SUPPLEMENTARY MATERIAL

Heavy metals concentration in sewage treated at the collective wastewater treatment plant

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Table S1. The research findings of different authors on the presence of heavy metals in sewage treated in wastewater treatment plants (WWTP)

Author	Research findings
Chipasa (2003)	• the variability of heavy metals concentration in sewage before a sand trap in mechanical-biological WWTP was greater than in sewage after secondary settling tank; • the variability of concentration was greater for Cu and Zn than for Pb and Cd; • the order of the tested heavy metals concentrations, from the highest, was Zn > Cu > Pb > Cd; • the highest concentration of Zn in raw sewage was 0.80 mg·dm^{-3}, in treated sewage was 0.18 mg·dm^{-3}; • the highest concentration of Cu in raw sewage was 0.27 mg·dm^{-3}, in treated sewage was 0.06 mg·dm^{-3}; • Cd concentrations in raw sewage and in treated sewage ranged from approx. 0.005–0.07 mg·dm^{-3}; • the achieved two-years average metals reduction was as follows: Zn – about 90%, Cu – over 50%, Pb – about 35%, Cd – about 15%; • a proportionality of heavy metals efficiency removal to their concentrations was stated: the higher metals concentration, the greater percentage reduction
Kulbat *et al.* (2003)	• it was found that biological treatment plays an essential role in heavy metals removal, while the share of mechanical treatment in total sewage treatment processes is small; • out of the tested heavy metals including Ag, Cr, Cu, Ni, Pb and Zn, the highest concentrations in raw sewage were attributed to the Zn (average approx. 0.30 mg·dm^{-3}), the second was Cu (average approx. 0.07 mg·dm^{-3}) and the lowest concentrations were attributed to Cd (average <0.01 mg·dm^{-3}); • Zn concentrations were four times higher than Cu concentrations, more than ten times higher than Cr concentrations, and even twenty times higher than Pb concentrations; • mechanical treatment resulted in average metals reduction ranged from 1.5% (nickel) to 25.1% (chromium) (first year of the study) and from 3.7% (nickel) to 18.1% (lead) (second year of the study); • total mechanical-biological treatment resulted in average metals reduction ranged from 1.5% (nickel) to 93.2% (copper) (first year of the study) and from 17.3% (nickel) to 80.7% (zinc) (second year of the study); • the achieved heavy metals reduction after mechanical-biological treatment, from the highest, was Cu > Zn > Pb > Cr = Ag > Ni (first year the study) and Zn > Cu > Pb > Cr > Ag > Ni (second year of the study)

Author	Research findings
Busetti *et al.* (2005)	• the order of the tested heavy metals concentrations in raw sewage flowing to the municipal WWTP (approx. 300,000 p.e.), from the highest, was Al > Fe > B > Zn > Ba > Mn > Cu > Pb > Hg = Ni > Cr = As > V > Ag > Cd, while in treated sewage, it was in order Fe > Al > Zn > Mn > Ba > Ni > Cu > Pb > Cr > Ag > As > Hg = V > Cd; • the achieved heavy metals reduction ranged from 50% (Ni) to 94% (Ag); • the achieved heavy metals reduction, from the highest, was Ag > Cu = Hg > Pb = Al > Fe > Cr > Ba = Cd > As > Zn > V > Mn > Ni
Olujimi *et al.* (2012)	• the order of the tested heavy metals concentrations in sewage treated on six WWTPs using activated sludge technology, from the highest, was Zn > As > Cd > Hg; • the achieved heavy metals reduction, from the highest, the most often was Hg > Zn > Cd > As (80–90% for Hg and 20–40% for As); • the average Zn concentration in raw sewage was in the range about 0.7–5.1 $mg \cdot dm^{-3}$, while in treated sewage, in the range 0.13–0.90 $mg \cdot dm^{-3}$; • the average As concentration in raw sewage was in the range about 0.004–0.028 $mg \cdot dm^{-3}$, while in treated sewage, it was up to about 0.004 $mg \cdot dm^{-3}$; • already after sewage treatment in primary settling tank, i.e. in mechanical part of WWTP, a significant heavy metals reduction, reaching 20–80%, was observed
Mansourri and Madani (2016)	• out of the tested heavy metals including Cr, Cu, Ni, Pb and Zn, the highest concentrations in sewage were attributed to the Ni, while the lowest concentrations, to the Cr; • depending on the season, average Ni concentration in raw sewage was in the range 0.325–0.660 $mg \cdot dm^{-3}$, while in treated sewage, in the range 0.205–0.354 $mg \cdot dm^{-3}$; • depending on the season, average Cr concentration in raw sewage was in the range 0.019–0.037 $mg \cdot dm^{-3}$, while in treated sewage, in the range 0.009–0.017 $mg \cdot dm^{-3}$; • the achieved heavy metals reduction was as follows: Cu – 40.5%, Ni – 42.5%, Pb – 44.7%, Cr – 55.1%, Zn – 71.1%
Agoro *et al.* (2020)	• out of the tested heavy metals including Cd, Cu, Fe, Pb and Zn in sewage flowing into the three WWTPs, in treated sewage and in the natural receiving waters, Fe was characterised by the highest concentration; • in all tested WWTPs, Fe was removed the most effectively (reduction ranging approx. 35–87%); poor reduction was noted for Cu and Cd
Sylwan and Thorin (2021)	• the removal of heavy metals at the primary sewage treatment was analysed. This is because, increased metal removal at this stage, can reduce the metal content, both in sewage and in sewage sludge from secondary treatment; • it was found that heavy metals sorption/desorption in primary settling tank, along with the speciation of heavy metals (i.e. knowledge of which ions, which heavy metals complexes and in what quantities are present in raw sewage), determine the ability to remove pollutants; speciation depends on the hardness, alkalinity, pH and sewage redox potential; • It was found that coagulation/flocculation and the use of cheap sorbents are the most promising methods that improve the removal of heavy metals during mechanical treatment in primary settling tanks; • It was observed that sorption may be the most effective for Cu and Ni removing, while coagulation may be effective for Cd, Cr, Cu, Pb, Zn and Hg removing

Source: own elaboration.

Agoro, M.A. *et al.* (2020) "Heavy metals in wastewater and sewage sludge from selected municipal treatment plants in Eastern Cape Province, South Africa," *Water*, *12*(10), pp. 1–19. Available at: https://doi.org/10.3390/w12102746.

Busetti, F. *et al.* (2005) "Occurrence and removal of potentially toxic metals and heavy metals in the wastewater treatment Plant of Fusina (Venice, Italy)," *Industrial & Engineering Chemistry Research*, 44(24), pp. 9264–9272. Available at: https://doi.org/10.1021/ie0506466.

Chipasa, K.B. (2003) "Accumulation and fate of selected heavy metals in a biological wastewater treatment system," *Waste Management*, 23(2), pp. 135–143. Available at: https://doi.org/10.1016/S0956-053X(02)00065-X.

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Olujimi, O.O. *et al.* (2012) “Preliminary investigation into occurrence and removal of arsenic, cadmium, mercury, and zinc in wastewater treatment plants in Cape Town and Stellenbosch,” *Polish Journal of Environmental Studies*, 21(6), pp. 1755–1765.

Sylwan, I. and Thorin, E. (2021) “Removal of heavy metals during primary treatment of municipal wastewater and possibilities of enhanced removal: A review,” *Water, 13(8)*, pp. 1–26. Available at: https://doi.org/10.3390/w13081121.