demonstrated to increase Hg methylation by inducing microbial activity [72]. Organic Hg and total organic carbon, as well as organic Hg and elemental Hg content, were found to have positive relations. These findings indicate that elemental Hg in the soil can be converted to reactive Hg^{II}, primarily by oxidation, and then methylated by microbial activity [73]. However, the formation of MeHg in the ecosystem will be governed by a variety of factors regulating microbial activity and/or the geochemical speciation of inorganic Hg^{II} [87]. According to Dang et al. [93], Selenium (Se) has also an impact on MeHg production via HgSe formation in soil and sediments.

Demethylation of MeHg is a reverse method of methylation of Hg. It may also proceed by biotic pathways or abiotic pathways, like methylation of Hg [73,90]. The major pathway of Hg demethylation in sediments and periphyton has been proposed to be the biotic process [94]. In summer, MeHg demethylation in sediments typically increases. Significant parameters that also control the processes of Hg demethylation are sediment's redox potential and often its association with Hg concentration [72]. Additionally, a laboratory incubation analysis of surface lake sediments in China found faster demethylation and slower methylation of Hg at higher concentrations of solid-phase Se and that pH effect was variable due to the availability of Hg and microbial activity [87].

Degradation of MeHg by bacteria primarily requires reduction of Hg^{2+} to HgO and under aerobic conditions seems to be preferred. Natural demethylation is normally activated by either microbial activity or photoreduction of light. Two forms of microbial demethylation reactions typically exist: reductive and oxidative. Reductive demethylation degrades MeHg into HgO and methane (CH_4), and HgO and carbon dioxide (CO_2) are formed by oxidative demethylation [29].

The deposition of Hg in surface soil under anaerobic and low pH conditions can be affected the formation of net MeHg and Hg methylation rate in soil may therefore also be a result of the concentration and deposition processes of atmospheric Hg [31]. Boszke et al. [34] indicate that low pH promotes the release of mercury from bottom sediments, whereas others argue that low pH enhances mercury sorption on the sediments.

5. Analysis of THg and MeHg in Soil and Sediments

The analysis is a sequential process involving extraction/pre-concentration, separation, and detection. Extraction/pre-concentration methods are liquid phase microextraction, purge and trap, solid-phase extraction, and solid-phase microextraction. Separation techniques are Chromatographic techniques and non-chromatographic techniques [54].

Most of the methods for the measurement of THg in solid samples require preliminary digestion. In an acidic medium to release Hg from the sample, nitric acid (HNO_3), hydrochloric acid (HCl), bromine monochloride (BrCl), sulfuric acid (H_2SO_4), perchloric acid ($HClO_4$), hydrogen peroxide (H_2O_2), vanadium pentoxide (V_2O_5), potassium permanganate ($KMnO_4$), potassium dichromate ($K_2Cr_2O_7$) are the most common reagents which have been used. Samples are normally digested at high temperatures, such as max. 90–100°C, in closed, semi-closed, or sealed containers. At high digestion temperatures, careful attention should be paid to preventing Hg loss. Thus, closed, or sealed digestion containers should be applied [29]. Soil samples are digested with aqua regia (HCl/HNO_3) using microwave-assisted digestion for the extraction of pseudo-THg, due to its capacity to dissolve HgS. Soil samples can be digested in HNO_3/H_2SO_4 containing large quantities of organic material and then diluted with BrCl solution to eliminate any remaining organic material [31].

For solid samples such as soil and sediments, lower and inconsistent results are provided by acid digestion using aqua regia. The use of acid digestion, including hydrofluoric acid (HF), is highly recommended to fully extract Hg from the inorganic matrix [29].

It is important to isolate MeHg from the sample before analysis to prevent matrix interference during sample processing [95]. Acid extraction (mostly combined with solvent extraction), distillation, and alkaline extraction are the most widely used methods for removing organomercury species from environmental samples [59]. The derivatization (chemical changes) steps needed for gas chromatography (GC) analysis are especially sensitive to matrix suppression. To remove MeHg from complex matrices, distillation methods are commonly used. This technique is based on a simple distillation of atmospheric pressure and does not require complex reagents for accurate results to be obtained. However, the use of distillation may lead to the formation of an artifact of MeHg [95].

Extraction of soil samples for MeHg analysis is more difficult. Extraction can include digestion to extract organic Hg from inorganic complexes with acidic potassium bromide (KBr) and copper sulfate ($CuSO_4$) solution, followed by dichloromethane (DCM) to extract MeHg, and then back-extraction by argon (Ar) purging into an aqueous solution. In a purge vessel using sodium tetraethyl borate, aqueous solutions are ethylated to convert MeHg to volatile methylethyl-Hg species [31].

Usually, extremely sensitive atomic absorption and atomic emission techniques assess only the total quantity of metal in the sample and must therefore be combined with a chromatographic or other separation technique until it is possible to classify individual species [96]. By using different methods, the organo-Hg material can then be detected [31]. High-performance liquid chromatography-chemiluminescence (HPLC-CL), electron capture gas chromatography (GC-ECD), and gas chromatography-atomic fluorescence spectrometry (GC-AFS), for these methods, MeHg results for all soil and sediments samples returned comparable. Although, it was reported that the HPLC-CL method performed poorly in analyzing high sulfur content samples [65]. Also, Due to its speed, simplicity, relative freedom from interference, low operating costs, and high sensitivity, especially when Hg vapor is pre-concentrated on gold by amalgamation, cold vapor atomic absorption spectrometry (CV-AAS) has been used. Many published methods have relied on plasma mass spectrometry that is inductively coupled (ICP-MS) [97].

Denmark et al. [98] developed a new method for extracting MeHg selectively from severely contaminated soil and sediment samples contaminated with Hg for analysis using chemical vapor generation inductively coupled plasma mass spectrometry (CVG-ICP-MS). HNO3 was shown to be the most effective for selective extraction of MeHg from soils when compared to HCl. Fast extraction of MeHg was achieved using ultrasonic agitation in HNO3 at room temperature. Using a dilute ammonium sulfide solution, soil extracts in HNO3 were used to precipitate HgS, which resulted in the elimination of all residual Hg^{2+} without affecting MeHg levels. Compared to chromatographic separation and speciation methods, the procedure is simple and quick, and it also has distinct advantages for determining trace levels of very dangerous MeHg from severely Hg-contaminated sediments and soil. In another recent study, Saniewska and Beldowska [99], tried to develop a simple thermo-desorption method for mercury fractionation in soil and sediment samples using a direct mercury analyzer and they used soil, beach sand and marine sediment in this study. Then, the temperature range in which mercury species were released was used to identify them. Despite some limitations, the results suggest that temperature fractionation can be used as a screening approach for determining the percentage contribution groups of Hg compounds with

similar properties in solid materials. This approach could be used on solid samples with low levels of Hg in the environment. Lastly, in 2013, Kodamatani and Tomiyasu [89], developed simultaneous determination of MeHg and ethylmercury (EtHg). The approach involves extracting MeHg and EtHg into toluene as chlorides after eluting mercury species from soil/sediment samples with HCl containing Cu^{2+} and Pd^{2+}. These alkylmercury chlorides were then back-extracted into an aqueous EDTA solution, forming EDTA complexes, which were subsequently separated using reverse-phase HPLC and identified using a tris ruthenium chemiluminescence process.

6. Conclusion

Anthropogenic emissions of Hg have a vast effect on the environment and therefore, pose an elevated risk to human beings. This overview aims to disclose sampling methods, use and storage; it also focuses on Hg forms, mobilization and analysis in soil and sediment.

The findings of this study are listed below:

- In the sampling method, different approaches depend on the chosen area, such as two-stage, cluster, judgmental, random, stratified random, systematic grid, search and transect. Tools made of polymer, glass, stainless steel, or aluminum are required during the collecting, pre-treatment, and storage phases of environmental samples. The best technique for preserving MeHg is to freeze soil and sediment samples immediately after collection, followed by freeze-drying, grinding, homogenization, and storing the dry material in cold, dark conditions until analysis. In most of the papers, it is not specified what type of sampling or drying methods were applied.
- Clay soils can absorb Hg and lead the creation of HgS.
- Organically rich soils, such as forest soils, peaty soils, or rice paddy fields are typically connected to higher THg concentrations.
- Hg binding to humic substrates is the major process in Hg sorption.
- Plants can play an important role in Hg transport and accumulation. MeHg concentrations in biomass were found to be higher in *Solanum nigrum* (BR3) and *Cynodon dactylon* (BR2).
- It appeared that the adsorptive capacity of Hg is higher than Cr, Cd, Cu, Zn and As but lower than Pb.
- Hg can be affected by most of the conditions in the environment, which can determine the final form in soil or sediment, such as pH, redox potential, and light.
- The soil profile, production of volatile Hg species, physical movement of Hg species, and physical and chemical sorption of Hg vapor all influence the depth of the soil layers that contribute to evaporation. When compared to unplanted regions, applying sulfur to the soil and growing a plant cover reduces Hg flow by around 70% to 80%.
- *Shewanella oneidensis* MR-1 and *Geobacter spp* are two bacteria that can mediate the biotic reduction of Hg^{2+} to HgO.
- The most common organic and toxic form of Hg in the environment is accepted as MeHg. Soil moisture highly impacts MeHg, through sulfate and iron-reducing bacteria.
- A laboratory incubation analysis of surface lake sediments revealed that higher levels of solid-phase Se resulted in rapid demethylation and slower methylation of Hg and that the pH impact was varied owing to Hg availability and microbial activity.
- Climate change and permafrost thawing have the potential to increase MeHg production. Arctic

permafrost represents an important source of Hg in case warming will not decrease in the future.

- In 2018, a simple and quick approach for analyzing MeHg utilizing chemical vapor generation inductively coupled plasma mass spectrometry was introduced. When compared to HCl, HNO_3 has proven to be the most effective for selective extraction of MeHg from soils. Ultrasonic agitation helped to produce rapid MeHg extraction.

Conflict of Interest

All authors declare no conflicts of interest in this paper.

References

1. Skrobonja A (2019) Formation, uptake, and bioaccumulation of methylmercury in coastal seas – a Baltic Sea case study. Doctoral Dissertation, Umea University. http://umu.diva-portal.org/
2. Kwasigroch U, Bełdowska M, Jędruch A, et al. (2021) Distribution and bioavailability of mercury in the surface sediments of the Baltic Sea. *Environ Sci Pollut Res* 28: 35690–35708. https://doi.org/10.1007/s11356-021-13023-4
3. Siedlewicz G, Korejwo E, Szubska M, et al. (2020) Presence of mercury and methylmercury in Baltic Sea sediments, collected in ammunition dumpsites, *Marine Environmental Research* 162: 105158. https://doi.org/10.1016/j.marenvres.2020.105158
4. Manzetti S (2020) Heavy metal pollution in the Baltic Sea, from the North European coast to the Baltic states, Finland and the Swedish coastline to Norway, Doctoral Dissertation. https://doi.org/10.13140/RG.2.2.11144.85769/1
5. Bełdowska M, Saniewska D, Falkowska, L (2014) Factors influencing variability of mercury input to the Southern Baltic Sea. *Mar Pollut Bull* 86: 283–290. http://doi:10.1016/j.marpolbul.2014.07.004
6. Kocman D, Horvat M, Pirrone N, et al. (2013) Contribution of contaminated sites to the global mercury budget. *Environ. Res.* 125:160–170. https://doi.org/10.1016/j.envres.2012.12.011
7. Panagos P, Jiskra M, Borrelli P, et al. (2021) Mercury in European topsoils: Anthropogenic sources, stocks and fluxes. *Environmental Research* 201: 111556. https://doi.org/10.1016/j.envres.2021.111556
8. SedNet, Objectives of Sediment and its management, 2021. Available From: https://sednet.org/about/objectives/.
9. Li C, Quan Q, Gan Y, et al. (2020) Effects of heavy metals on microbial communities in sediments and establishment of bioindicators based on microbial taxa and function for environmental monitoring and management. *Science of The Total Environment* 749: 141555. https://doi.org/10.1016/j.scitotenv.2020.141555
10. Szymczycha B, Miotk M, Pempkowiak J (2013) Submarine Groundwater Discharge as a Source of Mercury in the Bay of Puck, the Southern Baltic Sea. *Water Air Soils Pollut* 224: 1542. https://doi.org/10.1007/s11270-013-1542-0
11. Leipe T, Moros M, Kotilainen A, et al. (2013) Mercury in Baltic Sea sediments-Natural background and anthropogenic impact, *Geochemistry* 73: 249–259. https://doi.org/10.1016/j.chemer.2013.06.005
12. Helcom (2018) State of the Baltic Sea - Second HELCOM holistic assessment 2011-2016.

Baltic Sea Environment Proceedings 155: 1–155.
13. Bełdowska M, Jędruch A, Łęczyński L, et al. (2016) Coastal erosion as a source of mercury into the marine environment along the Polish Baltic shore. *Environ Sci Pollut Res* 23: 16372–16382. https://doi.org/10.1007/s11356-016-6753-7
14. Careghini A, Mastorgio A, Saponaro S, et al. (2015) Bisphenol A, nonylphenols, benzophenones, and benzotriazoles in soils, groundwater, surface water, sediments, and food: a review. *Environ Sci Pollut Res* 22: 5711–5741. https://doi.org/10.1007/s11356-014-3974-5
15. Peng W, Li X, Xiao S, et al. (2018) Review of remediation technologies for sediments contaminated by heavy metals. *J Soils Sediments* 18: 1701–1719. https://doi.org/10.1007/s11368-018-1921-7
16. Boszke L, Kowalski A (2006) Spatial Distribution of Mercury in Bottom Sediments and Soils from Poznan, Poland. *Pol J Environ Stud* 15: 211–218.
17. Wada SI (2002) Effect of clay mineralogy on the feasibility of electrokinetic soil decontamination technology. *Applied Clay Science* 20: 283–293. https://doi.org/10.1016/S0169-1317(01)00080-1
18. Shahidi D, Roy R, Azzouz A (2015) Advances in catalytic oxidation of organic pollutants - Prospects for thorough mineralization by natural clay catalysts. *Applied Catalysis B: Environmental* 174: 277-292. https://doi.org/10.1016/j.apcatb.2015.02.042
19. Kern K, Loffelsend T (2004) Sustainable development in the Baltic Sea region. Governance beyond the nation state. *Local Environment* 9: 451–467. https://doi.org/10.1080/1354983042000255351
20. Ullrich S, Tanton T, Abdrashitova S (2001) Mercury in the Aquatic Environment: A Review of Factors Affecting Methylation. *Critical Reviews in Environmental Science and Technology* 31: 241–293. https://doi.org/10.1080/20016491089226
21. EEA (European Environment Agency) (2000) Down to Earth: soils degradation and sustainable development in Europe. *Environmental issues series* 16: 32.
22. EEA (European Environment Agency) (2001) Proposal for a European soils monitoring and assessment framework. *Environmental issues series* 61: 58.
23. Ramos-Miras JJ, Gil C, Rodriguez Martin JA, et al. (2020) Ecological risk assessment of mercury and chromium in greenhouse soils. *Environ Geochem Health* 42: 313–324. https://doi.org/10.1007/s10653-019-00354-y
24. Lado L, Hengl Y, Reuter H (2008) Heavy metals in European soils: A geostatistical analysis of the FOREGS Geochemical database. *Geoderma* 148: 189–199. https://doi.org/10.1016/j.geoderma.2008.09.020
25. Long Q, Wang JY, Da LJ (2013) Assessing the spatial‐temporal variations of heavy metals in farmland soil of Shanghai, China. *Fresenius Environmental Bulletin* 22: 928–938.
26. Ballabio C, Jiskra M, Osterwalder S, et al. (2021) A spatial assessment of mercury content in the European Union topsoil. *Science of The Total Environment* 769: 144755. https://doi.org/10.1016/j.scitotenv.2020.144755.
27. Medyńska-Juraszek A, Kabala C (2010) Lead, mercury, and cadmium in forest soils impacted by copper smelting in south-west Poland. *15th International Conference on Heavy Metals in the Environment* 2010: 19–23.
28. Martin JAR, Gutierrez C, Escuer M, et al. (2021) Trends in soil mercury stock associated with pollution sources on a Mediterranean island (Majorca, Spain). *Environmental Pollution* 283:

117397. https://doi.org/10.1016/j.envpol.2021.117397.
29. Horvart M, Kotnik J (2019) Technical information report on mercury monitoring in soils. UN Environment. *Chemicals and Health Branch Switzerland* 2019: 54.
30. Robles, I, Lakatos, J, Scharek, P (2014) Remediation of Soils and Sediments Polluted with Mercury: Occurence, Transformations, Environmental Consideration and San Joaquin's Sierra Gorda Case, *InTech*, 35–75.
31. O'Connor D, Hou D, Ok Y, et al. (2019) Mercury speciation, transformation, and transportation in soils, atmospheric flux, and implications for risk management: A critical review. *Environment International* 126: 747–761. https://doi.org/10.1016/j.envint.2019.03.019
32. Jędruch A, Falkowska L, Saniewska D, et al. (2021) Status and trends of mercury pollution of the atmosphere and terrestrial ecosystems in Poland. *Ambio* 50: 1698–1717. https://doi.org/10.1007/s13280-021-01505-1
33. Sas-Nowosielska A, Galimska-Stypa R, Kucharski R, et al. (2008) Remediation aspect of microbial changes of plant rhizosphere in mercury contaminated soils. *Environ Monit Assess* 137: 101–109. https://doi.org/10.1007/s10661-007-9732-0
34. Boszke L, Kowalski A, Glosinska G. et al. (2003) Environmental factors affecting speciation of mercury in the bottom sediments; an overview. *Polish Journal of Environmental Studies* 12: 5–13.
35. Pacyna E, Pacyna J, Pirrone N (2001) European emissions of atmospheric mercury from anthropogenic sources in 1995. *Atmospheric Environment* 35: 2987–2996. https://doi.org/10.1016/S1352-2310(01)00102-9
36. Glodek A, Panasiuk D, Pacyna J (2010) Mercury Emission from Anthropogenic Sources in Poland and Their Scenarios to the Year 2020. *Water Air Soil Pollut* 213: 227–236. https://doi.org/10.1007/s11270-010-0380-6
37. Bartnicki J, Gusev A, Aas W, et al. Atmospheric Supply of Nitrogen, Lead, Cadmium, Mercury and Dioxins/Furans to the Baltic Sea in 2005. *EMEP,* 2007. Available from: https://emep.int/publ/helcom/2007.
38. Ministry of Environment of the Republic of Lithuania National environmental protection strategy, 2016. Available from: https://am.lrv.lt/uploads/am/documents/files/National%20Environmental%20Protection%20Strategy.pdf.
39. Šakalys J, Kvietkus K, Garbarienė I, et al. (2019) Long-term study of atmospheric mercury deposition at monitoring stations in Lithuania. *Lithuanian Journal of Physics* 59: 1. https://doi/10.3952/physics.v59i1.3940
40. Science for Environment Policy (2017) Tackling mercury pollution in the EU and worldwide. *In-depth Report 15 produced for the European Commission. DG Environment by the Science Communication Unit*.
41. EEA (European Environment Agency) (2018) Mercury in Europe's environment A priority for European and global action. *Environmental issues series* 11: 72. https://doi/10.2800/558803
42. Schuster P, Schaefer K, Aiken G, et al. (2018) Permafrost stores a globally significant amount of mercury. *Geophysical Research Letters* 45: 1463–1471. https:// doi.org/10.1002/2017GL075571
43. Artiola J, Brusseau M. (2019) 10 - The Role of Environmental Monitoring in Pollution Science, *Environmental and Pollution Science (Third Edition)*, Academic Press 2019: 149–162. https://doi.org/10.1016/C2017-0-00480-9

44. Artiola J, Pepper I, Brusseau M (2004) 1 - Environmental Monitoring and Characterization. Environmental Monitoring and Characterization. *Elsevier Academic Press* 2004: 1–9. https://doi.org/10.1016/B978-0-12-064477-3.X5000-0
45. Loveland P, Bellamy P (2005) Environmental Monitoring. *Encyclopedia of Soils in the Environment. Elsevier* 2005: 441–448. https://doi.org/10.1016/B0-12-348530-4/00092-8
46. Morvan X, Saby NPA, Arrouays D, et al. (2008) Soil monitoring in Europe: A review of existing systems and requirements for harmonisation. *Science of The Total Environment* 391: 1–12. https://doi.org/10.1016/j.scitotenv.2007.10.046
47. Van Leeuwen E, Saby N, Jones A, et al. (2017) Gap assessment in current soils monitoring networks across Europe for measuring soils functions. *Environ Res Lett* 12: 124007. https://10.1088/1748-9326/aa9c5c
48. Brils J (2008) Sediments monitoring and the European Water Framework Directive. *Annali dell'Istituto superiore di sanita* 44: 218–223.
49. Reuther R (2009) Lake and river sediments monitoring. Environmental Monitoring. *Encyclopedia of Life Support Systems II* 2009*: 9*.
50. SedNet Sediments Management-an essential element of River Basin Management Plans 28 pages, 2006. Available From: https://sednet.org/download/061122_Report_SedNet_Round_Table_Discussion.pdf.
51. Ramsey C (2015) Considerations for Sampling Contaminants in Agricultural Soils. *Journal of AOAC International* 98: 309–315. https://doi.org/10.5740/jaoacint.14-268
52. International atomic energy agency (IAEA) (2004) Soils Sampling for Environmental Contaminants, IAEA-TECDOC-1415. *Technical Reports Series*, Vienna.
53. International atomic energy agency (IAEA) (2019) Guidelines on Soils and Vegetation Sampling for Radiological Monitoring. *Technical Reports Series* 486, IAEA, Vienna.
54. Amde M, Yin Y, Zhang D. et al. (2016) Methods and recent advances in speciation analysis of mercury chemical species in environmental samples: a review. *Chemical Speciation & Bioavailability* 28: 51–65. https://doi.org/10.1080/09542299.2016.1164019
55. Yu L, Yan X (2003) Factors affecting the stability of inorganic and methylmercury during sample storage. *TrAC Trends in Analytical Chemistry* 22: 245–253. https://doi.org/10.1016/S0165-9936(03)00407-2
56. Diederick J (2013) Literature review on mercury speciation soils systems under oxidizing conditions. *Snowman Network*, Project No. SN-03/08.
57. Gilli R, Claudine K, Mischa W, et al. (2018) Speciation and Mobility of Mercury in Soils Contaminated by Legacy Emissions from a Chemical Factory in the Rhône Valley in Canton of Valais. *Switzerland Soils Syst* 2: 44. https://doi.org/10.3390/soilsystems2030044
58. Kodamatani H, Balogh S, Nollet Y, et al. (2016) An inter-laboratory comparison of different analytical methods for the determination of monomethylmercury in various soils and sediments samples: A platform for method improvement. *Chemosphere* 169: 32–39. https://doi.org/10.1016/j.chemosphere.2016.10.129
59. Leermakers M, Baeyens W, Quevauviller P, et al. (2005) Mercury in environmental samples: Speciation, artifacts and validation. *TrAC Trends in Analytical Chemistry* 24: 383–393. https://doi.org/10.1016/j.trac.2004.01.001

60. Kowalski A, Frankowski M (2016) Seasonal variability of mercury concentration in soils, buds and leaves of Acer platanoides and Tilia platyphyllos in central Poland. *Environ Sci Pollut Res* 23: 9614–9624. https://doi.org/10.1007/s11356-016-6179-2
61. Lepane V, Varvas M, Viitak A, et al. (2007) Sedimentary record of heavy metals in Lake Rõuge Liinjärv, southern Estonia. *Estonian Journal of Earth Sciences* 56: 221–232. https://doi.org/10.3176/earth.2007.03
62. Koniarz T, Tarnawski M, Baran A, et al. (2015) Mercury contamination of bottom sediments in water reservoirs of southern Poland. *Biblioteka Glowna* 41: 169–175. https://doi.org/10.7494/geol.2015.41.2.169
63. Dradrach A, Karczewska A (2013) Mercury in soils of municipal lawns in Wroclaw, Poland. *Fresenius Environmental Bulletin* 22: 968–972.
64. Gruba P, Socha J, Pietrzykowski M, et al. (2019) Tree species affects the concentration of total mercury (Hg) in forest soils: Evidence from a forest soil inventory in Poland. *Science of The Total Environment* 647: 141–148. https://doi.org/10.1016/j.scitotenv.2018.07.452
65. Kodamatani H, Maeda C, Balogh S, et al. (2017) The influence of sample drying and storage conditions on methylmercury determination in soils and sediments. *Chemosphere* 173: 380–386 https://doi.org/10.1016/j.chemosphere.2017.01.053
66. Arbestain M, Lado L, Bao M, et al. (2009) Assessment of Mercury-Polluted Soils Adjacent to an Old Mercury-Fulminate Production Plant. *Applied and Environmental Soils Science* 2009: 8. https://doi.org/10.1155/2009/387419
67. Leopold K, Foulkes M, Worsfold P (2010) Methods for the determination and speciation of mercury in natural waters- a review. *Analytica Chimica Acta* 663: 127–138. https://doi.org/10.1016/j.aca.2010.01.048
68. Schuster E (1991) The behavior of mercury in the soils with special emphasis on complexation and adsorption processes - A review of the literature. *Water, Air, and Soils Pollution* 56: 667–680. https://doi.org/10.1007/BF00342308
69. Saponaro S, Sezenna E, Bonomo L (2005) Remediation Actions by a Risk Assessment Approach: A Case Study of Mercury Contamination. *Water Air Soils Pollut* 168: 187–212. https://doi.org/10.1007/s11270-005-1248-z
70. Gabriel M, Williamson D (2004) Principal Biogeochemical Factors Affecting the Speciation and Transport of Mercury through the terrestrial environment. *Environmental Geochemistry and Health* 26: 421–434. https://doi.org/10.1007/s10653-004-1308-0
71. Saiz-Lopez A, Travnikov O, Sonke J, et al. (2020) Photochemistry of oxidized Hg(I) and Hg(II) species suggests missing mercury oxidation in the troposphere. *Proc Natl Acad Sci USA* 117: 30949–30956. http://10.1073/pnas.1922486117
72. Segade S, Teresa D, Elsa R (2011) Mercury methylation versus demethylation: Main processes involved. Methylmercury: Formation, Sources and Health Effects. *Nova Science Publishers* 7: 123–166. http://hdl.handle.net/10198/6750
73. Higueras P, Fernández-Martínez R, Esbrí J, et al. (2015) Mercury Soil Pollution in Spain: A Review. *Environment, Energy and Climate Change I* 32: 135–158. https://doi.org/10.1007/698_2014_280
74. Devasena M, Nambi I (2010) Migration and entrapment of mercury in porous media. *Journal of Contaminant Hydrology* 117: 60–70. https://doi.org/10.1016/j.jconhyd.2010.06.005

75. Bengtsson G, Picado F (2008) Mercury sorption to sediments: Dependence on grain size, dissolved organic carbon, and suspended bacteria. *Chemosphere* 73: 526–531. https://doi.org/10.1016/j.chemosphere.2008.06.017
76. Zhang L, Wu S, Zhao L, et al. (2019) Mercury Sorption and Desorption on Organo-Mineral Particulates as a Source for Microbial Methylation. *Environmental Science & Technology* 53: 2426–2433. https://doi.org/10.1021/acs.est.8b06020
77. Tangahu B, Abdullah S, Basri H, et al. (2011) A Review on Heavy Metals (As, Pb, and Hg) Uptake by Plants through Phytoremediation. *International Journal of Chemical Engineering* 2011. https://doi.org/10.1155/2011/939161
78. Li Q, Tang L, Qiu Q, et al. (2020) Total mercury and methylmercury in the soil and vegetation of a riparian zone along a mercury-impacted reservoir. *Science of The Total Environment* 738: 139794. https://doi.org/10.1016/j.scitotenv.2020.139794
79. Gworek B, Dmuchowski W, Baczewska-Dąbrowska H (2020) Mercury in the terrestrial environment: a review. *Environmental Sciences Europe* 32: 128. https://doi.org/10.1186/s12302-020-00401-x
80. Seo DC, Yu K, DeLaune RD (2008) Comparison of monometal and multimetal adsorption in Mississippi River alluvial wetland sediment: batch and column experiments. *Chemosphere* 73: 1757–1764. https://doi.org/10.1016/j.chemosphere.2008.09.003
81. Schluter K (2000) Review: Evaporation of mercury from soils. An integration and synthesis of current knowledge. *Environmental Geology* 39: 249–271. https://doi.org/10.1007/s002540050005
82. Sondreal E.A, Benson S.A, Pavlish J.H, et al. (2004) An overview of air quality III. Mercury, trace element and particulate matter. *Fuel Processing Technology* 85: 425–440. https://doi.org/10.1016/j.fuproc.2004.02.002
83. Zhao S, Pudasainee D, Duan Y, et al. (2019) A review on mercury in coal combustion process: Content and occurrence forms in coal, transformation, sampling methods, emission and control technologies. *Progress in Energy and Combustion Science* 73: 26–64. https://doi.org/10.1016/j.pecs.2019.02.001
84. Pogrzeba M, Ciszek D, Galimska-Stypa R, et al. (2016) Ecological strategy for soil contaminated with mercury. *Plant and Soil* 409: 371–387. https://doi.org/10.1007/s11104-016-2936-8
85. Caldwell C, Canavan C, Bloom N (2000) Potential effects of forest fire and storm flow on total mercury and methylmercury in sediments of an arid-lands reservoir. *Science of The Total Environment* 260: 125–133. https://doi.org/10.1016/S0048-9697(00)00554-4
86. Bigham G, Murray K, Masue-Slowey, et al. (2016) Biogeochemical controls on methylmercury in soils and sediments: Implications for site management: Geochemical Controls on Mercury Methylation. *Integrated Environ. Assessment and Management* 13: 249–263. https://doi.org/10.1002/ieam.1822
87. Xu J, Buck M, Eklöf K (2019) Mercury methylating microbial communities of boreal forest soils. *Sci Rep* 9: 518. https://doi.org/10.1038/s41598-018-37383-z
88. Tjerngren I, Karlsson T, Björn E, et al. (2012) Potential Hg methylation and MeHg demethylation rates related to the nutrient status of different boreal wetlands. *Biogeochemistry* 108: 335–350. http://www.jstor.org/stable/41410599

89. Kodamatani H, Tomiyasu T (2013) Selective determination method for measurement of methylmercury and ethylmercury in soils/sediments samples using high-performance liquid chromatography–chemiluminescence detection coupled with simple extraction technique. *Journal of Chromatography A* 1288: 155–159. https://doi.org/10.1016/j.chroma.2013.02.004
90. Strickman R, Mitchell C (2017) Methylmercury production and accumulation in urban stormwater ponds and habitat wetlands. *Environmental Pollution* 221: 326–334. https://doi.org/10.1016/j.envpol.2016.11.082
91. Yang Z, W Fang, X Lu, et al. (2016) Warming increases methylmercury production in an Arctic soil. *Environmental Pollution* 214: 504–509. https://doi.org/10.1016/j.envpol.2016.04.069
92. Dijkstra J, Buckman K, Ward D, et al. (2013) Experimental and Natural Warming Elevates Mercury Concentrations in Estuarine Fish. *PLoS ONE* 8: e58401. https://doi.org/10.1371/journal.pone.0058401
93. Dang F, Li Z, Zhong H (2019) Methylmercury and selenium interactions: Mechanisms and implications for soil remediation. *Critical Reviews in Environmental Science and Technology* 49: 1737–1768. https://doi.org/10.1080/10643389.2019.1583051
94. Li Y, Cai Y (2013) Progress in the study of mercury methylation and demethylation in aquatic environments. *Chin Sci Bull* 58: 177–185. https://doi.org/10.1007/s11434-012-5416-4
95. Perez P, Hintelman H, Quiroz W, et al. (2017) Critical evaluation of distillation procedure for the determination of methylmercury in soils samples. *Chemosphere* 186: 570–575. https://doi.org/10.1016/j.chemosphere.2017.08.034
96. Lund W (1990) Speciation analysis—why and how? *Fresenius' Journal of Analytical Chemistry* 337: 557–564. https://doi.org/10.1007/BF00322862
97. Bernalte E, Salmanighabeshi S, Rueda-Holgado F (2015) Mercury pollution assessment in soil affected by industrial emissions using miniaturized ultrasonic probe extraction and ICP-MS. *Int J Environ Sci Technol* 12: 817–826. https://doi.org/10.1007/s13762-013-0461-3
98. Denmark I. S, Begu E, Arslan Z, et al. (2018) Removal of inorganic mercury by selective extraction and coprecipitation for determination of methylmercury in mercury-contaminated soils by chemical vapor generation inductively coupled plasma mass spectrometry (CVG-ICP-MS). *Analytica chimica acta* 1041: 68–77. https://doi.org/10.1016/j.aca.2018.08.049
99. Saniewska D, Bełdowska M (2017) Mercury fractionation in soil and sediment samples using thermo-desorption method. *Talanta* 168: 152–161. https://doi.org/10.1016/j.talanta.2017.03.026

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