incorporate observations of surface and upper air winds to give accurate air *trajectories*, (iv) that days conducive to sea-breeze conditions are the key to the meteorology of high pollution in the MAQS region, and (v) that poor dispersion in the Sydney basin also implies inter-regional transport: from the Newcastle and Hunter Valley region to parts of Sydney, or from much of Sydney to the Illawarra.

1. INTRODUCTION

Exacerbated by the recirculation of air in sea breezes, Australia's large coastal cities with sunny climates experience the most intractable form of air pollution—photochemical smog characterised by the presence in the air of excessive concentrations of ozone gas, a respiratory irritant (Manins *et al.*, 1994). Figure 1 shows that there has been some success in reducing the problem in the largest cities of Sydney and Melbourne, but that there is no cause for complacency.

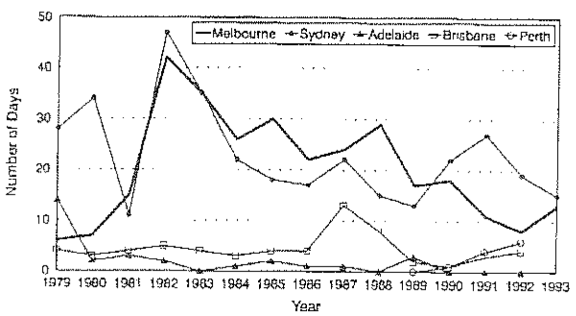


Figure 1. Number of days when peak 1-hour ozone concentrations exceeded 80 ppb in selected Australian cities, 1979-93 (courtesy S. Ahmet).

In 1993 the Environment Protection Authority (EPAN) of New South Wales (NSW) initiated the Metropolitan Air Quality Study (MAQS). EPAN was anticipating a big population growth in the major urban and industrial area of NSW, *viz* Newcastle-Hunter Valley/Central Coast/Sydney/Illawarra-Wollongong (shown in Figure 2), cognisant of predictions that an expansion in the western part of the Sydney basin could lead to a deterioration of air quality (Hyde and Johnson, 1990). MAQS is a multi-million dollar study of the present and expected future air quality in the region. The study has involved the enhancement of existing air quality measurement sites, establishment of additional sites, funding of health studies, and scientific studies of pollution mechanisms including numerical modelling. This last component of the study was contracted out to a consultancy team managed by Coffey Partners International. The tasks were to develop and validate an emissions inventory and a set of modelling tools for the region. These tools would be passed on to EPAN at the end of the study to assist in future assessment of urban and industrial planning issues.

The MAQS consultancy consisted of four major tasks:

1. Air Emissions Inventory (done by EPA of Victoria);
2. Meteorology - Air Movements (Macquarie University and CSIRO Division of Atmospheric Research);
3. Air Chemistry (CSIRO Coal & Energy Technology);
4. Development of Airshed Models (EPA of Victoria).

Here we describe the meteorological modelling component of the Meteorology - Air Movements task. The Environmental Consulting and Research Unit of the CSIRO Division of Atmospheric Research conducted selected numerical meteorological simulations for the MAQS region based on high pollution days categorised by Macquarie University using historical data. The meteorological predictions were used as input to other MAQS tasks: Air Chemistry, and Development of Airshed Models simulating smog formation and dispersion. In Section 2 we describe the modelling system used for the study, the configuration of the model for MAQS, and some results. Section 3 focuses on a detailed case study day for Sydney, and Section 4 summarises the results from various types of high pollution scenarios identified in the study.

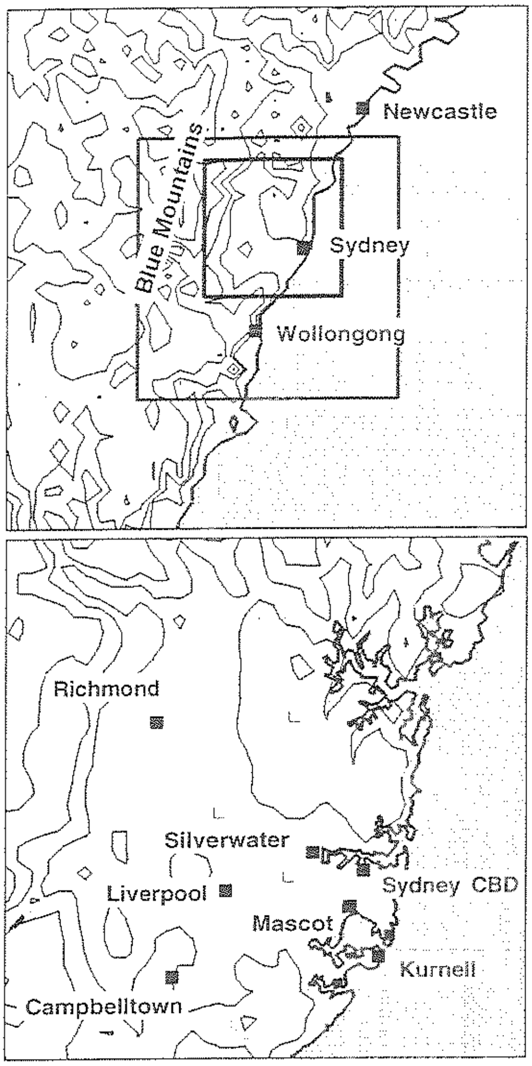


Figure 2. (Top) One of the 10 km spaced grid domains used by LADM (5.0, 2.5 km grid domains are marked inside it), showing the extent of the MAQS region (400 km across). (Bottom) A 2.5 km spaced grid domain for the Sydney Basin (100 km across).

2. MAQS METEOROLOGICAL MODELLING

While extensive surface wind and temperature data are available in MAQS from 20 or more stations throughout the region, the only upper air data are from the airports on the coast at Mascot and north of Newcastle (Figure 2). For airshed modelling of inter-region transport and smog dispersion to be successful, it is essential to have detailed data on the upper-air winds, the height of turbulent mixing in the atmosphere, and on the winds between the population centres. The approach adopted for the meteorological modelling for MAQS was the only one possible in the circumstances—we used the Lagrangian Atmospheric Dispersion Model (LADM), a complete air pollution modelling system described by Physick *et al.*, (1994) and Physick (1993). LADM has taken over 10 years to develop and has been applied to numerous air pollution studies across Australia.

2.1 LADM

LADM is a two-part prognostic model:

1. The first part is a mesoscale meteorological model which solves the primitive equations for fluid flow, predicting the three-dimensional local winds, turbulence, temperature and mixing heights on a grid in a complex geographic region using terrain data from Hutchinson *et al.* (1991). This semi-implicit model uses Lagrangian techniques; it is a fast (hydrostatic assumption) weather-forecasting model with long- and short-wave radiation schemes and a full vegetated surface scheme. The modelled region must be so large as to include all relevant terrain that causes the local wind to deviate from the large-scale (synoptic) wind. The predicted winds and turbulence parameters for every grid point are saved at frequent intervals for analysis or use by the second component of LADM.
2. The second part is a Lagrangian particle dispersion model. This predicts the transport and diffusion (including plume rise for hot emissions) from the pollutant sources using the wind data and turbulence characteristics predicted by the meteorological model. A stream of particles is released from each source at a rate proportional to the specified emissions. Each particle is tracked as it is moved in the wind and by random perturbations simulating the turbulence. To predict ground level concentrations the number of particles in surface-located boxes is counted over an averaging time.

2.2 Running LADM in MAQS

For MAQS two sets of nested grids were used: one set covering the Sydney and Illawarra sub-regions, and one set covering the Sydney and Newcastle sub-regions. The grids had horizontal dimensions of 40×40 points and 20 points in the vertical. The horizontal grid spacing was 40 km, 20 km, 10 km, 5km, and 2.5 km. Figure 2 shows 10 km, 5 km and 2.5 km spaced grid domains. Note that 40 km and 20 km spaced grids were run merely to set up realistic boundary conditions for the 10 km grid, thereby reducing the effects of imposed boundary conditions on the outer nest.

The model was generally started at 0300 hr on simulation day 1 and run for 63 hours through to 1800 hr on simulation day 3. Results from simulation days 2 and 3 are taken to correspond to a 48 hour period of interest. Two kinds of investigations were performed in MAQS:

- '*Generic*' modelling imposes the large-scale ('geostrophic') winds to drive the simulation without much concern with accuracy in reproducing local observations. This is done to help identify the mechanisms which characterise the type of days being modelled (*eg*: summer poor dispersion days in Sydney). The results are used to enhance understanding of available data and the general characteristics of the category of day being considered.

- '*Case study*' modelling is performed in order to describe as much detail about a particular day as possible. It involves first using the generic modelling approach, and then refining the imposed conditions (usually to a much greater degree than the accuracy of the available geostrophic wind measurements), until good agreement is obtained in detailed comparisons between predicted and locally observed meteorological variables.

2.3 A Summertime Pollution Day in Sydney: 13 Feb '93

A common summer pollution situation in the western region of Sydney has a broad area of high pressure off the east coast leading to large-scale northerly winds. Nighttime drainage flows in the Sydney basin and from the high slopes move cold air to the north towards Richmond (Figure 2) in the lee of the Blue Mountains and to the east towards the centre of Sydney. As the air travels over densely settled and industrial areas in the inner western suburbs, it accumulates pollutants. The air then flows out to sea during the morning. With the onset of the sea breeze the same air is frequently returned, travelling westward and reaching the western Basin near Penrith or Campbelltown in the afternoon.

To simulate these conditions, LADM was run by imposing a steady 5 m s^{-1} northerly geostrophic wind at the surface, backing to westerly by 2,500 m above sea level. All the features discussed above are shown in Figure 3 and compare well with observed data: the 1500 hr surface wind arrows show the presence of the sea breeze; the heavy lines show the paths followed by selected air parcels—the numbers indicate the parcel positions at the marked times. One path line shows that overnight there is a light northward drift in the western basin. Further to the east, the other path line shows polluted air that flows offshore in the early morning is returned in the sea breeze to the western suburbs, by then transformed in the sunlight to photochemical smog.

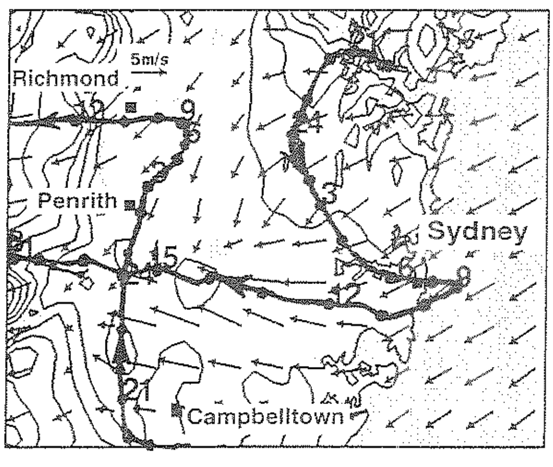


Figure 3. LADM predictions for a common summertime pollution day in the Sydney region (100 km east-west): 1500 hr on 13 February 1991. Also: selected air parcel trajectories with time marks.

2.4 Extensions of LADM for MAQS

The data from the predicted windfields were required for the airshed smog modelling of days with extensive surface observations, necessitating the following important capabilities of LADM being completed during MAQS:

- incorporation of time varying synoptic winds;
- accounting for cloud cover effects on surface radiation;
- assimilation of wind observations.

2.4.1 Time-Varying Synoptic Winds

To account for the variation of synoptic conditions over the three day simulation periods used for MAQS, LADM was modified to incorporate time-varying synoptic winds, potentially allowing a more accurate solution to be generated. Usually, synoptic conditions change on time scales of the order of several hours: for MAQS the imposed geostrophic conditions were changed approximately every six hours. Note that the model cannot presently account for horizontal variations of the synoptic conditions across the modelling domain, such as occurs during the passage of a cold front.

An example of the effect of the variation of synoptic winds with time is given in Figure 4: it shows the predicted movement at 0600 hr on 3 and 4 January 1993 of tracer particles from elevated point sources in the Upper Hunter Valley west of Newcastle, as well as from sources on the coast. These days were similar to that discussed in Section 2.3 but the modelled synoptic winds were stronger (10 m s^{-1}) and were at first from 30°, backing to be from 0° by 0000 hr on 4 January.

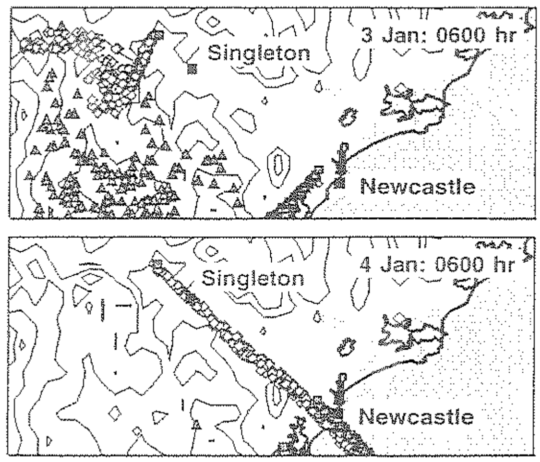


Figure 4. Predicted particle positions for two 500 m high point source releases from the Upper Hunter ◊, and Central Coast □, and a 200 m high release from near Newcastle Δ at 0600 hr on 3 January (top) and 4 January (bottom) 1993.

With a change of only 30° in synoptic wind direction over the period, the winds channelled by the Hunter Valley have changed from being up-valley (towards the west) to being down-valley (out to sea). Indeed, investigation showed that as little as a 10° change in synoptic forcing could give the same result on these kinds of days—so long as the synoptic forcing has no easterly component, the predicted winds in a deep layer in the Hunter are down-valley, otherwise they are up-valley. The prediction is supported by qualitative analyses of data on surface winds, but these are too subject to channelling for this to be a definitive test of wind directions at upper levels.

2.4.2 Cloud Cover Effects of Surface Radiation

Some of the days studied in MAQS were characterised by the presence of clouds. Regional predictive models generally either cannot account for effects of cloud at all, or treat them in such great detail that the model performance is compromised. In LADM the effect of cloud cover has been included only insofar as it affects surface radiation. This was done by fitting simple formulae to predictions from a detailed radiation model (Boers and Mitchell, 1994) for two cloud types and three height levels. The formulae account for the increase in net longwave radiation and decrease in net shortwave radiation at the ground due to cloud cover. The fitted data were obtained from Australian observer information at nine airports averaged over seven years.

As demonstration of the effect of using the new formulae, a test using LADM for three specific cases of cloud cover was performed:

1. No cloud cover
2. Full cover of mixed cumulus/stratus
3. Full cover of stratus cloud

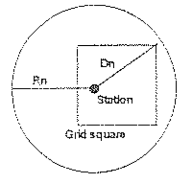
The results show that for both cases 2 and 3 the near-surface temperature minima at night are up to +3.4 K greater than in the no-cloud case. The daytime temperature maximum for case 2 (mixed cumulus/stratus) was minimally affected (due to increased longwave but decreased shortwave of approximately the same order). However, for the case of stratus cloud, the difference in daytime maximum temperature was as much as -4.4 K. These changes could significantly affect predictions of three-dimensional local winds in complex terrain, including a reduction in the speed of drainage winds overnight in valleys, and a reduction of sea-breeze strength during the day for coastal sites. Further details are given in Hurley and Boers (1995).

2.4.3 Data Nudging

Since an extensive network of wind observation stations was available in MAQS, a four-dimensional data assimilation method was employed to improve the predictions from LADM. One way is to assimilate measurements as an extra forcing term in the horizontal momentum equations. The model solution near these sites is thereby 'nudged' towards the measured winds. This technique has been used in various forms in the past, particularly for synoptic scale predictions by weather forecasting models. For the MAQS case study, we implemented in LADM an assimilation technique used by Stauffer and Seaman (1994). The approach was applied to the horizontal velocity variables (u, v), but not to temperature due to the detrimental effect it can have on the structure of the convective boundary layer (Stauffer *et al.*, 1991). An example of the method in operation is given in Section 3.

For a variable u at grid point (i,j,k) the prognostic momentum equation takes the form:

$$\frac{\partial u}{\partial t} = F + G_u \left(\frac{\sum_{n=1}^{N} W_n^2 \gamma_n (u_n - \hat{u}_n)}{\sum_{n=1}^{N} W_n} \right)$$



where the first term (F) on the right hand side of the equation is the normal forcing term for u, and the second term is an additional data nudging acceleration term, where:

$W_n = w_{Hn} w_{\sigma n} w_{tn}$
= weighting function made up of horizontal (w_{Hn}), vertical $(w_{\sigma n})$, and time (w_{tn}) weights;

$$w_{Hn} = \begin{cases} \frac{R_n^2 - D_n^2}{R_n^2 + D_n^2} & \text{for } D_n \le R_n; \\ 0 & \text{for } D_n > R_n. \end{cases}$$

$w_{\sigma n}$' = decreases linearly with height from a value of 1 at the observation height to a value of 0 at another height (eg: 50 m);

w_{tn} = piecewise linear function within a specified time window (eg : ± 30 min), ranging from a maximum of 1 in the middle of the window to 0 outside;

$\hat{u}_n$ = model value of u interpolated to observation point;

u_n = measured station value of variable u;

G_u = nudging coefficient (s^{-1});

γ_n = data confidence factor [0,...,1];

R_n = station horizontal radius of influence (m);

D_n = distance from grid point to station location (m),

N = the number of station observations.

3. MAQS CASE STUDY DAY (9-10 FEBRUARY 1994)

The period 9-10 February 1994 was selected as a case study 'day' because of the observations of high ozone levels in the southwest of the Sydney Basin and the completeness of monitoring data. The days were characterised by a high pressure system off the NSW coast directing northerly gradient winds over the Sydney region. Profiles of wind at Mascot show that north-northeasterly flow occurred in the lowest 1,000 m throughout the period, backing with height to be westerly by 2,000-3,000 m. In the period, the high drifted slowly eastward but for modelling purposes, was considered to be stationary.

Overnight surface winds were light, and increased during the day with the passage of the sea breeze across the region. Winds at the coast were stronger than at inland sites, particularly overnight. Wind direction at the coast remained north-northeasterly throughout the day, while a light southerly flow was apparent in the western half of the basin overnight, with northeasterly to easterly winds in the afternoon sea breeze.

3.1 The Geostrophic Winds and Initial Conditions

Initial conditions and the geostrophic wind forcing are given in Table 1. Sea surface temperature was specified as 295 K, and the mean sea level pressure was 1,015 hPa. A surface roughness length of 1 m was used, and a soil moisture content of 0.20 was taken, based on an analysis of rainfall data for the previous 12 months at Mascot Airport.

Table 1. Profiles of geostrophic (and initial) wind speed and direction, and initial potential temperature and mixing ratio for 9-10 February 1994.

Height (m)	Wind Speed ($m\ s^{-1}$)	Wind Direction (°)	Potential Temperature (K)	Mixing Ratio ($g\ kg^{-1}$)
0	13	15	298	15.0
500	13	20	303	13.0
1,000	13	20	306	5.5
1,500	13	330	309	5.5
3,000	13	240	313	4.0
5,000	13	210	325	0.1

3.2 Data for Nudging

Surface (10 m) anemometers provided wind speed and direction throughout the study area: data from 17 sites were used. Temperature and solar radiation measurements were also available from eight sites.

The simulation with data nudging required the input of the hourly average measured wind data and associated variables. The other main inputs were a 10 km radius of influence (R_n), a nudging coefficient (G_u) of 0.002 s^{-1}, and an assumed data confidence factor (γ_n) of 1. Only surface winds were nudged, due to the lack of detailed wind profiles in the region.

3.3 Predictions of Winds and Temperatures at Sites

Scatter plots of predicted *vs* observed u- and v-components of the wind and temperature (T) for the final case study run, without and with data nudging were prepared. The results without nudging give R^2 correlation measures of 0.48, 0.39, and 0.89 for u, v, and T respectively: there is an over-prediction of low wind speeds, an under-prediction of high wind speeds, and an under-prediction of minimum temperatures. As would be expected, the changes in the solution due to nudging were most pronounced at the observation sites. The results, shown in Figure 5, give improved R^2 values of 0.73 and 0.68 for u and v respectively, and a slight deterioration in the temperatures with an R^2 value of 0.79.

If the constraint of exact time matching was relaxed (allowing the predictions to be shifted by one hour from the measurements), the degree of scatter reduced, resulting in R^2 values of 0.65, 0.55, and 0.93 without nudging, and 0.84, 0.75, and 0.91 with nudging, for u, v, and T respectively.

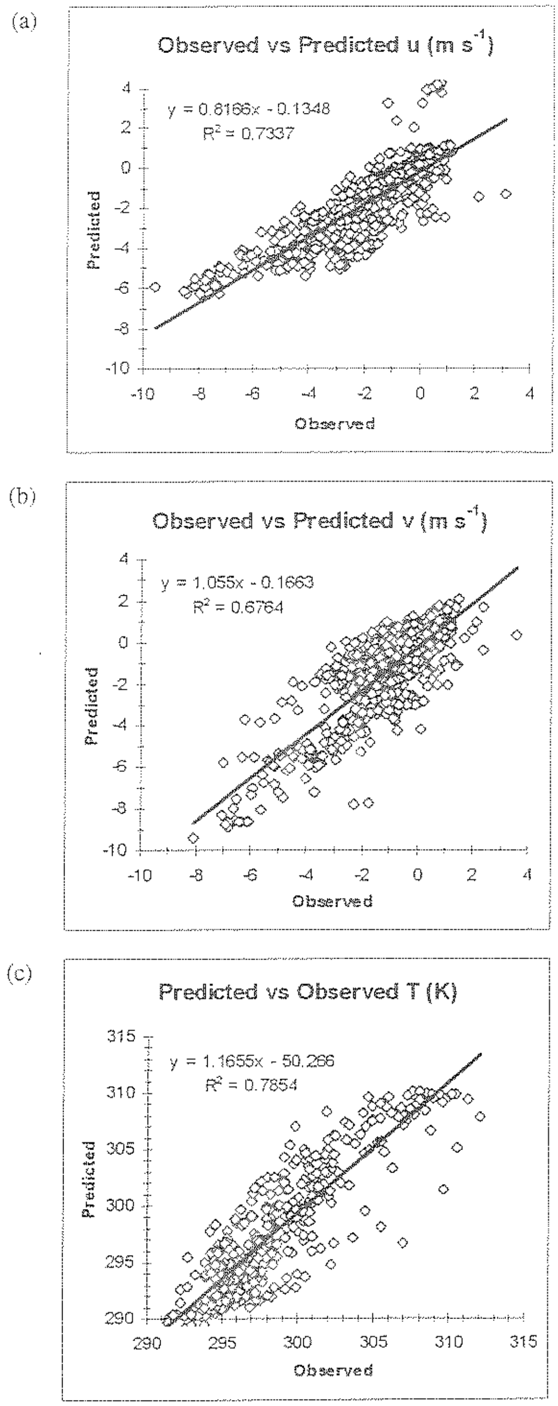


Figure 5. Scatter plots of (a) u-component, (b) v-component and (c) temperature at 17 monitoring sites in the Sydney Basin nudged for every hour of 9 and 10 February 1994.

Figure 6 shows a comparison of predicted versus measured wind speeds and directions for the case study without and with data nudging for the inland site of Liverpool. Generally, results on a site-by-site basis show a trend of light winds overnight and stronger northeasterly to easterly sea breeze flow during the afternoon. The strengths of the winds were predicted well at nearly all sites except for an overnight over-prediction on the western slopes of the basin, and a daytime overprediction at some central basin sites. The wind direction was generally predicted well when the wind speed was significant. Some of the differences may be explained by examining site locations and determining the importance of local effects not resolved by the model, such as channelling by small scale local terrain, and building effects.

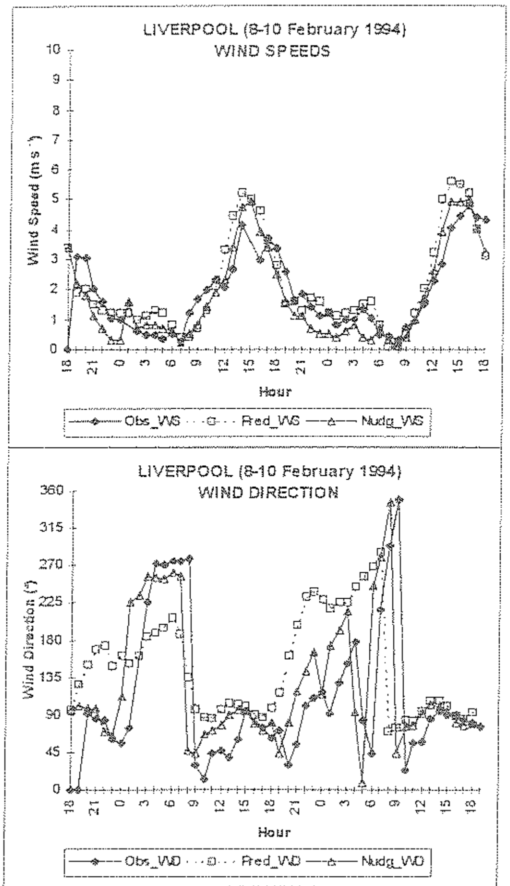


Figure 6. Comparison of observed wind speed and direction at the Liverpool air monitor with predictions from LADM.

3.4 Wind and Trajectory Predictions

Figure 7 shows an example of the predictions of winds at 1500 hr for the whole Sydney basin. By this time the sea breeze, which had formed at the coast by mid-morning, has travelled across much of the grid area producing northeasterlies at the coast and easterlies inland. The lighter north-easterly winds in the north of the western basin and the stronger easterlies to the south are a consistent feature of the predictions on many of the modelled days.

Three-dimensional dispersion calculations were performed for notional sources for the case study day to assist the interpretation of wind flow patterns and indicate pollutant trajectories from these sources. Trajectories were calculated using data from the nudged run with the Lagrangian particle model component of LADM.

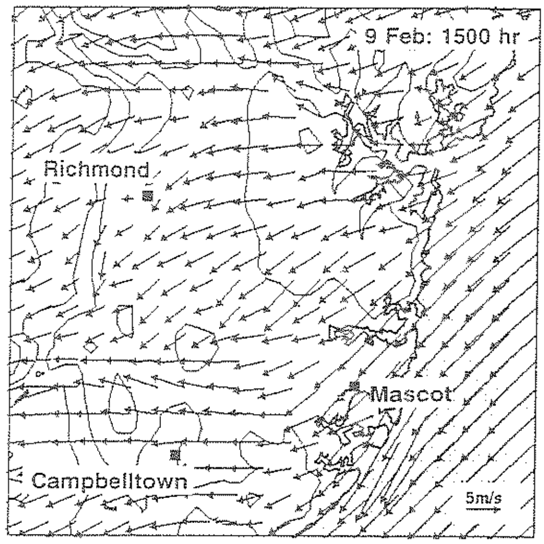


Figure 7. Predicted 10 m winds at 1500 hr in a simulation of 9 February 1994 in the Sydney Basin.

For the Sydney study region, particle releases from three notional sources were made (locations shown in Figure 2):

- Sydney central business district (CBD) area source;
- Inland Silverwater 200 m high point source;
- Southern Kurnell 200 m high point source.

Predictions of particle positions at 0600 hr on 9 February 1994 are shown in Figure 8. Overnight surface emissions from the CBD were caught in light northeasterly flow near the coast, travelled inland in an easterly flow, and then in light southerly flow in the western part of the basin: a consequence of terrain blocking of the winds (see *eg* Manins

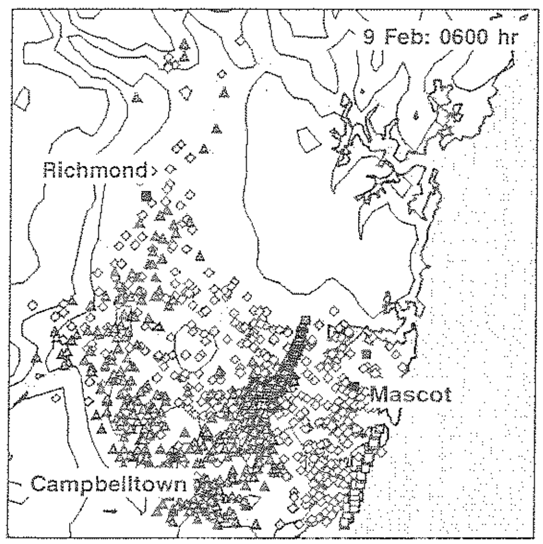


Figure 8. Predicted particle positions for an area source release from Sydney CBD ◊, and 200 m high point source releases from Silverwater □ and Kurnell Δ at 0600 hr in a simulation of 9 February 1994.

and Sawford, 1982). By sunrise, CBD pollutants are spread over most of the Sydney basin floor, covering the south-north extent of the grid domain and the west-east extent in southern Sydney; a broad L-shape pattern was formed. Even so, the majority of the particles are in the southern half of the basin. Pollutants from the notional source at Silverwater followed a similar path to the surface CBD emissions throughout the period. Particles from the source located at Kurnell travelled down the coast throughout the simulation.

Particles released from elevated sources on the Central Coast are predicted also to have entered the basin on 10 February. Overnight particles drifted over Sydney CBD and then followed the Silverwater particles northward in the western basin to Richmond and beyond. Later in the day they were predicted to have taken a more direct route to Richmond. The presence of emissions from either source could be the explanation of elevated sulfur dioxide readings recorded at Richmond at different times on that day.

3.5 Sensitivity of results

The specification of initial profiles of synoptic winds is only accurate to within approximately 2 m s^{-1} and 25°. This is due to the difficulty in interpreting synoptic pressure charts in slack gradient situations, and the need to eliminate any mesoscale effects from available measurements. The case study simulation was the result of a multitude of model runs, made in order to refine the initial and geostrophic conditions to produce model predictions in line with the detailed structure of the observed flow conditions. Geostrophic and initial wind directions below 1,000 m were varied between 10 and 30° with wind speeds varying between 7 and 15 m s^{-1}—final values used were 13 m s^{-1} and 15-20° in the lowest 1,000 m.

A major reason for choosing the selected run over the rest of the sensitivity runs was that the slightly more northerly wind direction in the lowest 500 m produced more northerly drift at around sunrise. This was a critical feature for the positioning of the urban plume to the south of the CBD. This enabled the sea breeze to transport the plume to the observed southern region by mid-afternoon. Aircraft ascent data from Mascot confirmed that the winds between the surface and 500 m showed significant north-northwesterly to northerly components. Such observations were more consistent with the selected run. These westerly component winds were not seen in the north-northeasterly surface winds both measured and predicted at the coast.

4. MECHANISMS LEADING TO HIGH POLLUTION

The following describes some of the major findings from the Meteorology - Air Movements task, determined by a combination of LADM modelling and data analysis.

4.1 Inter-regional transport

Poor dispersion days in Sydney also tend to be conducive to inter-regional transport, either to Sydney from the Newcastle region, or from Sydney to the Illawarra.

Southward transport of Newcastle and Sydney emissions

- During the afternoon, surface and elevated emissions within north-northeasterly synoptic winds and north-easterly sea breezes can travel overland from Newcastle and the Central Coast into the Sydney region. Pollutants could be trapped in stable layers over the basin overnight and be fumigated to the surface next morning.
- Under north-northwesterly synoptic flow conditions elevated emissions from Newcastle and the Central Coast, transported out to sea in offshore drainage flows, can be carried onshore over Sydney in the sea breeze.
- Elevated releases in the Upper Hunter Valley can travel to Newcastle under northerly synoptic winds if there is a westerly component to the synoptic flow (but not when there is an easterly component to the synoptic flow). Pollutants can be then carried into the Sydney basin within a northeasterly sea breeze. Or they can be transported directly to Sydney overnight, fumigating to the surface on the following morning.
- If there is a westerly component to the synoptic wind, Sydney surface and upper level emissions can be transported out to sea overnight and in the morning. Carried down the coast as a wide plume, the emissions can arrive off the Illawarra coast throughout the morning and afternoon. The sea breeze then brings this broad plume of pollutants ashore over several hours.

Northward transport of Sydney and Illawarra emissions

- Surface and elevated pollutant releases can travel from the Illawarra to the Sydney basin under nighttime conditions when synoptic winds have a southerly component.
- Surface and elevated pollutant releases can travel overnight from Sydney to Newcastle under southwesterly synoptic winds, and can be brought into Newcastle by the daytime sea breeze.
- Southerly synoptic change conditions can also transport Sydney or Illawarra emissions northward.

4.2 Locally poor dispersion

Sydney summertime conditions

- The movement of the sea breeze across the Sydney basin is consistent with the afternoon peaks of ozone observed in the sea-breeze front in the west and southwest parts of the Sydney basin.
- If there is no westerly component to the synoptic winds, Sydney emissions stay within the basin, spreading out from the coast to the western edge of the basin where they can be caught in southerly drainage flows and contribute to the observed morning build-up of ozone.
- The combined effect of overnight southerly drainage flows in western Sydney and northerly synoptic winds aloft, can induce a closed north-south vertical rotor

circulation. Sydney emissions caught in this circulation could be fumigated to the surface in the morning.

- In north-northeasterly synoptic winds, overnight blocking of stable flow by the topography of the Sydney basin leads to a clockwise circulation. The result is southerly flow up to 1,000 m deep in the western half of the basin. However, there are no upper level measurements available in the western region to confirm this effect, and winds at the coast give no indication, showing northeasterly flow at the coast.

Sydney wintertime conditions

- Winter poor dispersion days in Sydney with light westerly synoptic winds were shown to be prone to the accumulation of fine haze particles as a result of overnight trapping within light synoptic winds, late afternoon sea breezes, and cold-air drainage flow overnight.

Illawarra in poor dispersion conditions

- The observation of high readings of sulfur dioxide around Wollongong are consistent with Port Kembla emissions fumigating to the ground there in the late morning, as south-southwesterly offshore winds are displaced by an onshore southeasterly sea breeze.

Newcastle in poor dispersion conditions

- When northwesterly synoptic winds change to a southerly direction, emissions from Newcastle can be returned onshore as a result of the combined effect of southerly synoptic flow and a northeasterly sea breeze.

5. CONCLUSIONS ON PROGNOSTIC MODELLING

- The uncertainty in specifying surface synoptic meteorological data on high pollution days is very large (no better that approximately 2 m s^{-1} and 25°)—it is even larger aloft.

- While verification of LADM performance has been possible, absence of upper air data in key regions has left major predictions unvalidated.

- Even without assimilation of observational data, the ability of LADM to predict local winds and temperatures must be rated as very good.

- For smog modelling, where prediction of trajectories is required, it may well be that the necessary accuracy can only be achieved by incorporating observed surface and upper-air winds.

6. ACKNOWLEDGMENTS

This work was done as part of the MAQS consultancy led by Coffey Partners International, and was funded by EPAN. LADM modelling was performed in close association with, and depended on, data analysis and characterisation of event days by Dr. Robert Hyde and Ms. Margaret Young of Macquarie University, as part of the Meteorology - Air Movements Task.

7. REFERENCES

Boers, R.E. and R.M. Mitchell, Absorption feedback in stratocumulous clouds: influence on cloud top albedo, *Tellus*, **46A**, 229-241, 1994.

Hurley, P.J. and R.E. Boers, The effect of cloud cover on surface net radiation: simple formulae for use in mesoscale models, Submitted to *J. Appl. Meteorol.*, July 1995.

Hutchinson, M.F. and T.I. Dowling, A continental hydrological assessment of a new grid-based digital elevation model of Australia, *Hydrological Processes*, **5**, 45-58, 1991.

Hyde, R. and G.M. Johnson, Pilot Study: Evaluation of air quality issues for the development of Macarthur South and South Creek Valley regions of Sydney, *CSIRO MRL Investigation Report RIR 1885R*, 182 pp, 1990.

Manins, P.C., Physick, W.L., Hurley, P.J. and J.A. Noonan, The role of coastal terrain in the dispersion of pollutants from Australia's major cities, In *Clean Air '94: proceedings of the* Clean *Air Society of Australia and New Zealand 12th International Conference & 6th Regional Conference of the IUAPPA*, **2**, Perth. 179-188. Canning Bridge, W. A.: Promaco Conventions for the Society, 1994.

Manins P.C. and B.L. Sawford, Mesoscale observations of upstream blocking. *Quart. J. R. Met. Soc.*, **108**, 427-434, 1982.

Physick W.L., LADM (Lagrangian Atmospheric Dispersion Model), *Clean Air (Australia)*. **27**, 172-175, 1993.

Physick W.L., J.A. Noonan, J.L. McGregor, P.J. Hurley, D.J. Abbs and P.C. Manins, LADM: A Lagrangian Atmospheric Dispersion Model, *CSIRO Division of Atmospheric Research Technical Report No. 24*, 137 pp, 1994.

Stauffer D.R. and N.L. Seaman, Multiscale four dimensional data assimilation, *J. Appl. Meteorol.*, **33**, 416-434, 1994.

Stauffer D.R., Seaman N.L. and F.S. Binkowski, Use of four dimensional data assimilation in a limited area mesoscale model. Part I: Effects of data assimilation within the planetary boundary layer. *Monthly Weather Review*, **119**, 734-754, 1991.

Persistent Organic Pollutants (POPs) in Free Range Chicken Eggs from Western Balkan Countries: Bosnia and Herzegovina, Montenegro and Serbia 2014 – 2015

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Persistent Organic Pollutants

in Free Range Chicken Eggs from Western Balkan Countries

Bosnia and Herzegovina, Montenegro and Serbia / 2014–2015

ARNIKA

CENTRUM PRO PODPORU OBČANŮ

TRANSITION

Persistent Organic Pollutants

in Free Range Chicken Eggs from Western Balkan Countries

Million tons of steels per year is produced by ArcelorMittal in Zenica, Bosnia and Herzegovina. The levels of dust in air are 30 fold higher than in central London.

Photo: Adéla Turková / Arnika

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Persistent Organic Pollutants (POPs) in Free Range Chicken Eggs from Western Balkan Countries

Bosnia and Herzegovina, Montenegro and Serbia 2014 – 2015

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Read more: http://english.arnika.org

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Giant thermal power plant in Tuzla, Bosnia and Herzegovina, consuming from 3 to 4 million tons of lignite anually, is surprisingly not equipped by desulphurisation filters.

Photo: Jana Sobotková, Arnika

1. INTRODUCTION

Free range chicken eggs were used for monitoring levels of contamination by POPs at certain places in many previous studies (Pless-Mulloli, Schilling et al. 2001, Pirard, Focant et al. 2004, DiGangi and Petrlík 2005, Shelepchikov, Revich et al. 2006, Aslan, Kemal Korucu et al. 2010, Arkenbout 2014). Eggs have been found to be sensitive indicators of POP contamination in soils or dust and are an important exposure pathway from soil pollution to humans, and eggs from contaminated areas can readily lead to exposures which exceed thresholds for the protection of human health (Van Eijkeren, Zeilmaker et al. 2006, Hoogenboom, ten Dam et al. 2014, Piskorska-Pliszczynska, Mikolajczyk et al. 2014). Chickens and eggs might therefore be ideal "active samplers" and indicator species for evaluation of the level of contamination of sampled areas by POPs, particularly by dioxins (PCDD/Fs) and PCBs. Based on this assumption, we have chosen sampling of free range chicken eggs and their analyses for selected POPs as one of the monitoring tools within the projects "Legal Protection of Environmental Pollution Victims and Transfer of Experience from the Czech Republic" and "Arnika Regional & International Support for a Toxic Free Future" in three Balkan states.

The data and analyses of free range chicken eggs discussed in this report were obtained during a two-year joint project of Bosnian and Czech NGOs, and a yearlong joint monitoring project by Bosnian, Montenegrin, Serbian and Czech NGOs. They were obtained during field visits in 2014 and 2015, as in cases of the reports by Dvorská (2015) or Šír (2015). The sampled localities were chosen as those where selected sources of pollution by POPs were expected such as metallurgical plants, coal-fired power plants, and waste disposal sites.

2. SAMPLING AND ANALYTICAL METHODS

Samples of free range chicken eggs were collected at two locations in Bosnia and Herzegovina, two locations in Montenegro – of which one was expected to be clean – and finally one location in Serbia. Pooled samples of more individual egg samples were collected at each of the selected sampling sites in order to get more representative samples. Table 1 summarizes basic data about the size of samples and measured levels of fat content in each of the pool samples. Thirteen pool samples of free range chicken eggs were taken in total. One sample was taken in 2014 and twelve samples in 2015. A sample of cheese was taken in addition to the free range chicken eggs in Pljevlja, Montenegro in 2015.

Free range chicken eggs determined for analysis of PCDD/Fs and dioxin-like PCBs using the DR CALUX® method were sent to a Dutch ISO 17025 certified laboratory (BioDetection Systems B.V., Amsterdam). The procedure for the BDS DR CALUX bioassay has previously been described in detail (Besselink H 2004) but, briefly, H4IIE cells stably transfected with an AhR-controlled luciferase reporter gene construct were cultured in α-MEM culture medium supplemented with 10% (v/v) FCS under standard conditions (37°C, 5% CO2, 100% humidity). Cells were exposed in triplicate on 96-well microtiter plates containing the standard 2,3,7,8-TCDD calibration range, a DMSO blank. Following a 24 hour incubation period, cells were lysed. A solution containing luciferin (Glow Mix) was added and the luminescence was measured using a luminometer (Berthold Centro XS3).

The DR CALUX bioassay method is proven for screening analyses which can give a good picture about the level of pollution[1]; however, for confirmation it is necessary to go for more specific PCDD/Fs and DL PCBs congener analyses, which also allows examination of finger prints of dioxins (PCDD/F congener patterns), specific for different sources of pollution. Most of the samples were analyzed for content of individual PCDD/Fs and an extended list of PCB congeners by HRGC-HRMS at the accredited laboratories Axys Varilab and of the State Veterinary Institute in Prague, Czech Republic.

The egg samples were also analyzed for content of non-dioxin-like PCBs and OCPs in Czech certified laboratories (University of Chemistry and Technology, Department of Food Chemistry and Analysis and Axys Varilab). The analytes were extracted by a mixture of organic solvents hexane: dichloromethane (1:1). The extracts were cleaned by means of gel permeation chromatography (GPC). The identification and quantification of the analyte was conducted by gas chromatography coupled with tandem mass spectrometry detection in electron ionization mode.

The mercury content in the samples was analyzed with atomic absorption spectrometry in an Advanced Mercury Analyser (AMA 254, Altec) using standard operating procedure SOP 70.4 (AAS-AMA) at the State Veterinary Institute, Prague.

1 "Bioanalytical methods" means methods based on the use of biological principles like cell-based assays, receptorassays or immunoassays. They do not give results at the congener level but merely an indication of the TEQ level, expressed in Bioanalytical Equivalents (BEQ) to acknowledge the fact that not all compounds present in a sample extract that produce a response in the test may obey all requirements of the TEQ-principle. European Commission (2012). Commission Regulation (EU) No 252/2012 of 21 March 2012 laying down methods of sampling and analysis for the official control of levels of dioxins, dioxin-like PCBs and non-dioxin-like PCBs in certain foodstuffs and repealing Regulation (EC) No 1883/2006 Text with EEA relevance European Commission. Official Journal of the European Communities: L 84, 23.83.2012, p. 2011–2022.

In the village of Tetovo, Bosnia and Herzegovina, people keep chicken in their yards distant just few hundred meters from huge steelworks of ArcelorMittal.

Photo: Adéla Turková / Arnika

Table 1: Overview of free range chicken egg samples from selected sites in three Western Balkan states.

No	Sample	Locality	Country	Month of sampling	Number of eggs in pooled samples	Fat content
1	ZEN-1	Podbrežje (Zenica)	Bosnia and Herzegovina	01/2014	10	11.15
2	ZEN-15/1	Gračanica (Zenica)	Bosnia and Herzegovina	04/2015	5	15.7
3	ZEN 15/2 and 15/4	Tetovo (Zenica)	Bosnia and Herzegovina	04/2015	11	14.1
4	ZEN 15/3	Donja Gračanica (Zenica)	Bosnia and Herzegovina	04/2015	6	11.5
5	ZEN 15/5	Donja Vraca (Zenica)	Bosnia and Herzegovina	04/2015	6	15.6
6	BiH-E-01	Divkoviči I (Tuzla)	Bosnia and Herzegovina	04/2015	6	12.3
7	BiH-E-02	Divkoviči II (Tuzla)	Bosnia and Herzegovina	04/2015	5	15.6
8	PLZ-E1+E2+E3	Plužine – Orah	Montenegro	04/2015	3	12.5
9	PLZ-E4+E5+E6	Plužine – Seoce	Montenegro	04/2015	3	10.6
10	PLJ-EGGS-01	Pljevlja	Montenegro	04/2015	2	10.2
11	SRB-EGG-01	Grabovac I (Obrenovac)	Serbia	04/2015	2	13.6
12	SRB-EGG-02 and 03	Grabovac II (Obrenovac)	Serbia	04/2015	4	12.6
13	SRB-EGG-04, 05 and 06	Ušće – Gorjača – Gola bara (Obrenovac)	Serbia	04/2015	6	17.2
14	MN 17 (cheese)	Pljevlja	Montenegro	04/2015	-	32.2

Figure 1: Location of the chosen hot spots on a map of Bosnia and Herzegovina, Montenegro, and Serbia. The hot spots Obrenovac (Serbia), Pljevlja (Montengero), Tuzla, and Zenica (both Bosnia and Herzegovina) are marked by red flags together with the chosen background location Plužine (Montenegro).

3. DESCRIPTION OF HOT SPOTS

The four locations chosen for sampling (Obrenovac, Pljevlja, Tuzla and Zenica) are located in different parts of three Western Balkan states – Bosnia and Herzegovina, Montenegro and Serbia. Three of these locations were chosen as there was larger sampling of soil, sediments, vegetable and fish in relation to coal burning power plants in Obrenovac, Pljevlja and Tuzla. The Stockholm Convention has identified coal burning power plants as a sector *"for comparatively high formation and release"* of persistent organic pollutants such as dioxins, furans, PCBs, hexachlorobenzene, and pentachlorobenzene.[2] More information about these thermal power plants can be found e.g. in Šír (2015). There are more industrial facilities potentially releasing POPs in Tuzla in addition to the power plant, such as for example chlorine chemical industry and others. The fourth location, Zenica, was chosen as there is large steel mill, whose majority owner is the ArcelorMittal corporation. All hot spots were chosen as potential sources of POPs releases.

3.1. Obrenovac

Obrenovac is a town and municipality in northern Serbia. In 2011 the town had a population of 24,568, and the municipality had 71,419 inhabitants. Obrenovac is one of 17 municipalities that make up the greater Belgrade area. The largest Serbian thermal power plant is located on the outskirts of the town. Obrenovac was submerged and completely evacuated during the 2014 Southeast Europe floods (Wikipedia 2015).

2 Stockholm Convention Annex C, Part II

The samples in the Obrenovac area were collected in the surroundings of the Nikola Tesla B power plant and its ash landfill (see map in Figure 2). The Nikola Tesla power plants are located on the right bank of the river Sava, approximately 40 km upstream from Belgrade, near the town of Obrenovac. Nikola Tesla A is by far the largest one in Serbia: it has six blocks with a total installed capacity of 1,650 MW while Nikola Tesla B has two units with a total of 1,240 MW. The ash landfill contains a suspension of ash and water, which sometimes overflows and drains into the river Sava. In addition to the impact on water pollution, landfills represent a surface source of air pollution particles of ash. Due to the unfavourable physical and chemical characteristics of ash and of the way that ash disposal is carried out in open dumps, in dry and windy weather wind erosion of ash occurs. These power plants use lignite mined from the Kolubara mine basin as fuel.

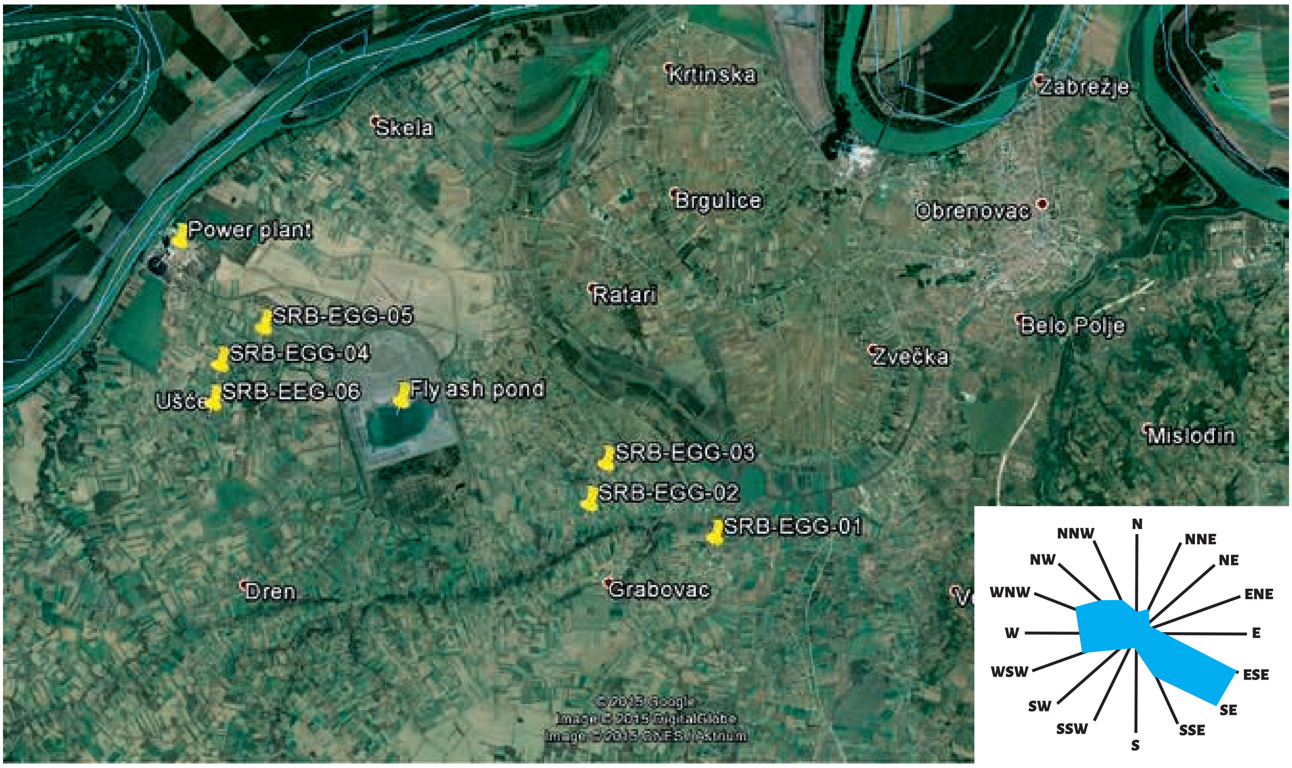


Figure 2: Location of samples taken in the surroundings of Obrenovac, Serbia, on a Google Earth map with a wind rose for this region (on the bottom part of the figure).

In rural areas of Western Balkan, many people consume own chicken eggs daily; surpluses are often sold at local markets. *Photo: Adéla Turková / Arnika*

3.2. Pljevlja

Pljevlja is a town and the centre of Pljevlja Municipality located in the north of Montenegro. The town lies at an altitude of 770 m. In 2011, the municipality of Pljevlja had a population of 30,786, while the town itself had a population of about 19,489. The municipality borders with the republics of Serbia and Bosnia and Herzegovina. With a total area of 1,346 km², it is the third largest municipality in Montenegro. Pljevlja is also one of the main economic centres of Montenegro. The only thermal power plant in Montenegro, which provides 45% of the electric power supply for Montenegro, is situated just outside Pljevlja as well as a coal mine with 100 % of the coal production in Montenegro (Wikipedia 2015). The sample in Pljevlja was taken 100 m from the ash deposit of the thermal power plant, which is 3 km southwest from the town of Pljevlja. After a reconstruction carried out 2009, the new power of the thermal power plant is 218.5 MW. Pljevlja I is fuelled by coal strip mines. The plant annually consumes an average of 1.35 million tonnes of coal, 3,500 tons of fuel oil and 660 tonnes of chemicals (lime, hydrochloric acid, alkali, etc.). Power plant flue gas is separated into the atmosphere through a 252 m high chimney. Its outlet exceeds 1,000 m above sea level. The power plant is supplied from the Coal Mine A.D. Pljevlja.

3.3. Tuzla

Tuzla city, the seat of the Tuzla Canton, is the third largest city in Bosnia and Herzegovina after Sarajevo and Banja Luka. The city is home to more than 80,000 inhabitants and represents the economic and scientific centre of north-eastern Bosnia.

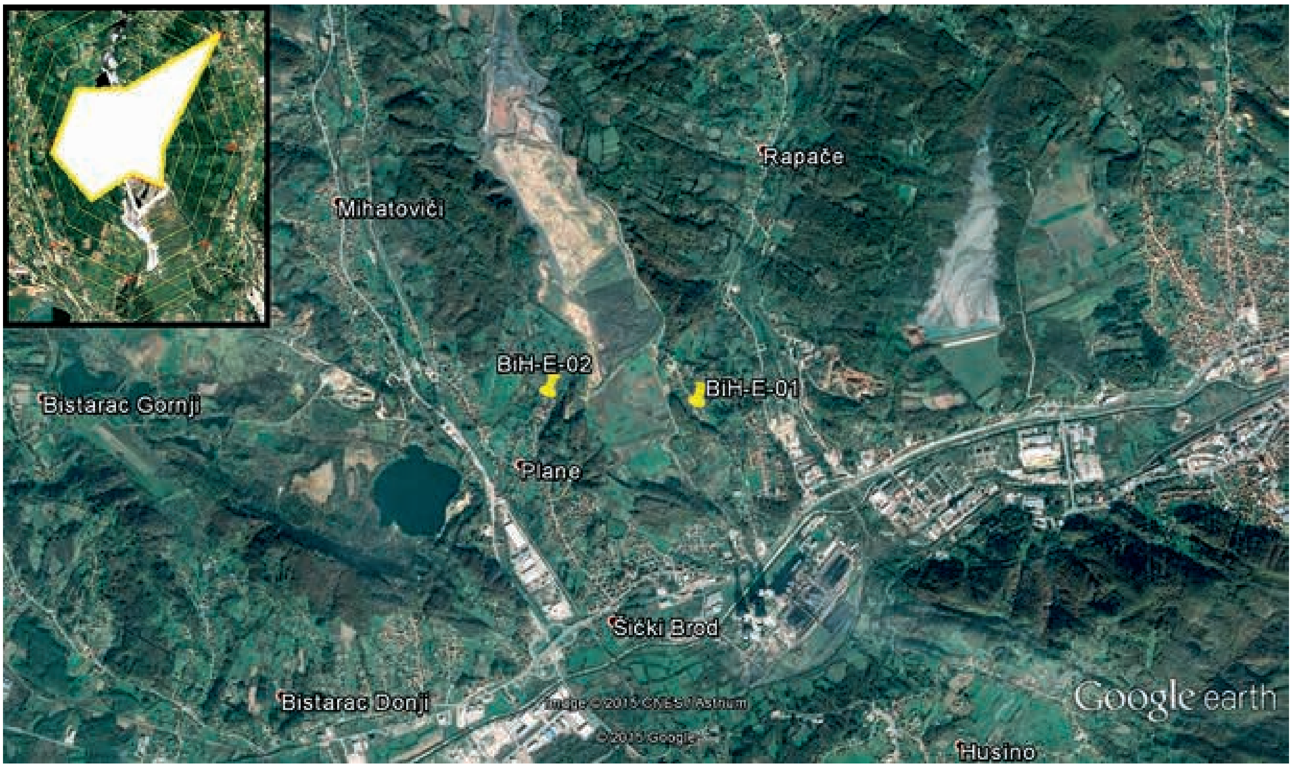


Figure 3: Location of samples taken in the surroundings of Tuzla, Bosnia and Herzegovina on a Google Earth map with a wind rose for this region (on the upper part of the figure).

Samples were taken close to one of the ash ponds on the edge of Tuzla as is visible on the map (see map at Figure 3). The ash pond serves Tuzla Power station which is the largest coal-fired power plants in Bosnia and Herzegovina. The power station has an installed electric capacity of 715 MW (without two 32 MW units that do not operate) and it produces around 3.1 TWh of electricity per year. In addition, it supplies heat for Tuzla and Lukavac. The plant burns 330,000 tonnes of coal annually. Units 1-6 are supplied from the Kreka and Banovići mines.

3.4. Zenica

Zenica is the fourth biggest city in Bosnia and Herzegovina. It lies in Zenica-Doboj Canton, 70 km from Sarajevo on the river Bosna. Zenica is home to around 73,000 inhabitants. The steelworks in Zenica was a state-owned factory built by the Socialist government. The steelworks, which extends over almost 30 km^2, employs around 3,000 people (before the war the production provided 22,000 working places for people from a wider area). The production capacity is 1 million tonnes annually. The direct negative impact of whole the industrial complex in Zenica affects the health and life of more than 130,000 people (Arnika – Citizens Support Centre 2015).

Samples were taken in the surroundings of the steelworks (see maps at Figures 5 and 6, page 15).

4. THE WESTERN BALKAN STATES, EU, AND OTHER LIMITS FOR POPS IN EGGS

Chicken eggs are a quite common part of the diet in many countries including the Western Balkan states. It is also common that people raise their own chicken and partly sell surplus chicken eggs at markets as raw eggs or as food in public restaurants. Limits for POPs in chicken eggs applied in Bosnia and Herzegovina are summarized in Table 2. There is same limit value for PCDD/Fs and PCBs in Bosnia and Herzegovina as in the EU (Bosnia and Herzegovina 2014)(see Table 2). This applies also to limit values for OCPs like DDT or HCHs. For mercury we found for example the limit value used in Kazakhstan. There is no limit set up for mercury content in eggs within the EU or in the three Western Balkan countries in which the egg samples presented in this study were collected.

Table 2: Limit concentration values for OCPs, mercury, PCBs and PCDD/Fs TEQs in chicken eggs

	Hen eggs		
	EU ML[2]	EU MRL[3]	KazakhMAC[7]
Unit	pg g^{-1} fat	ng g^{-1} fat	ng g^{-1} *
WHO-PCDD/Fs TEQ	2.5		
WHO-PCDD/Fs-dl-PCB TEQ	5.0		
PCBs[5]	40		
DDT total[6]		50	
γ-HCH (lindane)		10	
α-, β-HCH		20, 10**	
HCB		20	
Mercury			20

2 EU Regulation (EC) N°1259/2011
3 Regulation (EC) N°149/2008. Maximum residue level (MRL) means the upper legal level of a concentration for a pesticide residue in or on food or feed set in accordance with the Regulation, based on good agricultural practice and the lowest consumer exposure necessary to protect vulnerable consumers.
5 sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180
6 sum of p,p´-DDT, o,p´-DDT, p,p´-DDE and p,p´-DDD
7 Kazakhstan SanPin Hygienic safety requirement and nutrition value for food from 11.06.2003 .
* not clear whether calculated for fat content or not
** for each congener is MRL set separately

5. RESULTS

The results of the analyses by using DR CALUX are summarized in Table 3. The results of the analyses for other POPs and congener analyses by using HRGC-HRMS are summarized in Table 4. There are also few results for analyses of mercury content in selected samples of eggs in Table 4. The graph in Figure 7 compares the results of the analyses for 6 PCB indicator congeners. The graph also shows a comparison with the EU limit value for PCB content in chicken eggs. Free range chicken eggs from Belarus, China and Kazakhstan were also analyzed using the same methods (Petrlík, Kalmykov et al. 2015). So we can compare data from the hot spots in three Balkan states with similar locations in other countries as well. The results for DDT on a fresh weight basis are summarized in Table 6 and compared with the respective EU limit value.

5.1. Dioxins (PCDD/Fs) and dioxin-like PCBs measured by DR CALUX

Some samples of chicken eggs collected at hot spots in Western Balkan states during field visits in 2015 were screened for dioxins and dioxin-like PCBs by using the DR CALUX method in the BDS laboratory, Amsterdam. The results are summarized in Table 3.

Table 3: Results of DR CALUX bioassay analyses for both PCDD/Fs and DL PCBs for samples from Bosnia and Herzegovina, Montenegro and Serbia. Data are in pg BEQ g^{-1} fat.

Sample	Locality	Country	PCDD/Fs and DL PCBs (DR CALUX)	PCDD/Fs (DR CALUX)
ZEN-15/1	Gračanica (Zenica)	Bosnia and Herzegovina	12	8.8
BiH-E-01	Divkoviči I (Tuzla)	Bosnia and Herzegovina	7.7	5.6
BiH-E-02	Divkoviči II (Tuzla)	Bosnia and Herzegovina	6.5	4.3
PLZ-E1+E2+E3	Plužine – Orah	Montenegro	0.98	0.34
SRB-EGG-02 and 03	Grabovac II (Obrenovac)	Serbia	7.0	5.2
SRB-EGG-04, 05 and 06	Ušće – Gorjača – Gola Bara (Obrenovac)	Serbia	4.4	2.2

When PCDD/Fs levels determined by the DR CALUX method are discussed, the following has to be considered. This cell based reporter gene assay is a validated method for screening for PCDD/Fs and DL PCB contents in food according to EU Commission Regulation EC/252/2012 (European Commission 2012). Screening methodologies are usually used to exempt those samples that are below the maximum permitted limit (i.e. that are compliant with the limit) and that can, therefore, be released to the market. In addition, one needs to select those samples that require confirmation (i.e. are suspected to be non-compliant) of their PCDD/Fs TEQ level. When bioassays are used as screening tools, the interpretation of the obtained results should consider the higher variability associated with them (van Overmeire, van Loco et al. 2004, Gasparini M 2011).

Six pool egg samples were analyzed using the DR CALUX method for determination of dioxin activity in total. Among those only two samples, one from Plužine and one pooled sample from Ušće – Gorjača – Gola Bara in Obrenovac region were below limits set up by the EU also used for consideration of results obtained by DR CALUX analyses. All other four samples were above 5 pg BEQ g^{-1} fat level for total PCDD/Fs and DL PCBs content. The highest level of 12 was measured in chicken eggs from Gračanica near Zenica, east of the metallurgical plant. The level observed in these eggs is comparable with some samples from Balkhash, Kazakhstan, however in some pooled samples of chicken eggs collected there were also much higher levels of PCDD/Fs and DL PCBs measured by DR CALUX method at some sites in Balkhash (Petrlík, Kalmykov et al. 2015).

5.2. Dioxins (PCDD/Fs), PCBs and other POPs measured by gas chromatography methods

GCMS-HRMS analyses were chosen for bigger number of pooled chicken egg samples. All samples were also analyzed for other POPs, group of OCPs: hexachlorobenzene (HCB), hexychlorocyclohexanes (HCHs) and DDT and its metabolites. HCB is also considered to be unintentionally produced POP (U-POP) in the same processes as dioxins and DL PCBs (Stockholm Convention on POPs 2008), although it is commonly measured together with other OCPs. Nine pooled samples of eggs were analyzed for PCDD/Fs and DL PCBs in total and twelve samples of eggs and one cheese sample for other POPs. Nine samples, including cheese were also measured for mercury content. The results are summarized in Table 4.

Table 4: Summarized results of analyses for POPs and mercury for thirteen pooled free range chicken eggs samples and one cheese sample. There are also EU limit values for comparison. ***(Table continues on page 13.)***

Locality	Podbrežje (Zenica)	Gračanica (Zenica)	Tetovo (Zenica)	Donja Gračanica (Zenica)	Donja Vraca (Zenica)	Divkoviči I (Tuzla)	Divkoviči II (Tuzla)	Plužine – Orah	Plužine – Seoce
Sample	ZEN 1	ZEN 15/1	ZEN 15/2 + ZEN 15/4	ZEN 15/3	ZEN 15/5	BiH-E-01	BiH-E-02	PLZ-E1+E2+E3	PLZ-E4+E5+E
Fat content	11.15	15.7	14.1	11.5	15.6	12.3	15.6	12.5	10.6
PCDD/Fs (pg WHO TEQ g^{-1} fat)	1.93	2.40	5.57	4.73	3.86	2.51	NA	NA	NA
DL PCBs (pg WHO TEQ g^{-1} fat)	5.15	1.55	3.09	3.56	3.75	1.56	NA	NA	NA
Total PCDD/F + DL PCBs (pg WHO TEQ g^{-1} fat)	7.08	3.95	8.66	8.29	7.61	4.07	NA	NA	NA
PCDD/Fs and DL PCB (DR CALUX); (pg BEQ g^{-1} fat)	NA	NA	12	NA	NA	NA	6.5	0.98	NA
PCDD/Fs (DR CALUX); (pg BEQ g^{-1} fat)	NA	NA	8.8	NA	NA	NA	4.3	0.34	NA
HCB (ng g^{-1} fat)	<1.00	1.13	1.18	1.06	2.65	1.55	1.52	2.27	1.36
7 PCB (ng g^{-1} fat)	NA	2.97	12.78	14.69	14.45	NA	16.67	0.73	5.21
6 PCB (ng g^{-1} fat)	NA	2.31	10.03	12.97	12.62	19.38	15.06	0.59	3.01
sum HCH (ng g^{-1} fat)	NA	0.35	2.51	0.27	0.12	0	3.23	0.54	0
sum DDT (ng g^{-1} fat)	NA	3.81	341	144.6	172.73	6.85	933.48	1.83	0
Hg (ng g^{-1})	NA	NA	NA	NA	NA	14	3	1	1

Free range eggs have been found to be sensitive indicators of contamination in soils and are an important exposure pathway from soil pollution to humans.

Photo: Adéla Turková / Arnika

Locality	Pljevlja	Grabovac I (Obrenovac)	Grabovac II (Obrenovac)	Ušće – Gorjača – Gola Bara (Obrenovac)	Pljevlja	EU stand.
Sample	PLJ-EGGS-01	SRB-EGG-01	SRB-EGG-02 + SRB-EGG-03	SRB-EGG-04 + 05 + 06	MN cheese	
Fat content	10.2	13.6	12.6	17.2	32.2	
PCDD/Fs (pg WHO TEQ g-1 fat)	0.20	11.14	3.31	NA	NA	2.50
DL PCBs (pg WHO TEQ g-1 fat)	0.06	2.38	1.58	NA	NA	
Total PCDD/F + DL PCBs (pg WHO TEQ g-1 fat)	0.26	13.51	4.89	NA	NA	5.00
PCDD/Fs and DL PCB (DR CALUX); (pg BEQ g-1 fat)	NA	NA	7.0	4.4	NA	5.00
PCDD/Fs (DR CALUX); (pg BEQ g-1 fat)	NA	NA	5.2	2.2	NA	2.50
HCB (ng g-1 fat)	0.43	5.39	2.12	1.73	4.4	20.00
7 PCB (ng g-1 fat)	0	5.22	1.64	5.45	0	-
6 PCB (ng g-1 fat)	0	2.06	1.13	2.9	0	40.00
sum HCH (ng g-1 fat)	0.24	0.55	0.57	0.68	0.26	-
sum DDT (ng g-1 fat)	5.14	84.2	106.95	119.2	6.91	-
Hg (ng g-1)	2	1	2	3	1	-

5.3. Dioxins (PCDD/Fs) and dioxin-like PCBs (DL PCBs)

Dioxins belong to a group of 75 polychlorinated dibenzo-p-dioxin (PCDD) congeners and 135 polychlorinated dibenzofuran (PCDF) congeners, of which 17 are of toxicological concern. Polychlorinated biphenyls (PCBs) are a group of 209 different congeners which can be divided into two groups according to their toxicological properties: 12 congeners exhibit toxicological properties similar to dioxins and are therefore often referred to as 'dioxin-like PCBs' (DL PCBs). The other PCBs do not exhibit dioxin-like toxicity but have a different toxicological profile and are referred to as 'non dioxin-like PCB' (NDL PCBs) (European Commission 2011). Levels of PCDD/Fs and DL PCBs are expressed in total WHO-TEQ calculated according toxic equivalency factors (TEFs) set by WHO experts panel in 2005 (Van den Berg, Birnbaum et al. 2006). These new TEFs were used to evaluate dioxin-like toxicity in nine pooled samples of chicken eggs from three Balkan states.

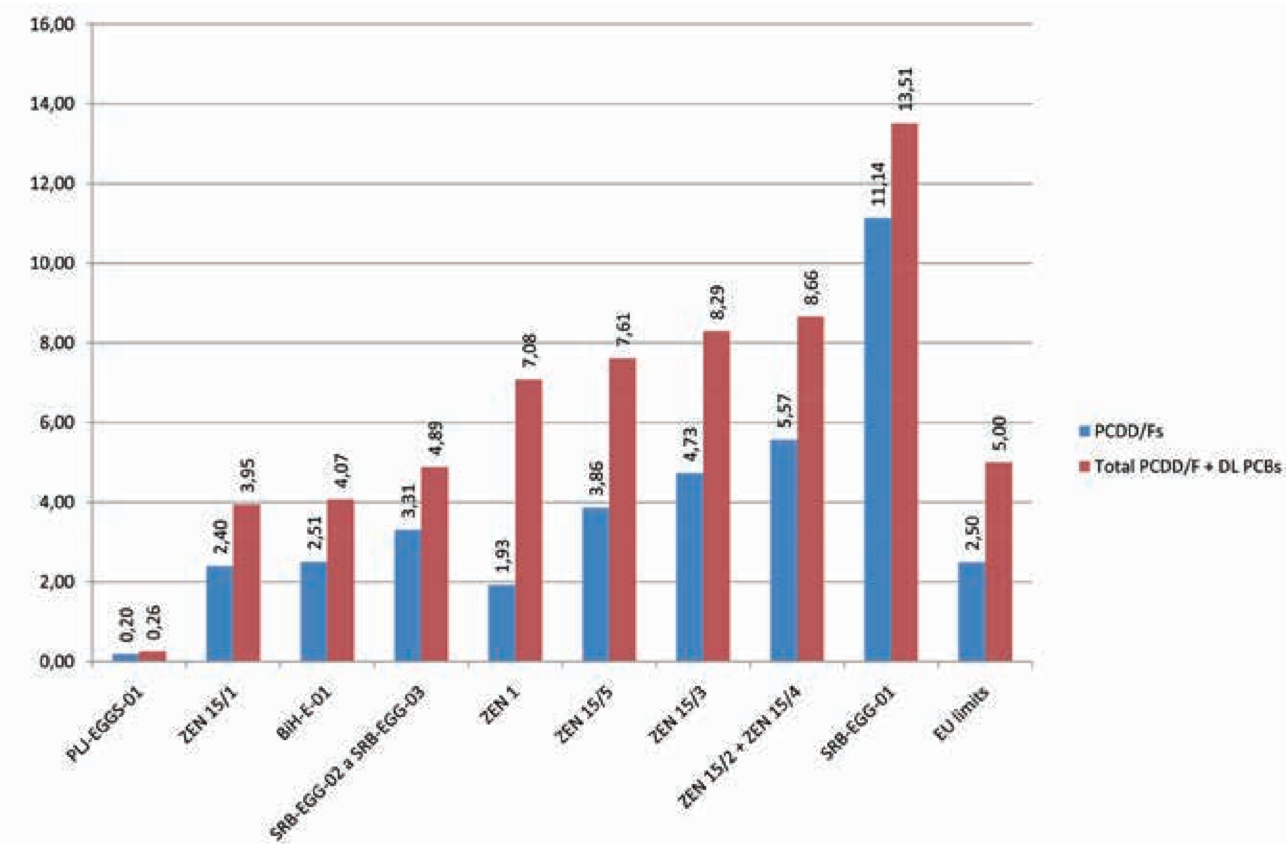


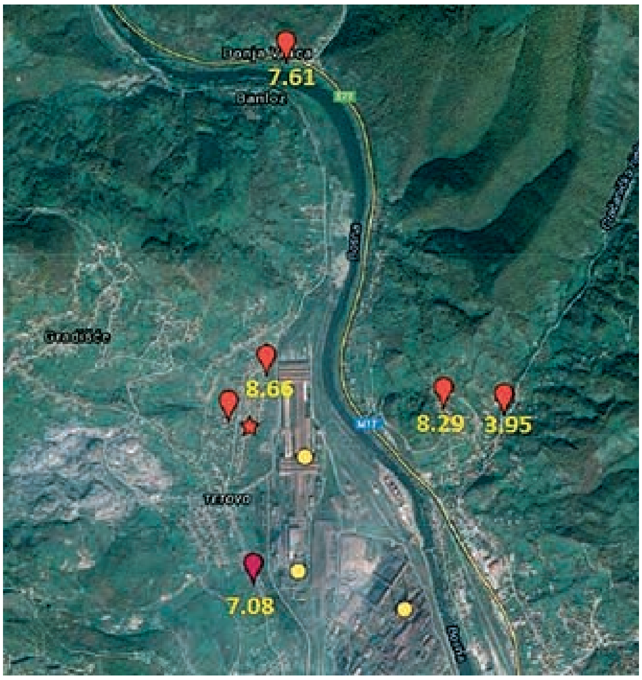
Figure 4: Graph showing comparison of total PCDD/Fs + DL PCBs, and PCDD/Fs only in pg WHO-TEQ g⁻¹ of fat for different pooled chicken eggs samples from Zenica (Bosnia and Herzegovina), Tuzla (Bosnia and Herzegovina), Pluzine (Montenegro, background location) and Obrenovac (Serbia), measured by GCMS – HRMS.

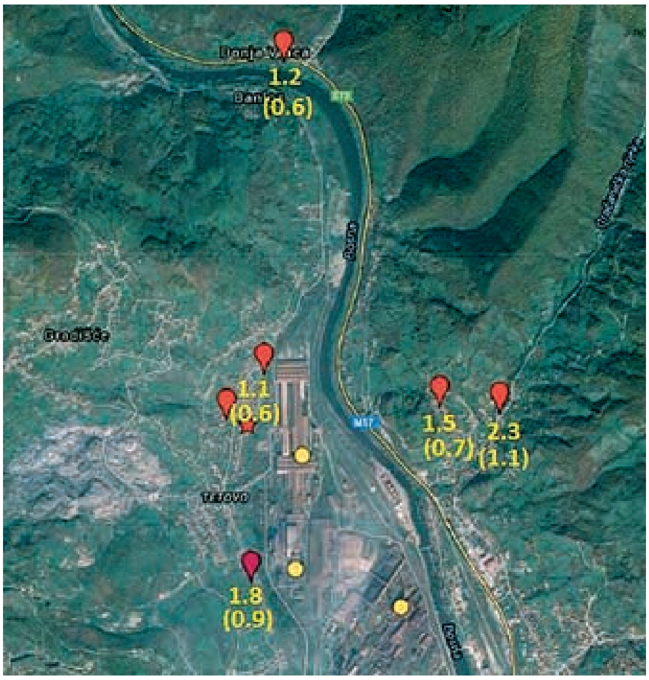
Six out of nine samples from Western Balkan states exceeded the EU ML of PCDD/Fs congeners in chicken eggs, (compare Tables 4 and 2 and see graph at Figure 4) and five samples exceeded the EU limit value for both PCDD/Fs and DL PCBs in chicken eggs (European Commission 2011). The background levels for PCDD/Fs and DL PCBs measured in chicken eggs from Pljevlja were 0.20 and 0.06 pg WHO-TEQ g^{-1} fat, respectively (see also the discussion about background levels further in chapter 4.1). The highest level of dioxins (11.14 pg WHO-TEQ g^{-1} fat) was measured in the sample from the Grabovac I site, near Obrenovac, and the second highest level (5.57 pg WHO-TEQ g^{-1} fat) was measured in the sample from Tetovo (ZEN 15/2 + ZEN 15/4), near the steelworks of ArcelorMittal in Zenica. In both samples the toxicity of PCDD/Fs exceeded the total WHO-TEQ value for PCB congeners. Most of the egg samples showing high levels of total WHO-TEQ had a prevalence of PCDD/Fs share over DL PCBs on total WHO-TEQ, as shown by the graph in Figure 3. This doesn't apply to two samples from Zenica (ZEN 1 and ZEN 15/5).

We tried also to answer the question: How many free range chicken eggs can be eaten by an adult man or woman with an approximate body weight of 70 kg and how many of them can be eaten by a 10-year-old child with an approximate body weight of 35 kg? We stick to the lower bound of TDI of 1 pg WHO-TEQ/kg of body weight per day (van Leeuwen, Feeley et al. 2000) in our calculation, bearing in mind that dioxin and DL PCBs occur not only in eggs but also in other food according to data available for the region (Petrović, Jovanović et al. 2008, Aslan, Kemal Korucu et al. 2010). The calculation was made by using the following formula: N adult = 70 g WHO-TEQ / (pg WHO-TEQ g^{-1} fresh weight×50 g); N 10years = 35 g WHO-TEQ / (pg WHO-TEQ g^{-1} fresh weight×50 g). The results are summarized in Table 5. The calculations are based on the precondition that one chicken egg weight is on average 50 g and the TDI for PCDD/Fs and DL PCBs is within the range of 1 – 4 pg WHO-TEQ/kg of body weight per day (van Leeuwen, Feeley et al. 2000).

Table 5: Calculation of suggested maximum consumption of free range chicken eggs from pool samples by adults and/or 10-year-old children per day in order to meet the TDI lower bound level for PCDD/Fs and DL PCBs, which is 1 pg WHO-TEQ/kg body weight/day.

Sample	ZEN 1	ZEN 15/1	ZEN 15/2 + ZEN 15/4	ZEN 15/3	ZEN 15/5	BiH-E-01	PLJ-EGGS-01	SRB-EGG-01	SRB-EGG-02 + SRB-EGG-03
Fat content	11.2	15.7	14.1	11.5	15.6	12.3	10.2	13.6	12.6
pg TEQg^{-1} of fat	7.08	3.95	8.66	8.29	7.61	4.07	0.26	13.51	4.89
pg TEQg^{-1} fresh weight	0.79	0.62	1.22	0.95	1.19	0.50	0.03	1.84	0.62
pg TEQ in 1 egg	39.45	30.99	61.07	47.68	59.38	25.03	1.32	91.89	30.80
Number of eggs per adult / day	1.8	2.3	1.2	1.5	1.2	2.8	53	0.76	2.3
Number of eggs per 10 year old child / day	0.89	1.1	0.57	0.73	0.59	1.4	27	0.38	1.1





Figures 5 and 6: Locations of samples taken in the surroundings of Zenica on Google Earth map with marked levels of PCDD/Fs and DL PCBs measured in pooled chicken egg samples (on the left Figure 5) and maximum amount of eggs consumed per day in order to meet the WHO's TDI for adults and for 10-year- old children in brackets (on the right, Figure 6). For the explanation of the calculation see the text and Table 5.

Appart the eggs collected in Pljevlja, where the PCDD/Fs and DL PCBs were at a level considered as a background level in general (DiGangi and Petrlik 2005, Petrlík, Kalmykov et al. 2015), all other locatios showed considerably high levels of dioxins and dioxin-like PCBs and their consumption should be minimized. The most critical situation is in Grabovac I, where the calculation suggested that three quarters of an egg can be consumed per day by adults. The contamination of eggs from Zenica is also quite serious. Evaluation of levels of dioxin-like compounds in eggs from that area is shown on maps at Figures 5 and 6. It is clear that contamination of eggs is higher in the valley where the steelworks are located while the side of the valley has a slightly lower level of dioxin like compounds in free range chicken eggs.

The total WHO-TEQ levels of PCDD/Fs and DL PCBs in samples from selected hot spots in three Western Balkan states varies. The total WHO-TEQ level in the pooled egg sample from Pljevlja is comparable to those generally considered as background levels, as mentioned already above. The levels of PCDD/Fs and DL PCBs in one sample from Zenica (ZEN 15/1), one sample from Grabovac II in the Obrenovac area (SRB-EGG-02 + SRB-EGG-03) as well as in a sample from Tuzla – Divkoviči I (BiH-E-01) were below the EU MAC and are not considered as high, however the level of PCDD/Fs expressed in the WHO-TEQ from Tuzla exceeded very slightly the EU MAC set just for PCDD/Fs. The samples from Zenica and Obrenovac belong to those with quite elevated levels of PCDD/Fs and DL PCBs in comparison with the collection of samples from IPEN´s The Egg Report from 2005, and comparable with samples from Bolshoy Trostenec, Belarus (waste dumpsite), Barangay Aguado, Philippines (medical waste incinerator), Santos, Mozambique (cement kiln) or Mossville, USA (petrochemical complex) (DiGangi and Petrlik 2005, IPEN Dioxin PCBs and Waste Working Group, Cavite Green Coalition et al. 2005, IPEN Dioxin PCBs and Waste Working Group, Foundation for Realizaiton of Ideas et al. 2005, IPEN Dioxin PCBs and Waste Working Group, JA! Justiça Ambiental et al. 2005, IPEN Dioxin PCBs and Waste Working Group, Mossville for Environmental Action Now et al. 2005). Putative sources of dioxin and dioxin-like PCBs contamination at selected Balkan hot spots are considered in the discussion section below.

5.4. Polychlorinated biphenyls (PCBs)

None of the thirteen free range chicken eggs samples from the hot spots in the three Balkan states exceeded the EU limit for 6 PCB indicator congeners in hen eggs. Elevated levels above 10 ng g^{-1} fat were observed in samples of eggs from Tuzla and Zenica. 6 PCB congeners in sample BiH-E-01 from Tuzla reached half of the EU limit (see the graph in Figure 7).

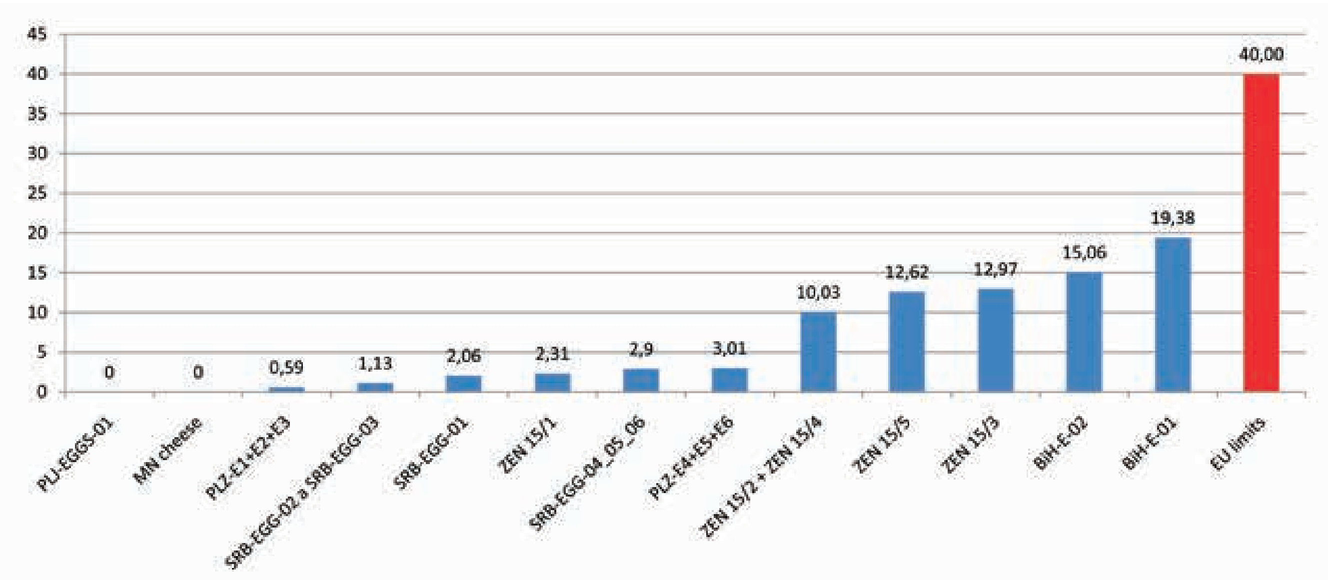


Figure 7: Graph comparing 6 PCB congener levels in different pooled chicken eggs samples from three Balkan states (full set of results is in Table 4).

5.5. Organochlorinated pesticides (OCPs)

EU limits for pesticide residues, including OCPs in chicken eggs, are set per fresh weight of egg. A comparison of DDT metabolites in twelve samples of chicken eggs and one cheese sample from Western Balkan states is in Table 6. The highest observed level of 4 DDT metabolites (145.44 ng g^{-1} f.w.) in eggs from Tuzla (BiH-E-02) was three times higher than the EU limit. DDT in eggs collected close to the steelworks in Zenica, Bosnia and Herzegovina was also very close to the limit value (47.71 ng g^{-1} f.w.). Significantly elevated levels of DDT were observed also in samples from the Obrenovac area, Serbia as well as from Zenica, Bosnia and Herzegovina (see Table 6).

The sum of α-HCH, γ-HCH, and β-HCH was within the range of 0.02 – 0.45 ng g^{-1} fresh weight. None of the samples exceeded EU limit values for individual congeners (10 – 20 ng g^{-1} fresh weight). The highest level of HCHs was measured in free range chicken eggs BiH-E-02 from Tuzla.

Table 6: Summarized results of analyses for DDT and its metabolites for twelve pooled free range chicken egg samples and one cheese sample from three Balkan states. There are also EU limit values (European Commission 2008) for comparison. These results are expressed in ng g-1 fresh weight because EU limits are set for fresh weight for OCPs.

Sample	ZEN 15/1	ZEN 15/2 + ZEN 15/4	ZEN 15/3	ZEN 15/5	BiH-E-01	BiH-E-02	PLZ-E1+E2+E3	PLZ-E4+E5+E6	PLJ-EGGS-01	SRB-EGG-01	SRB-EGG-02 + SRB-EGG-03	SRB-EGG-04 + 05 + 06	MN cheese
Sum of DDT	0.63	48.09	16.65	26.95	1.10	145.62	0.32	0.05	0.83	13.16	16.71	18.62	1.11
Sum of DDT (EU)	0.61	47.71	16.63	26.83	1.08	145.44	0.31	0.03	0.82	13.14	16.69	18.60	1.09

5.6. Mercury

The highest level of mercury (14 ng g^{-1} f.w.) was measured in the pooled eggs sample from Tuzla (BiH-E-01). This result complements findings by Šír (2015), that: *"Higher concentrations of heavy metals (nickel, chromium, cadmium, arsenic and mercury) in soils and sediments were found in the closer distance from the ash depositions …".* 14 ng g^{-1} is higher than the level of mercury measured in eggs from Rostovka close to the Nura river which is contaminated with mercury. Levels of mercury in other egg samples from Western Balkan states were much lower (see Table 4). The source of mercury contamination could be e.g. the chlor alkali plant in Tuzla or the coal-fired power plant.

6. DISCUSSION

6.1. Background levels of POPs in eggs

We did not analyse levels of unintentionally produced POPs in free range chicken eggs sample from Plužine, considered as a background location with regards to POPs, by using the GCMS – HRMS method[3] but there were low levels of dioxin, PCBs and HCB in eggs from the Pljevlja hot spot located in Montenegro. The levels of POPs in this sample were lower for PCDD/Fs and DL PCBs as well as for HCB, and NDL PCBs (DiGangi and Petrlík 2005), compared to those observed in the background samples from other studies of POPs in chicken eggs, although it does not come from a non-industrialized remote area. A comparable low level of PCDD/Fs + DL PCBs was measured for example in commercial eggs from Turkey (Aslan, Kemal Korucu et al. 2010), while a higher level of 0.90 pg WHO-TEQ g^{-1} of fat was observed in eggs from a supermarket obtained in Karaganda, Kazakhstan (Petrlík, Kalmykov et al. 2015). So we suggest considering levels of U-POPs observed in free range chicken eggs in Pljevlja as background levels for the region, while considering the levels of DDT 0; 1.83 ng g^{-1} of fat) and HCHs (0; 0.53 ng g^{-1} of fat) observed in two free range chicken eggs samples from Plužine as background levels for the region. HCB concentrations (1.36; 2.27 ng g^{-1} of fat) in the eggs from Plužine – Orah were higher, in comparison with sample from Pljevlja (0.43 ng g^{-1} of fat). Levels of PCDD/Fs and DL PCBs in eggs from Plužine (see chapter 3.1.) which were analysed only by using the DR CALUX method were comparable to the egg sample from the supermarket in Karaganda mentioned above.

3 PCDD/Fs and DL PCBs were measured by DR CALUX bisoassay method in eggs from Plužine (see chapter 3.1).

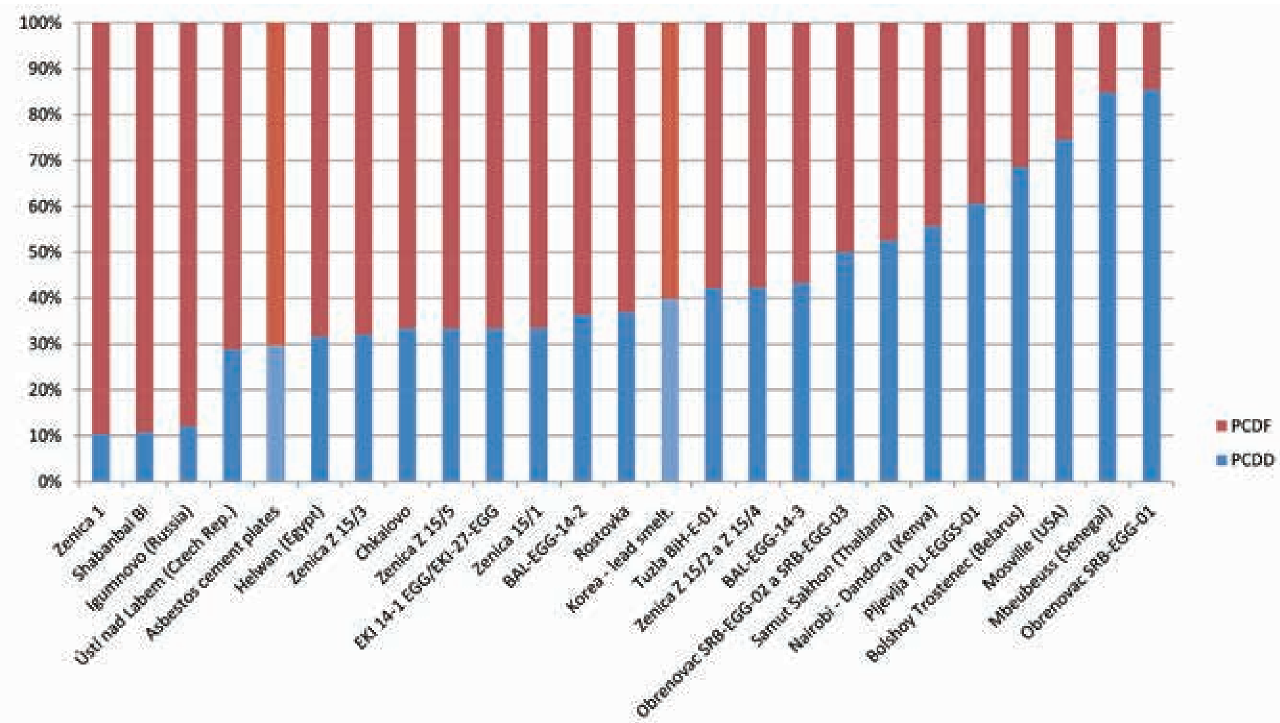
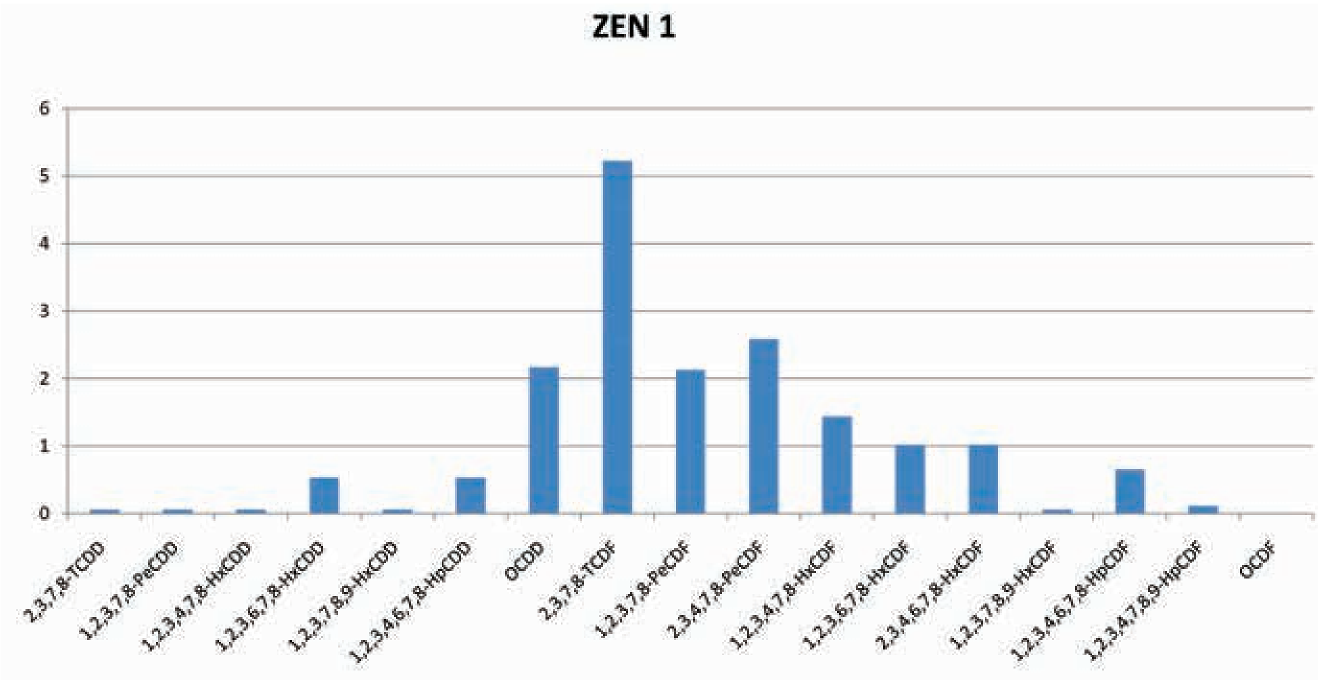
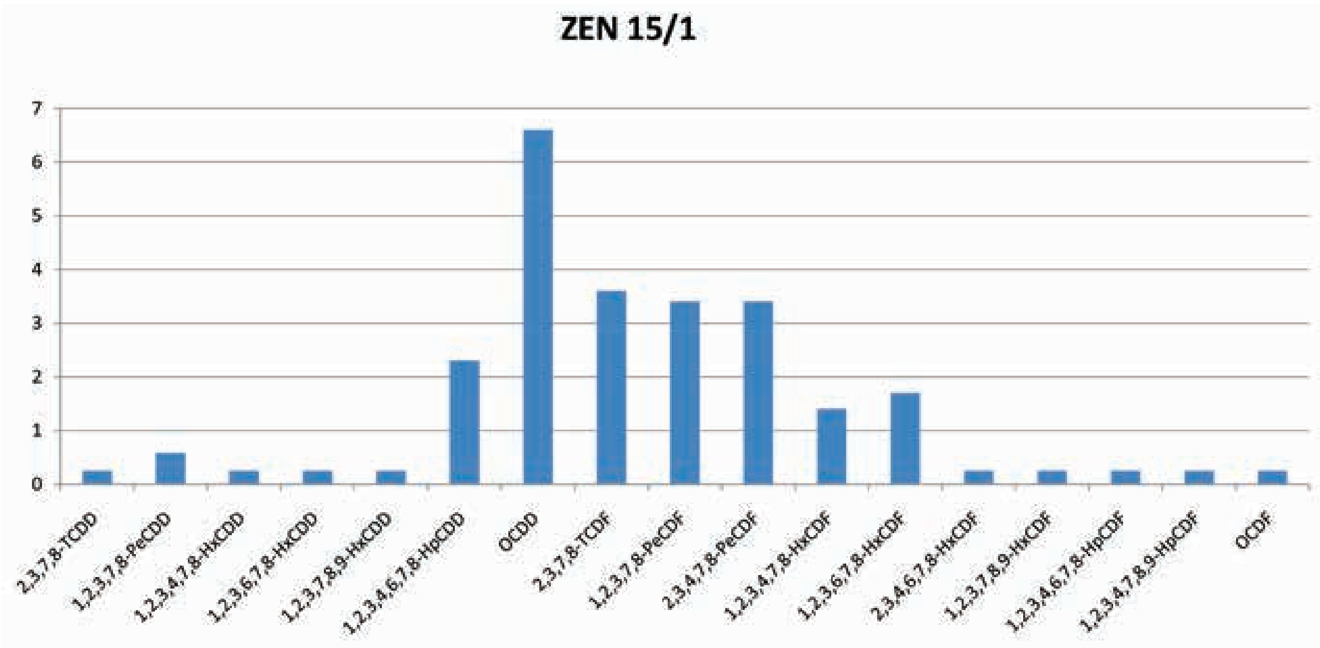


Figure 8: Share of PCDD and PCDF congeners on total WHO-TEQ values in different free range chicken eggs (in darker colours) and two other matrix samples (bars in less intense colour). Sources of information: for data on eggs (IPEN Dioxin PCBs and Waste Working Group, Eco-SPES et al. 2005, IPEN Dioxin PCBs and Waste Working Group, Envilead et al. 2005, IPEN Dioxin PCBs and Waste Working Group, Foundation for Realizaiton of Ideas et al. 2005, IPEN Dioxin PCBs and Waste Working Group, Periyar Malineekarana Virudha Samithi – PMVS et al. 2005); for other than egg samples data (Sam-Cwan 2003, Winkler 2015).

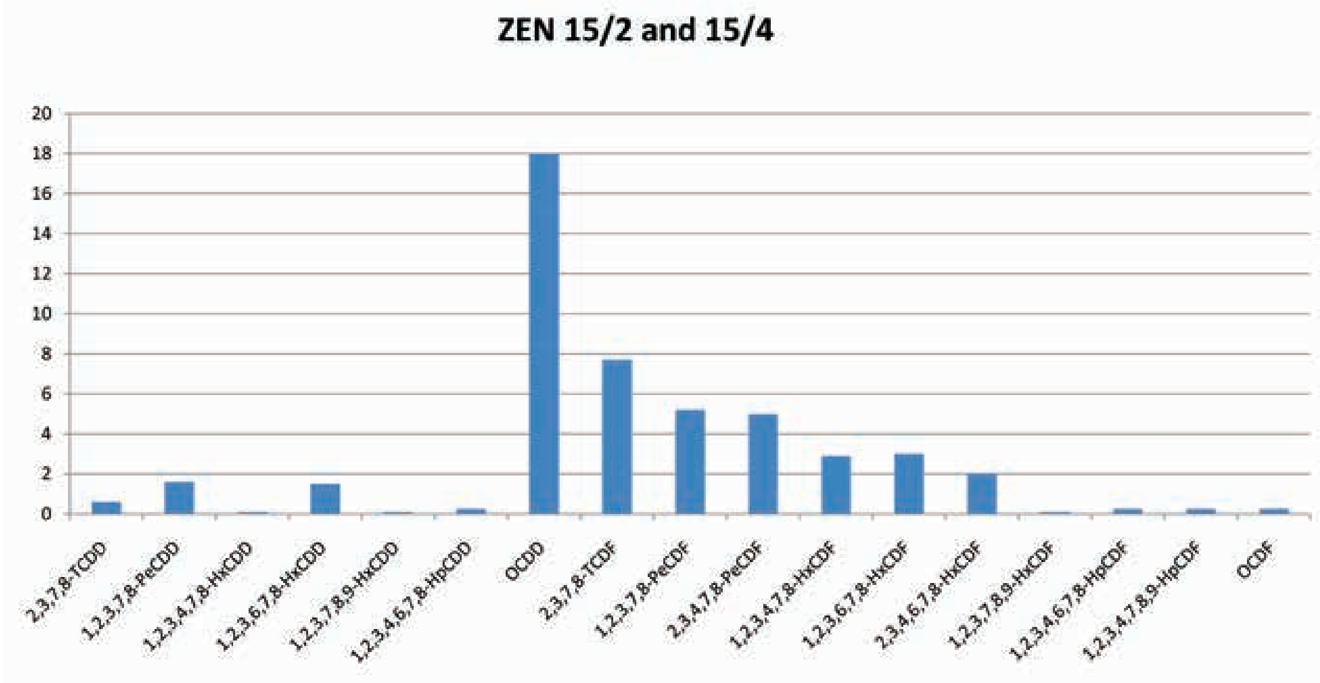
6.2. Dioxin congener patterns and putative sources of pollution

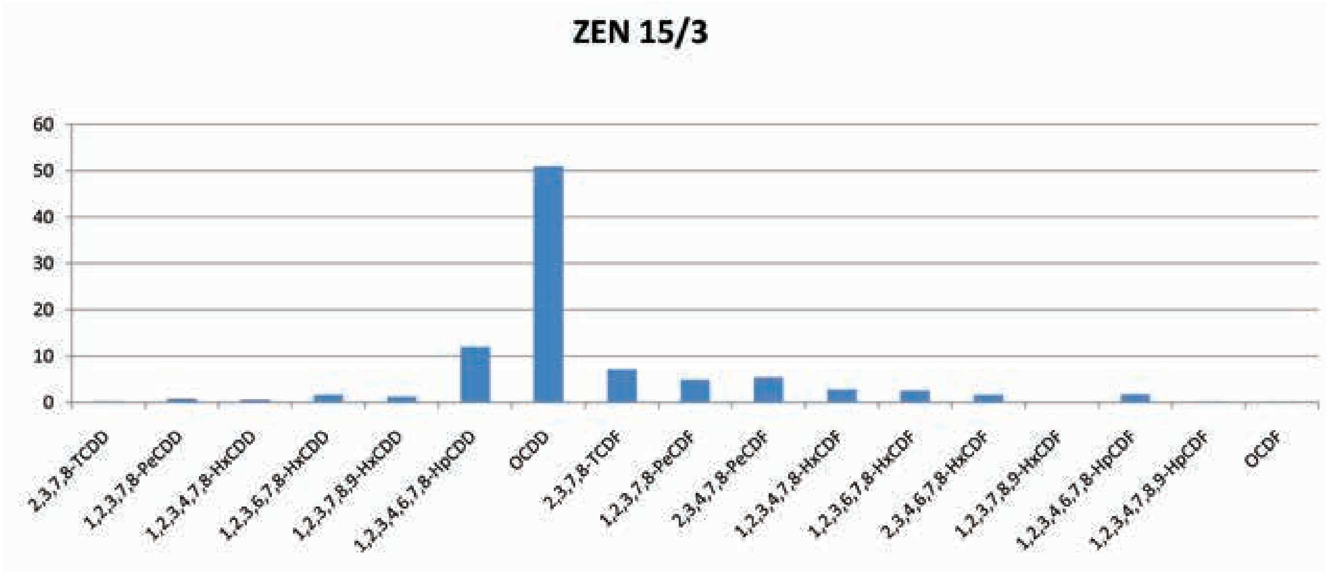
We can compare dioxin congener patterns in free range chicken eggs with their typical patterns for certain types of pollution sources in order to get closer to discovery of their sources at the studied sites. The graph in Figure 8 shows the share of PCDD and PCDF congeners against total WHO-TEQ levels of PCDD/Fs in egg samples and two non-egg samples (air emissions from a lead smelter or the content of PCDD/Fs in asbestos cement fibre plates). There are egg samples from a previous IPEN report where the most likely dioxin sources were identified. The division between PCDD and PCDF congeners in toxic equivalents is used as one of the criteria for a basic classification of potential sources (Sam-Cwan 2003, Yoon-Seok 2003). However, it can be only used as basic information; further analysis of the dioxin congener pattern is needed.

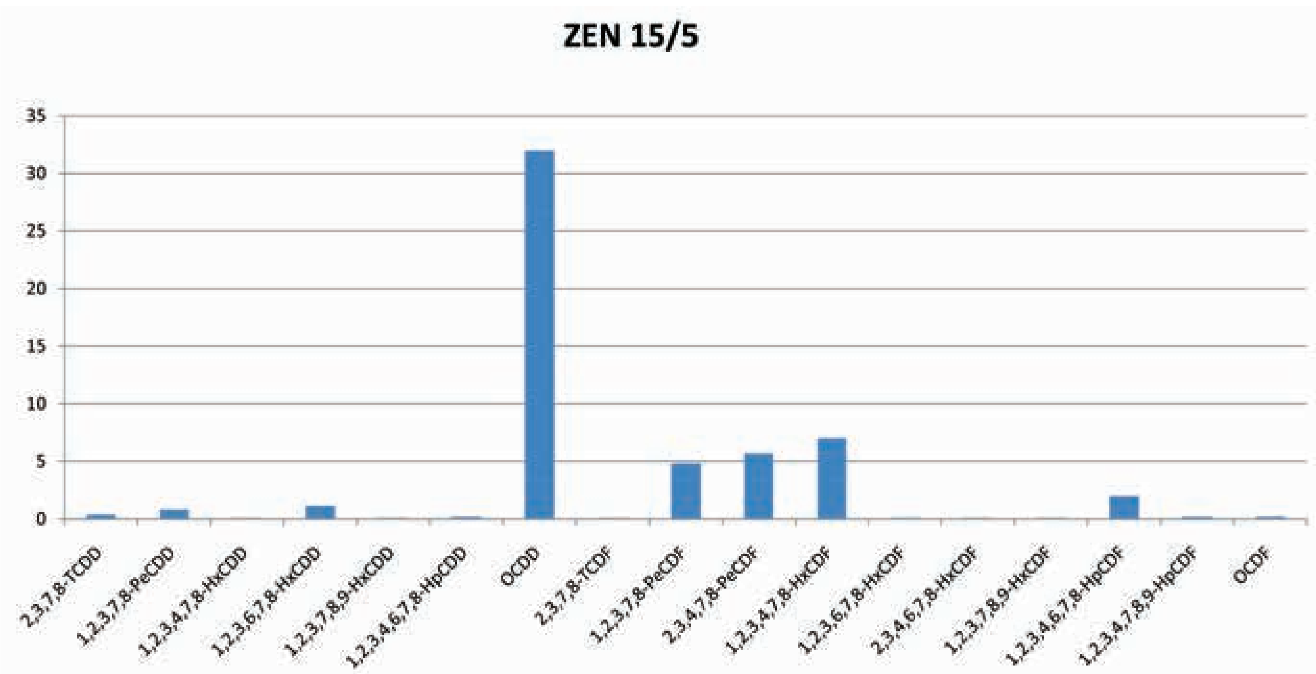




Figures 9–13: Dioxin congener patterns for free range chicken samples from the broader Zenica area.







Figures 9–13: Dioxin congener patterns for free range chicken samples from the broader Zenica area.

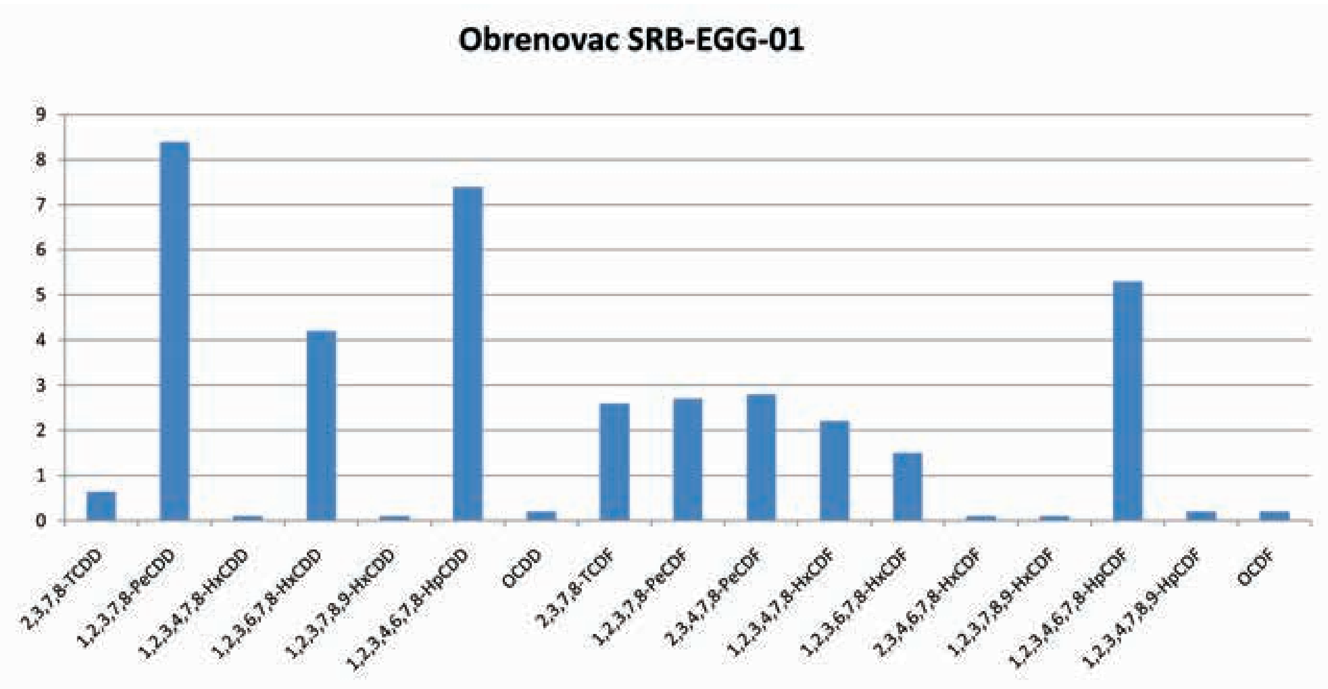
ArcelorMittal is one of the major polluters in Bosnia and Herzegovina. While the steelworks is located in the deep valley, villages occupy hills all around smoking chimneys. *Photo: Adéla Turková / Arnika*

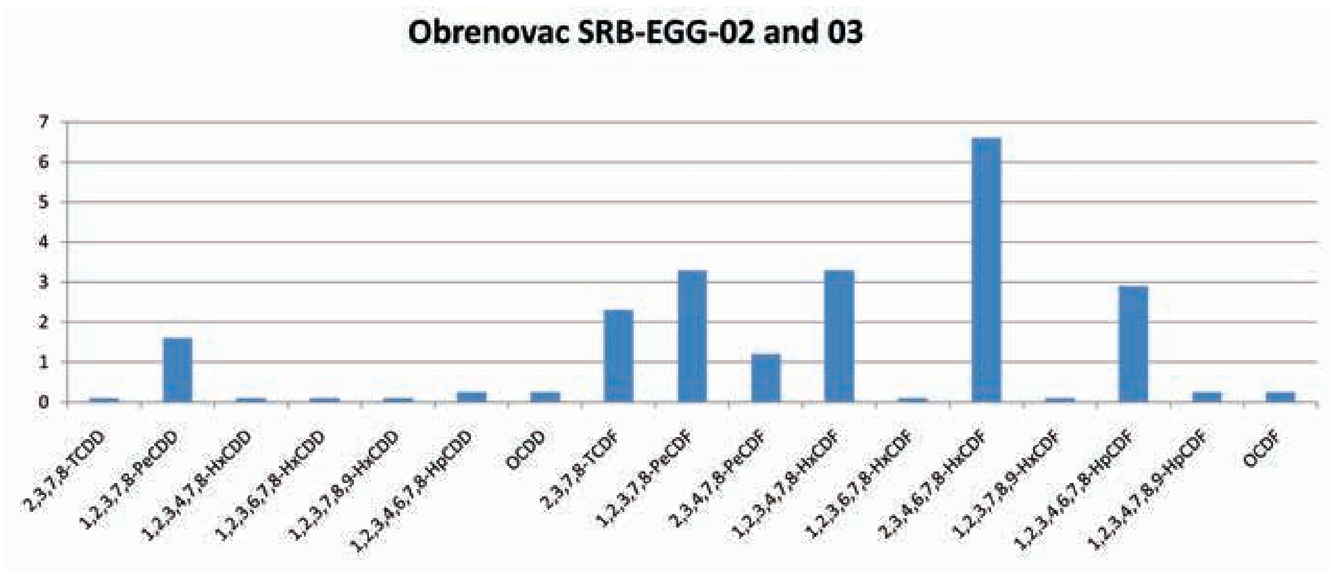
6.2.1. Zenica

The even balance between PCDD/Fs and PCBs congeners against total WHO-TEQ levels within samples from Zenica show that putative sources of pollution can vary in different parts of the valley/households. It is clear that there is not only one single source of contamination of free range chicken eggs in Zenica area when we compare dioxin congener patterns for these samples (see graphs in Pictures 9 – 13). Only three of them, ZEN 15/2 + 4, ZEN 15/3, and ZEN 15/5 are closer each to other and show similarities to some extent. OCDD dominates those patterns. This congener is dominant also in sample ZEN 15/1, however that sample has a very different share of PCDD and PCDF against total WHO-TEQ level in comparison with other samples from the Zenica area (see Figure 8). The prevalence of PCDFs shows some combustion sources of pollution by dioxins (Everaert and Baeyens 2002). They can vary from open burning of waste to metallurgy. Most likely there will be multiple sources of pollution by PCDD/Fs however the decreasing level of WHO-TEQ in free range chicken eggs in a side valley could mean that the steelworks are a significant source of dioxin contamination, although they are probably not the only source of dioxin pollution.

6.2.2. Obrenovac

Dioxin congener patterns for two samples from Obrenovac (see Figures 14 – 15) are specific and differ even more than the samples from Zenica. A higher level of total WHO-TEQ was observed in sample SRB-EGG-01, from the localition on south east of the Nikola Tesla power plant and its ash pond (see map at Figure 2). It is in the opposite direction of the prevailing winds. Also the prevalence of PCDD congeners over PCDF congeners in sample rather points to chemical production as a potential source of contamination of eggs (see graph on Figure 8) like for example in eggs from Mbeeubeus, Senegal (IPEN Dioxin PCBs and Waste Working Group, Pesticide Action Network (PAN) Africa et al. 2005) or Mossville, USA (IPEN Dioxin PCBs and Waste





Figures 14 – 15: Dioxin congener pattern for two pooled free range chicken eggs samples from the Obrenovac area, Serbia.

Working Group, Mossville for Environmental Action Now et al. 2005). We didn't find a specific dioxin pattern close to that one for sample from Grabovac (SRB-EGG-01) and we are not aware of any location with obsolete chemicals close to this place. The chicken owner doesn't buy additional food for the chickens and the chicken house is not painted. We can exclude these pathways as potential source of contamination of eggs. One of the options might be residual contamination in soil after floods brought from other distant place and/or residual contamination after the Kosovo conflict (UNEP and UNCHS 1999). The other sample from nearby (SRB-EGG-02 + 03) has a prevalence of PCDFs, which rather points to combustion sources of dioxin pollution (Everaert and Baeyens 2002) and also the level of PCDD/Fs in the egg sample was lower (see chapter 3.1).

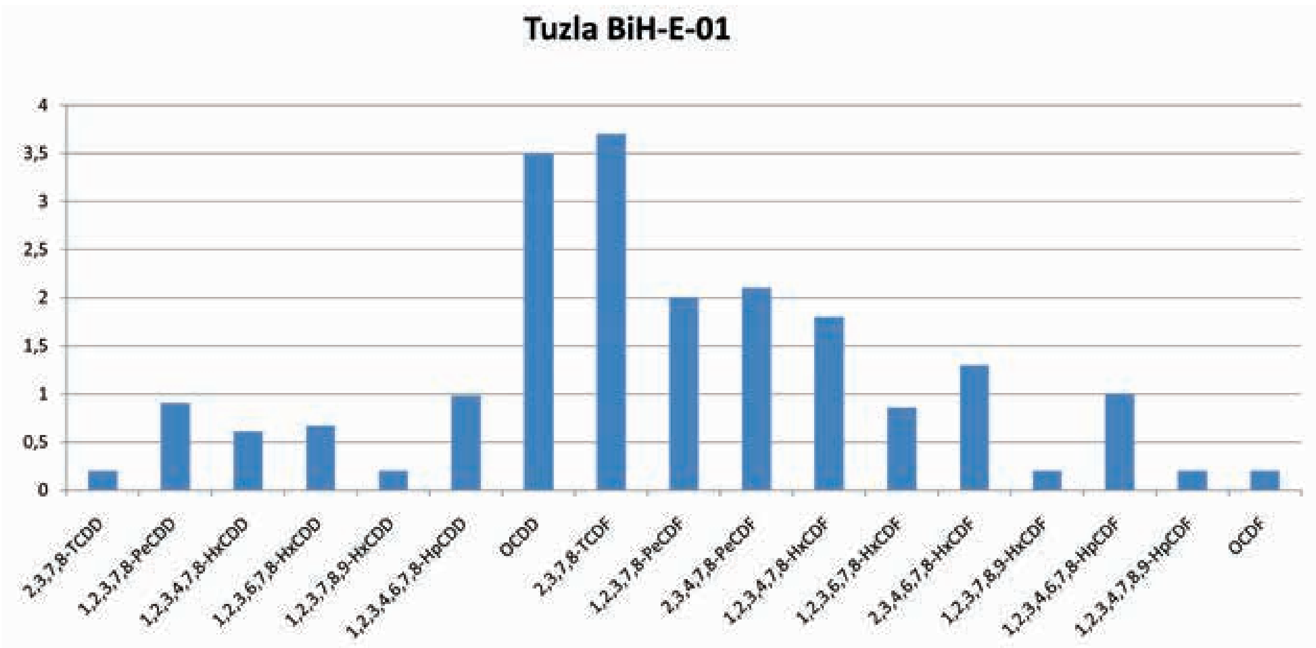


Figure 16: Dioxin congener pattern for free range chicken eggs sample from Tuzla.

6.2.3. Tuzla

The dioxin congener pattern in egg samples from Tuzla (see Figure 16) is similar to those from Balkhash – Rembaza (Petrlík, Kalmykov et al. 2015) (see Figures 17 – 18) to some extent, however they are not identical. The prevalence of PCDF congeners and OCDD points to large combustion sources of potential pollution by dioxins in these cases (Everaert and Baeyens 2002, Petrlík, Kalmykov et al. 2015), however most likely there are multiple sources of pollution by dioxins in Tuzla, including large combustion plants, and potential burning of wastes in households. Also the nearby chlorine chemical plant cannot be excluded.

6.3. Large coal combustion plants as potential sources of dioxin pollution

Both the metallurgic industry and coal fired power plants are signicant sources of dioxin, and other unintentionally produced POPs, and are listed as such also in Annex C to the Stockholm Convention [4] (Stockholm Convention 2010). They are also listed in the Dioxin Toolkit (UNEP and Stockholm Convention 2013) as such, and accompanied with specific emission factors for PCDD/Fs released to all environment compartments.

Fernández-Martínez et al. Fernández-Martínez, López-Vilariño et al. 2004) studied PCDD/Fs releases from power plants in Spain with the following result: *"A total of five plants were selected for the study located at different provinces in Spain. In all the cases, the results revealed very low levels, in the range of 0.41 pg I-TEQ m^{-3}. The profile indicated in the majority of the cases predominance of highly chlorinated congeners being OCDD the most important contributor. The findings were also used to estimate contribution of PCDDs/PCDFs emitted from coal-fired power plants in Spain. Individual plant results revealed values below 0.02 g I-TEQ per year and plant. Nevertheless, considering the total coal consumption in Spain in 1997, the values are comparable to those reported in other countries in the range of 0.6–0.7 g I-TEQ per year."* Data in Czech PRTR system reported for 2014 show values up to 0.55 g I-TEQ per year per one coal-fired power plant (IRZ 2015).

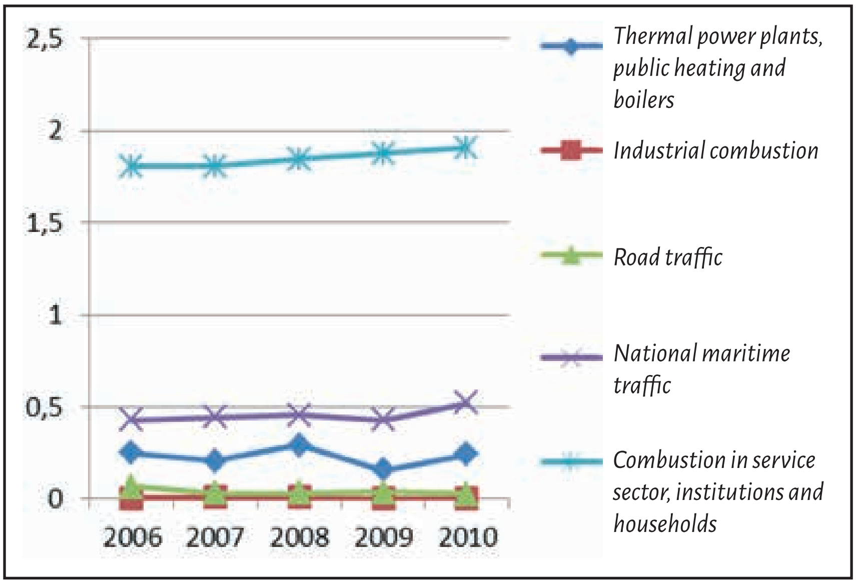


Figure 17: Graph showing development of PCDD/Fs emissions from combustion sources in Montenegro for the period 2006–2010, calculated by using CLRTAP emission factors. Source: (Ministry of Sustainable Development and Tourism 2013) . Graph is indicated in g I-TEQ per year.

Another report from Poland focused on monitoring of dioxins in pine needles concluded that: *„The CDD/F homologue groups and congeners profiles of pine needles with highly dominant HpCDD/F and OCDD/F found in this survey suggest on lack of significant other than coal/lignite/wood combustiont sources of PCDD/Fs diffusion to ambient air in Poland."* (Bochentin, Hanari et al. 2007).

With regards to DL PCBs, one study done in the UK observed that: *„Levels of dioxin-like PCB reported in the literature and measured in UK plant tests showed that well-controlled modern combustion plants with comprehensive pollution controls gave low emissions, typically about 5-10% of the toxic equivalent of the emissions of polychlorinated dibenzodioxins and dibenzofurans at the same plants and below the widely used standard of 0.1 ng TEQ m^{-3}."* (Dyke, Foan et al. 2003).

Specific measurements of PCDD/Fs releases from coal burning power plants in any of the three studied Western Balkan states are virtually non-existent. The Serbian National Implementation Plan for the Stockholm Convention (Ministry of Environment and Spatial Planning of the Republic of Serbia 2010) doesn't mention coal-fired power plants in its dioxin releases inventory despite the fact that it is listed among significant sources of pollution by PCDD/Fs. Čudić, Kisić et al (2007) looked at levels of different contaminants in fly ash from the Obrenovac (Nikola Tesla) power plant and found content of PCDD/Fs less than 5 pg TEQ g^{-1} of dry mass. The analysis of the deposited fly ash done for this study didn't find level of PCDD/Fs above LOQ (LOQ = 0.9 pg TEQ g^{-1}).

4 Stockholm Convention Annex C, Part II and Part III

Dumpsite of the power plant in Plevlja, Montenegro, looks like moonscape and stretches for kilometers.

Photo: Jitka Straková, Arnika

The National Implementation Plan for Stockholm Convention for Montenegro calculates total emissions of PCDD/Fs from combustion sources as is shown on graph in Figure 19. This calculation is based on default emission factors developed within the framework of the Convention on Long Range Transboundary Air Pollution (CLRTAP).

In the light of the above mentioned reports we come to the conclusion that also in the cases of free range chicken eggs from both the Obrenovac and Tuzla broader areas which contained significant levels of PCDD/Fs and DL PCBs, the local coal fired power plants and their ash deposits should be considered as one of contributing sources to this contamination, however further investigation is needed to discover all major dioxin pollution sources in these areas.

Formation of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) can be accompanied by formation of polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs) or polyhalogenated dibenzo-p-dioxins and dibenzofurans, depending on the presence and balance of chlorine and bromine in the coal or the combustion process (Lemieux and Ryan 1998, Lemieux, Stewart et al. 2002). While chlorine or bromine content in the coal enhances formation of dioxins, sulfur inhibits it (Pandelova, Lenoir et al. 2005), so the content of different elements in coal is important information with regards to the evaluation of the potential of burning certain coal typed for leading to halogenated dioxin formation. We did not have the information about the full set of elements contained in coals burned in power plants in Pljevlja, Obrenovac and Tuzla.

A huge fly ash dumpsite in the vicinity of the Nikola Tesla thermal power plant in Obrenovac, Serbia. *Photo: Jitka Straková, Arnika*

"Resettle us or the power plant" – citizens of Tuzla, Bosnia and Herzegovina, demanded in 2013 in reaction to the catastrophic air pollution.
Photo: Centar za Ekologiju i Energiju Tuzla (www.ekologija.ba)

7. CONCLUSIONS AND RECOMMENDATIONS

POPs contamination in some free range chicken eggs from Bosnian and Serbian hot spots shows that there are significant sources of pollution by dioxins and dioxin like PCBs as well as significant levels of DDT in the environment at some places in Tuzla, Zenica, and the Obrenovac area in particular. High levels of PCDD/Fs and DL PCBs were found in free range chicken egg samples from the Obrenvac and Zenica areas. More than half of the samples exceeded the EU MAC for PCDD/Fs and DL PCBs in chicken eggs. More regular monitoring of dioxins and DL PCBs in food samples should be undertaken by the national authorities.

Identical Bosnian and EU MAC for PCDD/Fs and DL PCBs for chicken eggs used in this study were exceeded more often than those for OCPs. None of the egg samples exceeded MAC for 6 PCB congeners. High levels of dioxins and dioxin-like PCBs in free range chicken eggs from Tuzla confirm serious contamination of the city by these pollutants at least in some areas.

Apart the eggs collected in Pljevlja, where the value of PCDD/Fs and DL PCBs was at a concentration considered as background level in general (DiGangi and Petrlík 2005, Petrlík, Kalmykov et al. 2015), all other locations showed considerably high levels of dioxins and dioxin-like PCBs and their consumption should be minimized. Most critical is the situation in Grabovac and Zenica. Dioxin-like compounds in free range chicken eggs in the sample from Grabovac allow consumption of only three quarters of an egg per day for adults and one third of an egg per day for 10-year-old children.

It is clear that contamination of eggs in Zenica by PCDD/Fs and DL PCBs is higher in the valley where the steelworks are located while the side of the valley has somewhat lower levels of dioxin like compounds in free range chicken eggs; however there may be several sources of pollution by dioxins.

In the light of the studies mentioned in the discussion part of this study we come to the conclusion that also in the cases of free range chicken eggs from both the Obrenovac and Tuzla broader areas which contained significant levels of PCDD/Fs, local coal fired power plants and their ash deposits should be considered as one of the contributing sources to this contamination, however further investigation is needed to discover all major dioxin pollution sources in these areas.

Inhabitants at all selected hot spots should be warned before burning wastes in their household stoves and/or its open burning as it can be a serious source of pollution of the environment by POPs.

National plans for addressing sources PCDD/Fs and DL PCBs releases should be developed. The BAT/BEP Guidelines of the Stockholm Convention (Stockholm Convention on POPs 2008) should be applied when permitting potential sources of pollution by U-POPs such as metallurgical, chemical, and large coal combustion plants in all three countries. Special attention should be paid to waste management.

People are usually not aware of possible contamination of their food. Chicken fancier from Pljevlja, Montenegro, is raising his chicken just behind the edge of the fly ash dumpsite.

Photo: Jitka Straková, Arnika

Because chicken are generally kept in the gardens or yards, their eggs can contaminate from the soil polluted by the industry. Tuzla, Bosnia and Hercegovina. *Photo: Jitka Straková, Arnika*

The National Implementation Plan for the Stockholm Convention in Bosnia and Herzegovina has not yet been submitted to the Stockholm Convention Secretariat (Stockholm Convention 2015). Preparing a NIP with the cooperation of all stakeholders, and civil society in particular, is a crucial step to addressing POPs contamination in the country.

8. REFERENCES

Arkenbout, A. (2014). "Biomonitoring of Dioxins/dl-PCBs in the north of the Netherlands; eggs of backyard chickens, cow and goat milk and soil as indicators of pollution." Organohalog Compd 76: 1407-1410.

Arnika – Center for Citizens' Support. (2015, 06/2015). " Arcelor Mittal Steelworks Zenica " Retrieved 20-12-2015, 2015, from http://english.arnika.org/bosnia-and-herzegovina/hot-spots/arcelor-mittal-steelworks.

Aslan, S., M. Kemal Korucu, A. Karademir and E. Durmusoglu (2010). "Levels of PCDD/Fs in local and non-local food samples collected from a highly polluted area in Turkey." Chemosphere 80(10): 1213–1219.

Besselink H, J. A., Pijnappels M, Swinkels A, Brouwer B (2004). "Validation of extraction, clean-up and DR CALUX® bioanalysis. Part II: foodstuff." Organohalog Compd 66: 677-681.

Bochentin, I., N. Hanari, A. Orlikowska, B. Wyrzykowska, Y. Horii, N. Yamashita and J. Falandysz (2007). "Polychlorinated dibenzo-p-dioxins (PCDDs) and –furans (PCDFs) in pine needles of Poland." Journal of Environmental Science and Health, Part A 42(13): 1969-1978.

Bosnia and Herzegovina (2014). Pravilnik o maksimalno dozvoljenim količinama za određene kontaminante u hrani 68-14. Službeni Glasnik, Sarajevo: 39-49.

Čudić, V., D. Kisić, D. Stojiljković and A. Jović (2007). "Ash from Thermal Power Plants as Secondary Raw Material." Arhiv za higijenu rada i toksikologiju 58(2): 233-238.

DiGangi, J. and J. Petrlik (2005). The Egg Report – Contamination of chicken eggs from 17 countries by dioxins, PCBs and hexachlorobenzene.

Dvorská, A. (2015). Persistent Organic Pollutants in Ekibastuz, Blalkhash and Temirtau. Final report on the results of environmental sampling conducted in Kazakhstan in 2013 and 2014 as a part of the project Empowering the civil society in Kazakhstan in improvement of chemical safety . Toxic Hot Spots in Kazakhstan. Monitoring Reports. Prague-Karaganda, Arnika – Toxics and Waste Programme.

Dyke, P., C. Foan and H. Fiedler (2003). "PCB and PAH releases from power stations and waste incineration processes in the UK." Chemosphere 50(4): 469-480.

European Commission (2008). Commission Regulation (EC) No 149/2008 of 29 January 2008 amending Regulation (EC) No 396/2005 of the European Parliament and of the Council by establishing Annexes II, III and IV setting maximum residue levels for products covered by Annex I thereto. Text with EEA relevance European Commission. Official Journal of the European Communities: L 58, 51.53.2008, p. 2001–2398.

European Commission (2011). Commission Regulation (EU) No 1259/2011 of 2 December 2011 amending Regulation (EC) No 1881/2006 as regards maximum levels for dioxins, dioxin-like PCBs and non dioxin-like PCBs in foodstuffs (Text with EEA relevance). European Commission. Official Journal of the European Union. EC 1881/2006: 18-23.

European Commission (2012). Commission Regulation (EU) No 252/2012 of 21 March 2012 laying down methods of sampling and analysis for the official control of levels of dioxins, dioxin-like PCBs and non-dioxin-like PCBs in certain foodstuffs and repealing Regulation (EC) No 1883/2006 Text with EEA relevance European Commission. Official Journal of the European Communities: L 84, 23.83.2012, p. 2011–2022.

Everaert, K. and J. Baeyens (2002). "The formation and emission of dioxins in large scale thermal processes." Chemosphere 46(3): 439-448.

Gasparini M, B. B., Schinetti M, Di Millo S, Tilola M, Maccabiani G, Menotta S, Losio MN, Ferretti E (2011). "Application of DR-CALUX to Milk and Egg Samples: Comparison Between HRGC-HRMS and Screening Data." Organohalogen Compounds 73: 2120-2123.

Hoogenboom, R., M. ten Dam, M. van Bruggen, M. Zeilmaker, S. Jeurissen, W. Traag and S. van Leeeuwen (2014). Dioxines en PCB´s in eieren van particuliere kippenhouders. Wageningen, RIKILT (University & Research centre): 25.

IPEN Dioxin PCBs and Waste Working Group, Cavite Green Coalition, EcoWaste Coalition, GAIA, HCWH and Arnika Association (2005). Contamination of chicken eggs from Barangay Aguado in Philippines by dioxins, PCBs and hexachlorobenzene. Keep the Promise, Eliminate POPs Reports. Manila, Prague, IPEN, Arnika Association, EcoWaste Coalition: 30.

IPEN Dioxin PCBs and Waste Working Group, Eco-SPES, Eco-Accord and Arnika Association (2005). Contamination of chicken eggs from the Dzerzhinsk region, Russia by dioxins, PCBs and hexachlorobenzene. Keep the Promise, Eliminate POPs Reports. Dzerzhinsk, Moscow, Prague, IPEN, Arnika Association, Spolocnost priatelov Zeme: 30.

IPEN Dioxin PCBs and Waste Working Group, Envilead and Arnika Association (2005). Contamination of chicken eggs near the Dandora dumpsite in Kenya by dioxins, PCBs and hexachlorobenzene. Keep the Promise, Eliminate POPs Reports. Nairobi, Prague, IPEN, Arnika Association, Envilead: 22.

IPEN Dioxin PCBs and Waste Working Group, Foundation for Realizaiton of Ideas and Arnika Association (2005). Contamination of chicken eggs near the Bolshoi Trostenec dumpsite in Belarus by dioxins, PCBs and hexachlorobenzene. Keep the Promise, Eliminate POPs Reports. Minsk, Prague, IPEN, Arnika Association, Foundation for Realization of Ideas: 26.

IPEN Dioxin PCBs and Waste Working Group, JA! Justiça Ambiental and Arnika Association (2005). Contamination of chicken eggs from Matola, Mozambique by dioxins, PCBs and hexachlorobenzene. Keep the Promise, Eliminate POPs Reports. Maputo, Prague, IPEN, Arnika Association, JA!: 29.

IPEN Dioxin PCBs and Waste Working Group, Mossville for Environmental Action Now, Advocates for Environmental Human Rights and Arnika Association (2005). Contamination of chicken eggs from Mossville, Louisiana, USA by dioxins, PCBs and hexachlorobenzene. Keep the Promise, Eliminate POPs Reports. Mossville, Prague, IPEN, Arnika Association, MEAN, AEHR: 30.

IPEN Dioxin PCBs and Waste Working Group, Periyar Malineekarana Virudha Samithi – PMVS, Thanal and Arnika Association (2005). Contamination of chicken eggs from Eloor in Kerala, India, by dioxins, PCBs and hexachlorobenzene. Keep the Promise, Eliminate POPs Reports. Kochi, Prague, IPEN, Arnika Association, Thanal: 29.

IPEN Dioxin PCBs and Waste Working Group, Pesticide Action Network (PAN) Africa and Arnika Association (2005). Contamination of chicken eggs near the Mbeubeuss dumpsite in a suburb of Dakar, Senegal by dioxins, PCBs and hexachlorobenzene. Keep the Promise, Eliminate POPs Reports. Dakar, Prague, IPEN, Arnika Association, PAN Africa: 29.

IRZ. (2015, 30-09-2015). "Integrated Pollution Register Data about Releases and Transfers of Pollutants from the Enterprises Based in the Czech Republic for Period 2004 – 2014." from http://www.irz.cz.

Lemieux, P. and J. Ryan (1998). "Enhanced formation of dioxins and furans from combustion devices by addition of trace quantities of bromine." Waste Management 18(6-8): 361-370.

Lemieux, P. M., E. S. Stewart and J. V. Ryan (2002). "Pilot-scale studies on the effect of bromine addition on the emissions of chlorinated organic combustion by-products." Waste Management 22(4): 381-389.

Ministry of Environment and Spatial Planning of the Republic of Serbia (2010). National Implementation Plan for the Stockholm Convention. Belgrade: 295.

Ministry of Sustainable Development and Tourism (2013). National Implementation Plan for the Stockholm Convention 2014-2021. Podgorica: 70.

Pandelova, M., D. Lenoir, A. Kettrup and K. Schramm (2005). "Primary measures for reduction of PCDD/F in Co-combustion of lignite coal and waste: effect of various inhibitors." Environ Sci Technol 39(9): 3345-3350.

Petrlík, J., D. Kalmykov and P. Behnisch (2015). Persistent Organic Pollutants (POPs) in free range chicken eggs from hot spots in Central Kazakhstan. Final report on the results of environmental sampling conducted in Kazakhstan in 2013 and 2014 as a part of the project Empowering the civil society in Kazakhstan in improvement of chemical safety . Toxic Hot Spots in Kazakhstan. Monitoring Reports. Prague-Karaganda, Arnika – Toxics and Waste Programme.

Petrović, V., Ć. Jovanović, Marijana, S. Janković, L. Turubatović and B. Antonijević (2008). Average intake of dioxins and polychlorinated biphenyls among adult population in Serbia. 7th XenobioticMetabolism and Toxicity Workshop of Balkan Countries. Novi Sad, Serbia, 3-6 June 2008.

Pirard, C., J. Focant, A. Massart and E. De Pauw (2004). "Assessment of the impact of an old MSWI. Part 1: Level of PCDD/Fs and PCBs in surrounding soils and eggs." Organohalogen Compounds 66: 2085-2090.

Piskorska-Pliszczynska, J., S. Mikolajczyk, M. Warenik-Bany, S. Maszewski and P. Strucinski (2014). "Soil as a source of dioxin contamination in eggs from free-range hens on a Polish farm." Science of The Total Environment 466–467(0): 447-454.

Pless-Mulloli, T., B. Schilling, O. Paepke, N. Griffiths and R. Edwards (2001). "Transfer of PCDD/F and heavy metals from incinerator ash on footpaths in allotments into soil and eggs." Organohalogen Compounds 51: 48-52.

Sam-Cwan, K., Jin-Gyun, N., Sung-Hun, C., Jung-Hee, L., Yeon-Ho, K., Seung-Ryu, H., Chang-Han, J., Dong-Ho, M., Jae-Cheon, Y., Sang-Won, L., Sang-Eun, J. (2003). "PCDDs/PCDFs Emission from Nonferrous Metal Industry." Organohalog Compd 63: 81-85.

Shelepchikov, A., B. Revich, D. Feshin, S. Brodsky, V. Zilnikov and O. Sergeyev (2006). "Contamination of chicken eggs from different Russian regions by PCBs and chlorinated pesticides." Organohalogen Compounds 68: 1959-1962.

Stockholm Convention (2010). Stockholm Convention on Persistent Organic Pollutants (POPs) as amended in 2009. Text and Annexes. Geneva: 64.

Stockholm Convention. (2015). "NIPs Transmission." Retrieved 20-12-2015, 2015, from http://chm.pops.int/Implementation/NIPs/NIPTransmission/tabid/253/Default.aspx.

Stockholm Convention on POPs (2008). Guidelines on Best Available Techniques and Provisional Guidance on Best Environmental Practices Relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants. Geneva, Secretariat of the Stockholm Convention on POPs.

Šír, M. (2015). Impact of Balkan Power Plants on Inhabitants and the Environment Prague, Arnika – Toxics and Waste Programme: 45.

Šír, M. (2015). Results of environmental sampling in Kazakhstan: heavy metals in sediments and soils. (Final report). Toxic Hot Spots in Kazakhstan. Monitoring Reports. Prague-Karaganda, Arnika – Toxics and Waste Programme.

UNEP and Stockholm Convention (2013). Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs under Article 5 of the Stockholm Convention. Geneva, United Nations Environment Programme & Stockholm Convention Secretariat: 445.

UNEP and UNCHS (1999). The Kosovo conflisct consequences for the environment and human settlements: 99.

Van den Berg, M., L. S. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker and R. E. Peterson (2006). "The 2005 World Health Organization reevaluation of human and Mammalian toxic equivalency factors for dioxins and dioxin-like compounds." Toxicol Sci 93(2): 223-241.

Van Eijkeren, J., M. Zeilmaker, C. Kan, W. Traag and L. Hoogenboom (2006). "A toxicokinetic model for the carry-over of dioxins and PCBs from feed and soil to eggs." Food Additives & Contaminants: Part A 23(5): 509 – 517.

van Leeuwen, F. X. R., M. Feeley, D. Schrenk, J. Larsen, W. Farland and M. Younes (2000). "Dioxins: WHO's tolerable daily intake (TDI) revisited." Chemosphere 40(9-11): 1095-1101.

van Overmeire, I., J. van Loco, P. Roos, S. Carbonnelle and L. Goeyens (2004). "Interpretation of CALUX results in view of the EU maximal TEQ level in milk." Talanta 63: 1241-1247.

Wikipedia. (2015, 21-12-2015). "Pljevlja." Retrieved 21-12-2015, 2015, from https://en.wikipedia.org/wiki/Pljevlja.

Wikipedia. (2015a, 10-11-2015). "Obrenovac." Retrieved 21-12-2015, 2015, from https://en.wikipedia.org/wiki/Obrenovac.

Winkler, J. (2015). "High levels of dioxin-like PCBs found in organic-farmed eggs caused by coating materials of asbestos-cement fiber plates: A case study." Environment International 80: 72-78.

Yoon-Seok, C., Byeong-Woon, Y., Young-Hoon, M., Min-Kwan, K., Jong-Dai, K. (2003). "Inventory Study of PCDD/Fs for Metal Industries in South Korea." Organohalog Compd 63: 94-97.

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