

CDM Smith was commissioned by Cinkarna in July 2015 to prepare a Human Health and Ecological Risk Assessment and to identify, evaluate and compare potential remedial alternatives for the Cinkarna Celje production site and for the two sites Bukovžlak and Za Travnikom.

Based on results of previous environmental baseline studies and current soil and groundwater sampling campaigns between August and December 2015, the risks derived from identified environmental impacts on sensitive receptors were evaluated and classified. Based on this evaluation, recommendations for additional investigations were proposed to close identified data gaps to fully characterize the previously defined contamination pathways. The evaluations and recommendations are provided in the report "Human Health & Ecological Risk Assessment" by CDM Smith dated 15 April 2016. Based on the proposed measures, a field investigation program was developed and executed between May and October 2016.

The present report includes the results of the previous document, summarizes the 2016 site investigation results, and provides combined conclusions based on all the data collected from previous investigations. Therefore, Sections 3 to 6 remain unchanged from the April 2016 report. Section 7 provides a new summary of these previous findings. Section 8 summarizes the additional investigation program in late 2016 and provides results. Finally, Section 9 combines all previous and new results in the Final Conclusions and Recommendations Section.

As requested by Cinkarna, all collected information was evaluated based on the procedures of the German Soil Protection Law (Bundesbodenschutzgesetz BBodSchG) which provides guidelines concerning the risk assessment of the following contaminant exposure pathways:

- Soil – Human Health;
- Soil – Plants;
- Soil – Groundwater.

The guideline provides threshold values for the most common harmful parameters and differentiates the threshold levels and the investigation requirements according to the specific site use (e.g. residential areas versus industrial areas).

In 2014, during previous baseline investigations, potential areas of concern at the Cinkarna Celje site were identified based on historical and current site use, and a total of 55 borings were drilled to depths to 6,0 m below ground surface to collect soil samples. In addition, 25 temporary monitoring wells were installed on the production site to obtain shallow groundwater samples. Between August and December 2015, 16 new groundwater wells were

installed at the Cinkarna production site and soil and groundwater samples were collected and analyzed for a wide range of parameters.

The current site investigation program performed in September and October 2016 included installation and sampling of 10 additional monitoring wells at or close to the Cinkarna Production Site, three wells at the Bukovžlak site and one well at the Za Travnikom site. In addition, soil and surface water samples were collected and all locations were surveyed for coordinates and elevation.

CDM Smith combined the data from all campaigns and reviewed a comprehensive collection of existing data from the Cinkarna production site, Bukovžlak and Za Travnikom site. The review included general geological data, investigation and monitoring reports, surface water and sediment sampling data.

As a result of the human health risk assessment, the following conclusions can be summarized:

The current operations of the **Cinkarna Celje production site** do not represent any identified risk to off-site receptors (human health or environment). Relevant low-risk impacts were identified on-site via the pathway soil – human health and up-take scenario by direct contact with soil or pulmonary uptake via breath. Considering the application of standard occupational safety measures and procedures however, no further measures are required.

A significant on-site impact via the pathway soil – groundwater was identified. Although the documented on-site groundwater contamination by mainly zinc, lead, arsenic and chloro-benzene would require remedial action based on German soil protection law, it should be noted that the impact on the subsequent “sensitive receptor” (surface water body of the Ložnica river) is below the applicable thresholds.

However, the wide-spread groundwater impact has a potential to migrate off site and to further increase measured concentrations in surface water of the rivers and their sediments. The receiving rivers Hudinja and Ložnica north and west of the site function as hydraulic barriers preventing contamination migration across the river towards off-site areas north and west of the Cinkarna Production Site.

A technology screening has been performed to identify measures to mitigate the on-going, continuous processes of overlying soils and fill material contaminating the on-site groundwater and the migration of polluted groundwater into adjacent rivers. Based on the current knowledge of the site and collected data, containment measures and long-term measures for mass reduction have been identified as suitable technologies.

Considering the above mentioned legal situation and the currently available data, two different remedial options were discussed:

Option 1: Decontamination of the on-site groundwater impact by “pump and treat”;

Option 2: Safeguarding of the sensitive receptor (river surface water) by “funnel and gate”.

The estimated costs for Option 1 are in a range of 3.300.000 € to 4.950.000 €; Option 2 ranges from 3.000.000 to 5.800.000 €. Given the size of the site and the complexity of the impact on soil and groundwater, these options are expected to be operated as long-term measures over a timescale of 20 years.

However, significant reductions in time and costs can be achieved by implementing the standard technical approach of delineating hot-spot areas so that remedial efforts can be limited to the resulting smaller, more locally defined areas. Instead of site-wide containment measures, more target-oriented local treatments to contain, immobilize or treat contaminants could be implemented.

In the course of the human health risk assessment, no unacceptable on-site or off-site risk to environment or human health was identified deriving from the **Za Travnikom** site.

At investigated areas downgradient of the site, metal concentrations, predominantly cadmium and lead, were measured in unsaturated soil zones above the groundwater table. However, given the current site use and based on an evaluation of the applicable contaminant pathways, no corrective actions for the Za Travnikom site are currently necessary. Contaminant transport via the pathway soil – groundwater from the site to the downgradient areas north of the road to Prosenisko can be excluded. Summarizing the statements above, no corrective actions for the Za Travnikom site are required.

Although a water collection system connected to a water treatment plant is already installed at the **Bukovžlak** site, contaminated perched groundwater flows in a thin, spatially limited layer towards the north and drains out of slope close to a residential area. On-going construction activities at the lower part of the site include drainage systems at the western and central area as well as capping of the surface. To avoid further migration of contaminated groundwater along the eastern side towards northern agricultural areas, additional drainage systems are recommended to be installed at the slope along the road to Prosenisko and to be connected to the existing piping system to pump collected water to the Cinkarna Celje site for treatment. Construction duration is estimated to be less than a year, additional costs are estimated on 270.000 to 525.000 €. After completion of these measures a contaminant migration towards off-site areas north of the road to Prosenisko from Bukovzлак site via the pathway soil-groundwater-plants can be excluded. However, samples from soil and plants should be collected from an agriculturally used area between the site and the road to Prosenisko to verify that no negative impact has been occurred at this specific area.

The following figure summarizes the identified impacts, “on-site” and “off-site” for the three assessed areas.

Site / Location		Primary Pathway ¹⁾			Secondary Pathway ²⁾		
		Soil – Human Health via <u>direct</u> contact or pulmonary up-take	Soil – Plants via <u>direct</u> transition from soil	Soil – Groundwater	Soil – Groundwater via surface water	Soil – Human Health via groundwater/ surface water	Soil – Plants via groundwater/ surface water
Cinkarna Celje Production Site	On-site	+/-	-	++	--	--	--
	Off-site	--	--	--	--	+/-	--
Bukovžlak Sites	On-site	+/-	-	++	--	--	--
	Off-site	--	--	++	+/-	+/-	++
Za Travnikom Site	On-site	+/-	-	++	--	--	--
	Off-site	--	--	+/-	--	--	--

Dark Grey: ++ : Identified impact
 Light Grey: +/- : Identified risk, but of low relevance (under adherence of defined measures)
 Light green: - : Pathway not applicable for formal reasons (work instructions presupposed)
 Dark green: -- : Significant risks to human health and environment can be excluded or pathway not relevant
 (1): Pathway according to regulatory framework (with thresholds)
 (2): Additional pathways; not defined by regulatory framework (no thresholds or reference values)

Figure 1 Overview on results of Risk Assessment